Ground Water in Permafrost Regions—An Annotated Bibliography

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1792

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By JOHN R. WILLIAMS

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A brief history of permafrost investigations in the Soviet Union, United States, and Canada is given; annotations with particular emphasis on Alaska and a glossary of terms are included

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ILLUSTRATION

GROUND WATER IN PERMAFROST REGIONS—AN ANNOTATED BIBLIOGRAPHY

By John R. Williams

ABSTRACT

This annotated bibliography of the literature on the occurrence of ground water in permafrost regions and the principles relating thereto covers the North American, Scandinavian, and Russian material published through 1960. Of the 862 articles listed, annotations are available for 715. A glossary of 317 terms used in the literature is given as an aid to the reader. A brief historical summary of permafrost investigations in the United States and of current trends in research in the Soviet Union and Canada is provided as background.

INTRODUCTION

Permafrost, or perennially frozen ground, underlies one-fifth to one-quarter of the earth's land surface in the subpolar and polar regions and in mountainous parts of the temperate region (pl. 1). It occupies 85 percent of Alaska, 40–50 percent of Canada (Johnston, 1930; Jenness, 1949; Brown, R. J. E., 1960), 47 percent of the Soviet Union (Sumgin, 1933b), large segments of adjacent North China and Mongolia, the Arctic archipelagoes, and all but the southern tip of Greenland. Scattered permafrost is known in Iceland and Scandinavia (Troll, 1944), in the high mountains of central Asia along the southern border of the U.S.S.R., in the North American Cordillera, and in the Alps of Europe. In the southern hemisphere permafrost occurs in ice-free sections of Antarctica (Avsiuk, Markov, and Shumskii, 1956; Ball and Nichols, 1960; Grigoriev, N. F., 1960) and at high elevations in the Chilean Andes of South America (Lliboutry, 1957).

With acceleration of development and population of the permafrost regions in the last 30 years, a gradual change has taken place from the primitive hunting-trapping-fishing-mining economy to greater urbanization and increased development of industry and mining. Not only has knowledge of permafrost conditions been required for the new construction undertaken during this period, but also it has proved vital in providing the many new settlements and industries with reliable year-round supplies of water. Use of ground water has increased because of freedom from problems of silting, freezing of intakes, long distribution lines from points of intake to points of use, and extreme variations in quantity that characterize streams in the permafrost region. As compared to surface water, which is at 32°F in winter, ground water a few degrees above the freezing point retards freezing of distribution lines and services.

PURPOSE AND SCOPE

The purpose of this bibliography is to assemble the pertinent literature on present knowledge of the occurrence of ground water in permafrost regions and on the principles based on this knowledge. As a prerequisite to any further research on the principles of the occurrence of ground water in permafrost regions, an extensive study of the literature was recommended by Cederstrom, Johnston, and Subitsky (1953), who conducted an earlier study of this subject. The literature in this bibliography was chosen also to provide a research tool for an investigation of the relation of ground water to permafrost in Alaska. The content of the bibliography, therefore, is more extensive for Alaska than for the rest of the permafrost regions. As many references as possible are included for other countries, but because of difficulties in obtaining some works in translation, the available literature of these nations is far less comprehensive than that of Alaska. The bibliography includes only works published through December 31, 1960.

A brief historical résumé of ground-water and permafrost studies in the United States and abroad is given to provide background information. A bibliographic list of source material used for this report and additional source material are provided for those interested in further study of this subject. A glossary of terms relating to permafrost and ground water is included together with references to sources of the definitions.

The annotated bibliography presents the literature in alphabetical order by author surname, and the works of each author in chronological order. Two or more works of an author published in the same year are listed alphabetically, with the letters *a*, *b*, *c*, etc., appended to the year. Credit for the annotation is shown at the end, with author, date, and page, or with the Snow, Ice, and Permafrost Research Establishment (SIPRE) Bibliography number, or the Arctic Bibliography [1] number for annotations that are direct quotations. Authors' abstracts are used for many annotations. Where the annotations used in other bibliographies or publications have been condensed

[1] Prepared for and published by the Dept. of Defense under the direction of the Arctic Institute of North America.

or altered by the compiler, the word "From" precedes the credit line. Annotations that bear no credit line were prepared by the compiler from original material. The compiler assumes responsibility for correct quotation of the work of others.

The Russian references are taken, for the most part, from the lists and annotations in the Snow, Ice, and Permafrost Research Establishment (SIPRE) Bibliography and from the Arctic Bibliography. Both these publications use the style of transliteration of the Library of Congress. The diacritical marks have been omitted from the Russian material in this bibliography.

Certain publications that were not available for examination, or that are similar to those annotated elsewhere, are listed by title only. Because of the special purpose of this bibliography, only the sections of the various works listed that relate to permafrost and ground water are summarized in the annotations.

The stratigraphic nomenclature used in discussions is that of the various authors and is not necessarily that in use by the U.S. Geological Survey.

HISTORY OF PERMAFROST INVESTIGATIONS

SOVIET UNION

Permafrost investigations in the Soviet Union, summarized by Sumgin and others (1940), were largely centered in the present area of the Soviet Union and in Spitzbergen, Novaia Zemliia, New Siberian Islands, and other islands lying just north of the Eurasian continent. The early inhabitants of this region were doubtless familiar with the existence of permafrost, from experiences in their daily lives, but little information reached centers of learning until the 17th century, when reports of permafrost on Novaia Zemliia and the north coast of Siberia and of frozen carcasses of mammoths were published (Sumgin and others, 1940). The meager information available in the 17th and early 18th centuries was slow in reaching centers of learning and was insufficient to dispel the doubts of the scientific world as to the existence of permafrost.

The second half of the 18th century and the first half of the 19th century are called by Sumgin (Sumgin and others, 1940) the period of preliminary accumulation of facts on permafrost and of their dissemination in the scientific world. The reports of Gmelin (Sumgin and others, 1940), based on travels in Siberia from 1733 to 1743, include description of an unsuccessful water well at Yakutsk, dug in permafrost to a depth of 91 meters in 1685–86. In 1799 a frozen mammoth carcass was discovered east of the mouth of the Lena River and was described by Adams (Sumgin and others, 1940) in 1805. In 1757 Lomonosov attributed existence of permafrost to severe climate (Shvetsov, 1959c). In the early 19th century noteworthy investigations were made by Schrenk in European Russia and by Figurin, Matiushkin, and Vrangel' in northern Siberia (Sumgin and others, 1940; Shvetsov, 1959c), but results of their work were not sufficient to overcome distrust and disbelief in the existence of permafrost. The skeptics argued that the high temperature emanating from the earth's supposedly molten core would prevent formation of permafrost even in the upper layers of the ground, and that vegetation could not grow on frozen soil. Gel'mersen in 1833 investigated excavations at Yakutsk. Erman (1838) made an estimate (also reported by Von Baer, 1838) of permafrost thickness at Yakutsk on the basis of temperature gradient in the upper part of the Shergin shaft, which had been under construction for some time. The Russian Academy of Science at St. Petersburg (Leningrad) also had heard of the excavation. A. Th. von Middendorf was sent by the Academy to investigate the shaft at Yakutsk, among other objectives of his 1842–46 expedition. Not only did Von Middendorf (1848), on the basis of ground-temperature gradient, successfully predict permafrost depth (Obruchev, V. A., 1946), but his investigations (Von Middendorf, 1867) between the Yenisei River and the Sea of Okhotsk extended knowledge of ground temperature and the areal distribution of permafrost. These studies resolved the remaining doubts as to the existence of permafrost.

The second half of the 19th century and the first quarter of the 20th, according to Sumgin (Sumgin and others, 1940), was a period of accumulation of facts and the first attempts at generalization. The work of Maidel, Lopatin, Koz'min, IAchevskii, Von Toll, Bogdanov, Obruchev, Pod'iakonov, Prasolov, Filatov, Sukachev, L'vov, Pol', and Sumgin on permafrost in Russian territory, that of Grigor'ev, Tolmachev, and Von Toll on ground ice, and the work of Högbom, Meinardus, and others in the Arctic islands contributed to a broadening knowledge of the character and distribution of perennially frozen ground. The Berezovka mammoth evoked great academic interest in permafrost (Tolmachev, 1903). Wild (1882) proposed a climatic hypothesis for the formation of permafrost. A. A. Voiekov (1889, 1895, 1904), a physicist and climatologist, contributed the concept of thermodynamic equilibrium in a three-layer system, consisting of the lithospere, the ground, and the atmosphere (Shvetsov, 1958). Construction of the Trans-Siberian and Amur Railroads in the late 19th and early 20th centuries without adequate knowledge of permafrost conditions resulted in many structural failures. The lessons learned in these failures were reported by Bodganov (1912) in a textbook on engineering in permafrost regions

(Obruchev, 1945a). By the end of this period, during the revolutionary period 1905–17, came the beginnings of a planned program of study, paralleling national effort in other fields (Sumgin and others, 1940). Knowledge accumulated to 1927 was summarized by Sumgin (1927, rev. 1937).

The early years of the Soviet Government brought increased emphasis on development and political consolidation of the northern and eastern parts of the country, and to accomplish these aims, much information was required on permafrost. Accordingly, in 1930, under the leadership of V. I. Vernadskii and M. I. Sumgin, the Commission for the Study of Permanently Frozen Ground (Komissii po izucheniiu vechnoi merzloty) was established in the Academy of Sciences under the chairmanship of V. A. Obruchev. A series of expeditionary studies by both older scientists and younger men was made of various parts of the permafrost zone, especially in the Far East where construction was anticipated or underway. Much laboratory work done in connection with the railroad construction was of use in studying the mechanics of frozen ground.

In 1936 the commission was reorganized into the Committee on Permafrost (Komitet po vechnoi merzloty), also within the Academy of Sciences, and still under the chairmanship of V. A. Obruchev. The research, instead of consisting of expeditions, shifted its emphasis to studies at field stations. Permafrost research stations were established in areas in which considerable construction activity was planned, and the data gathered have great practical importance toward the fields of engineering permafrostology and the hydrogeology of permafrost regions. The data have been used to establish instructions, procedures, and specifications for use in construction and other fields.

Up to 1935 very little research had been conducted on permafrost in the Soviet Arctic territory served by Glavsevmorputi (Administration for the Northern Sea Route). In 1935, research stations were established at Anadyr, Yakutsk, and Amderma, and the study of permafrost was tied into hydrogeologic work at Noril'sk, at Spitzbergen, and at the mouths of the Ob' and Khatanga Rivers. In 1936 similar work was planned at Nordvik and at Ugol'naia Bay. A central laboratory was to be established in Moscow, where the results of the permafrost and hydrogeologic and engineering work could be studied (Ponomarev, 1936).

In 1939 the committee became the Institute for the Study of Frozen Ground (Institut Merzlotovedenie); it was later renamed the V. A. Obruchev Institute for the Study of Frozen Ground (Institut Merzlotovedeniia im. V. A. Obrucheva) (Obruchev, 1945a). The Institute, like its predecessors a part of the Academy of Sciences of the

U.S.S.R., calls conferences to be attended by other groups working on permafrost problems. Six conferences were held up to 1941 (Obruchev, 1945c). The Institute maintains laboratories at Moscow and Leningrad for study of physicomechanical properties of permafrost, and field research stations at Vorkuta, Igarka, Yakutsk, and Anadyr, where permafrost is studied in its natural environment. A summary report of knowledge through 1939 by Sumgin and others (1940), as editor, was based on about 200 available sections; the report contains a summary by N. I. Tolstikhin of work in hydrogeology to that date. In 1941 Tolstikhin published a book on ground water in the frozen zone of the lithosphere.

During the war with Germany, 1941–45, the entire scientific effort was applied to problems of national defense. By 1945 a great increase in knowledge over that of 1930 marked the 15th anniversary of organized research in the field of permafrost. Phenomena such as ground ice and icings had been explained, and knowledge of the hydrology of permafrost areas increased. Greater use was being made of subpermafrost ground water as sources of supply.

In the period between 1945 and 1955, progress was made in understanding the following fundamental principles (Shvetsov, 1958): (1) mechanics of frozen ground and melting grounds, (2) construction of stable structures on frozen ground and maintenance of their frozen condition during operation of the structures, (3) construction of stable structures on ground that melts during construction, (4) construction of stable structures on ground that is previously melted and compacted, especially along the southern boundary of the permafrost zone, (5) electrometric determination of the elements that make up the layers of frozen bedrock, (6) search and prospecting for ground water in the permafrost zone, (7) determination of the location and depth of utility (gas) mains, (8) modern glaciology, (9) classification of the permafrost zone into regions for structural engineering purposes and geocryolitic mapping of the region of propagation of frozen bedrock, and (10) classification of the permafrost area into hydrogeologic regions. In addition, modern concepts have been formulated on the position and dynamics of the southern permafrost boundary, on the origin of the extensive deposits of ground ice, and on the occurrence and significance of geochemical processes in frozen bedrock. The fundamentals of heat exchange between lithosphere, soil, and atmosphere are being investigated.

Although there are permafrost research stations in Vorkuta (Northern Division), Igarka, Aldan, Yakutsk (Northern Division), Anadyr, and Zagerskii (Moscow), Shvetsov (1958) urged that new stations be established in the Viliuy region, in the Chitinskaia Oblast, and at

Noril'sk. In addition, Shvetsov urged that the weakly developed geocryological sections of the West Siberian, East Siberian, and Far Eastern Branches of the Academy of Sciences be strengthened. Presniakov and Tkachuk (1957) state that there is an almost complete lack of information on hydrogeologic conditions in the permafrost areas of eastern Siberia. This deficiency should be remedied by resuming the work of the permafrost and hydrogeological stations of the Academy of Sciences. Research stations are operated at Magadan and Noril'sk by the Academy of Construction and Architecture of the Ministry of Transport Construction (Shvetsov, 1958), and at Moscow State University there is a chair of frozen-ground science in the geologic faculty.

According to Shvetsov (1958), the U.S.S.R. has no more than 200 qualified geocryologists. Apparently there is dissatisfaction with the small number available and the poor prospects for increasing it.

Because of the widespread interest in permafrost among Government organizations, it became desirable in 1958 to establish the interdepartmental Coordinating Commission for Permafrost Studies (Koordinatsionnaia Komissiia po Merzlotovedeniiu) as a part of the V. A. Obruchev Institute for Permafrost Studies of the Academy of Sciences (Akad. Nauk SSSR, 1958). The first annual meeting was held in March 1957; the following persons constitute the group to act between meetings: P. F. Shvetsov, Director of the Obruchev Institute of Permafrost Studies (chairman); I. F. Nasedkin, Deputy Director of the All-Union Institute of Transport Construction; M. V. Kim, Head, Research Section, Noril'sk Mining and Metallurgical Combine; A. L. Kalabin, Head, Permafrost Section, 1st Research Institute of Dal'stroy; V. A. Kudriavtsev, Head of the Department of Permafrost at Moscow State University; two unnamed members; and A. M. Chekotillo, Obruchev Institute of Permafrost Studies, as secretary. In addition to the organizations represented, the following are concerned with permafrost studies: Vorkuta Coal Combine (Vorkutaugol), Research Institute for Foundations and Subterranean Constructions of the Academy of Construction and Architecture of the U.S.S.R. (Nauchno-issledovatel'skii Institut Osnovanii i Podzemnykh Sooruzhenii Akademii Stroitel'stva i Arkhitektury SSSR), the West Siberian and Far Eastern Branches of the Academy of Sciences of the U.S.S.R. (Akademiia Nauk SSSR), and the Gidroproiekt, and institutions of unknown responsibilities active in northwestern Siberia.

According to Shvetsov (1958, in translation)—

the most important trends in the development of geocryology will henceforth be general cryological and engineering-cryological, with considerable reinforcement of the experimental-physical natures for the investigation in natural and manufacturing set-ups (artificial set-ups) and physical-mathematical analysis, as well as the development of methods for calculation of the observed processes and phenomena. To solve the foregoing and other important problems in geocryology, the Institute of Frozen-Ground Science must concentrate its effort on investigation of the principal laws of the development of zones of frozen grounds and mountain rocks (bedrock), the change in composition, structure, and physical-mechanical properties of freezing, frozen, and thawing grounds. Particular problems, the solution of which interests the design and investigation organizations of narrow specialties (railroads, mining, hydrotechnical, sanitary-engineering, airport, etc.), can be solved successfully by engineering geocryological divisions, laboratories, and stations of the scientific research institutions of the ministries, of the Academy of Construction and Architecture, of the sovnarkhozes and of other organizations.

The results of recently accumulated knowledge have been summarized by Tsytovich (1958) and Shvetsov (1959).

UNITED STATES AND CANADA

The first record of permafrost in North America was made by Martin Frobisher in 1577, in his second voyage in search of the Northwest Passage (Ray, L. L., 1952). Subsequent accounts of permafrost are few until the discovery by Von Kotzebue (1821) of the ice exposed in the bluffs bordering Eschscholtz Bay of Kotzebue Sound in western Alaska. The origin of the ice in these exposures was debated by Beechey (1831), Richardson (1854), Hooper (1881, 1884), Dall (1881), Maddren (1907), Quackenbush (1909), and others. In Canada, Sir John Richardson (1841) reported the results of investigations made in 1825–26, and of responses to inquiries made of the factors (agents) of the Hudson's Bay Co. at several posts in the Canadian north beginning in 1835. This report was the first study of areal distribution of permafrost in North America. H.M.S. Herald during 1845–51 touched at several points in northern Canada where Richardson (1854) was able to observe permafrost. Other contributions to knowledge were made by Lefroy (1886), by explorers, and by the early military expeditions up to 1890.

In the 1890's increasing effort was expended in exploring Alaska and northwestern Canada, and after discovery of gold in the Circle district of Alaska in 1893, and in the Klondike, Yukon Territory, Canada, in 1898, many additional surveys were undertaken by military and civilan Government agencies in both countries. Most of the exploration, however, was done by prospectors who roamed nearly every area of northwestern Canada and Alaska, sinking shafts to bedrock in search of gold; unfortunately, the geologic information obtained from these shafts was not recorded, and is now lost. Many of the shafts were noted, however, by geologists and engineers working in Alaska and northern Canada during the period of greatest prospecting activity, between 1890 and 1920, principally in the reports of Cairnes, Cockfield, McConnell, Ogilvie, Tyrrell, and Dawson in Canada; and of Maddren, Mertie, Harrington, P. S. Smith, Brooks, Knopf, Mendenhall, Eakin, Prindle, Hess, Katz, and Moffit in Alaska.

E. deK. Leffingwell in 1906 began a 9-year study of the Canning River region in northeastern Alaska along the Arctic Ocean; the results of this study were the first systematic description of frozen ground and ground ice (Leffingwell, 1915, 1919) produced in Alaska. On the basis of years of travel in the arctic regions of Canada and Alaska, Stefansson (1910) reported on ground ice.

Between 1910 and 1925, much of the literature in the mining-engineering field concerned placer mining in frozen gravel and development of economical means of thawing the muck and gravel overburden. This work led to the development, by 1922, of cold-water thawing as a method of preparing for exploitation deep placer ground that previously was uneconomical to work.

In Canada the construction of the Hudson Bay Railroad and the discovery of oil on the Mackenzie River near Norman Wells provided additional data on frozen ground in that country. O'Neil (1924) observed frozen ground during a reconnaissance of the Arctic coast west of the Kent Peninsula, 1913–18.

In Alaska in 1935, Taber (1943b) worked in Fairbanks and Nome and other areas to test theories of ice segregation during the freezing process (Taber, 1916, 1918a, b, 1926, 1930a, b, 1939). Eardley (1938a, b) noted the frozen condition of unconsolidated deposits along the lower Yukon River. Shortly before World War II, P. S. Smith (1939) summarized the available information on permafrost in Alaska. Maps of permafrost distribution in North America were prepared by Nikiforoff (1928), by P. S. Smith (1939), by the Russian, Bratsev (1940), and by Taber (1943b). Up to World War II, no ground-water studies had been undertaken, but many references to "live water" in prospect shafts and to flooding of shafts by ground water had been published. (See especially Tyrrell, 1904.)

During World War II, the threat posed by Japanese invasion of the Aleutian Islands awakened interest in Alaska and northern Canada as bases for military operations. Many airfields were constructed in 1940 to 1942 along the present route of the Alaska Highway, built in 1942 and 1943. Oil pipelines of the Canol Project were laid from Norman Wells to Whitehorse and along the Highway to Fairbanks. Much of this construction was under strict deadline, and some of it failed because of settling of the ground due to thaw of ground ice, or because the ground-water regime was disturbed and icings were formed on roads. The failures, perhaps like those that occurred during construction of the Trans-Siberian Railroad at the turn of the century, served to focus attention on the problem of permafrost.

To prevent recurrence of these failures and to achieve a better understanding of permafrost, a compilation of the results of Russian work on permafrost was made by the U.S. Geological Survey in cooperation with the Office of the Chief of Engineers, U.S. Army (Muller, 1945). The Corps of Engineers, through its St. Paul District, later its Arctic Construction and Frost Effects Laboratory, started field studies at an experiment station near Fairbanks, at Northway airfield, and at other places, initiated investigations on the suitability of aerial photographs as a means of identifying permafrost, and began a series of laboratory studies on frozen soils. The U.S. Geological Survey began a program of investigation of permafrost areas in Alaska in cooperation with the Corps of Engineers. The Office of Naval Research, U.S. Navy, supported an investigation of ground ice in the Point Barrow area by R. F. Black, of the Geological Survey. The Corps of Engineers created the Snow, Ice, and Permafrost Research Establishment to coordinate the Department of Defense research on permafrost in Alaska with that being done elsewhere; in 1961 the responsibility for this work was shifted to the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). Review articles covering knowledge accumulated through the late forties were prepared by Jenness (1949) and Black (1950, 1954).

The investigations by the Geological Survey and by the Cold Regions Research and Engineering Laboratory are being conducted in the field in Alaska and in laboratories and research stations in Alaska and the conterminous United States. A program of basic permafrost research by Lachenbruch and Brewer is based on thermometry in test wells in Naval Petroleum Reserve No. 4 and elsewhere; this work is supported by various agencies. The Arctic Research Laboratory of the University of Alaska and the Arctic Institute of North America conduct research in various aspects of permafrost.

Research on permafrost in Canada is currently being undertaken by the Defense Research Board; McGill University; Geological Survey of Canada and Geographical Branch, both part of the Department of Mines and Technical Surveys; Northern Building Section, division of Building Research, National Research Council; Institute for Northern Studies of the University of Saskatchewan; Department of Transport; Arctic Institute of North America; Department of Public Works; and individual scientists and private companies. These organizations are represented on a subcommittee of the National Research Council (R. J. E. Brown, written commun., July 6, 1962). Research by Division of Building Research includes studies of thickness and areal distribution of permafrost, its moisture and ice content, and its effect on construction of buildings in the north. These studies were made in connection with the relocation of the Mackenzie Valley town of Aklavik to a new site at Inuvik, at the Northern Research Station at Norman Wells, Northwest territories, opened in 1952, at Kelsey, Manitoba, at Fort Simpson, at Whitehorse, and at other sites. Thermal measurements, experimental drilling, and geophysical explorations have been carried on as part of the research program of Division of Building Research at several localities within the permafrost region. Permafrost in the Schefferville iron mines, Quebec (Ives, 1960), is under study by McGill University. The Geological Survey of Canada is studying permafrost in Quaternary deposits and the occurrence of ground water in permafrost regions (Brandon, 1960). Other aspects of the problem now under study are paleobotanical studies, construction techniques for roads and airfields, muskegs and their relation to permafrost, physical properties of frozen soils, patterned ground, geomorphology in permafrost areas, and climatological studies.

Since the close of World War II, ground-water investigations have been started in Alaska and northwestern Canada. In Canada, Brandon (1960) has made a systematic well inventory and evaluation of ground-water resources of the settlements in the District of Mackenzie, Northwest Territories, and is currently engaged in a similar study of Yukon Territory. In Alaska the ground-water investigations in the permafrost region were begun in 1947 (Cederstrom and Péwé, 1948) with a well inventory at Fairbanks, followed by pumping tests and drilling in 1948 and 1949 [2] and by experimentation with jet drilling techniques in 1954.[3] In 1949 and 1950 a test well was drilled at Kotzebue (Cederstrom, 1955). An inventory of well data and evaluation of the ground-water resources at the principal settlements of Alaska as of 1950 was made by Cederstrom (1952).

The first studies specifically directed to determining the relationship between ground water and permafrost in Alaska were undertaken in 1952 by the Geological Survey at the request of, and with funds made available by, the Engineer Research and Development Laboratory, Corps of Engineers, U.S. Army, Fort Belvoir, Va. The field investigations included well inventories in the accessible settlements along the major highways, by Mundorff and Johnston of the Ground Water Branch, Water Resources Division, Geological Survey, a literature survey, experimental geophysical work, and office research. The major reports describe the occurrence of ground water and drilling techniques used in permafrost regions (with bibliography) (Cederstrom, Johnston, and Subitsky, 1953), and the application of techniques

[2] Cederstrom, D. J., 1963, Ground-water resources of hte Fairbanks area, Alaska: U.S. Geol. Survey Water-Supply Paper 1590.

[3] Cederstrom, D. J., and Tibbitts, G. C., Jr., 1961, Jet drilling in the Fairbanks area, Alaska: U.S. Geol. Survey Water-Supply Paper 1539–B, 28 p.

of aerial-photograph interpretation to the problems of ground water in permafrost regions (Hopkins, Karlstrom, and others, 1955).

Following this special project, the Ground Water Branch of the Geological Survey has carried on investigations in parts of western and northwestern Alaska where water supplies were needed for local communities and for military bases and other governmental purposes (Trainer, 1953b; Waller, 1957a, b, c; 1958; 1959a, b; 1960a, b).

SOURCES OF INFORMATION

The following reports and bibliographic works contain source material on the occurrence of ground water in permafrost regions and on permafrost. Of these 47 reports, 35 provided the references cited in this annotated bibliography; the other 12 reports, marked with an asterisk in the list below, were not available for compilation of this report.

Akademiia Nauk SSSR, Institut Geografii, 1956, Bibliography concerning periglacial formations and permafrost in the U.S.S.R. (Bibliographie concernant les formations periglaciaires et le pergelisol en U.R.S.S.) : Poland, Lodzkie towarz. nauk., Biul. Peryglacjalny 4, p. 37–46. List of 152 Russian articles with titles translated into French, German, and English.

***Akademiia Nauk SSSR,** Reference Journal, Geology (Referativnyi Zhurnal, Geologiia) : Akad. Nauk SSSR, Inst. Nauchn. Inf. A continuing classified annotated bibliography of geology. [Russian.]

American Geological Institute, 1953–58, Geological Abstracts: v. 1–6. 1959–60, Geoscience Abstracts: v. 1–2.

American Geophysical Union, 1941, Annotated bibliography on hydrology, United States of America for the year 1940: Am. Geophys. Union under sponsorship of the Internat. Assoc. Sci. Hydrology, Internat. Union Geodesy and Geophysics, 93 p. Fifth in a series of biennial and annual bibliographies of hydrology; contains about 500 entries.

American Geophysical Union, 1952, Annotated bibliography on hydrology, 1941–50 (United States and Canada) : Compiled under auspices of Subcommittee on Hydrology, Federal Inter-Agency River Basin Committee, by American Geophysical Union, National Research Council of the National Academy of Sciences, as their Notes on hydrologic activities, Bull. 5, 408 p.

1955, Annotated bibliography on hydrology, 1951–54, and sedimentation, 1950–54 (United States and Canada) : Compiled and edited under auspices of Subcommittee on Hydrology and Sedimentation, Inter-Agency Committee on Water Resources, by American Geophysical Union, National Research Council of the National Academy of Science, 207 p.; 600 references.

Armstrong, Terence, 1948, Recent Soviet research on permanently frozen soil: Polar Rec., v. 5, p. 217–218.

Black, R. F., 1950, Permafrost, *in* Trask, P. D., Applied sedimentation: New York, John Wiley & Sons, chap. 14, p. 247–275.

1954, Permafrost—A review: Geol. Soc. America Bull., v. 65, p. 839–856; 237 references.

Brochu, Michel, 1956, Canada: Poland, Lodzkie towarz. nauk., Biul. Peryglacjalny 4. p. 9–14; 38 references, including some on permafrost, in French.

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GLOSSARY OF TERMS

A glossary of the English and some foreign terms on permafrost and the more specialized terms applied to ground water in permafrost regions is included in this bibliography as an aid to the reader. The terms are arranged alphabetically. Alternate definitions are given for terms having differences in definition in the literature, not necessarily in the order of preference. The definitions of Muller (1945) and Hennion (1955) are generally accepted in the United States.

Source of the definition is given and reference by author and year of publication is made to the annotated bibliography. For many terms the source of the original definition is not available and that of a later author is used, as in the glossary by Muller (1945), in which translations and amended definitions are given for definitions taken from various Russian works. For most terms, the definitions for which author, date, and page number of the reference are cited are direct quotations; those that are credited as "from" or "after" are definitions that have been rephrased to some extent by the compiler.

Acicular ice. (*See also* Needle ice.) Formed at the bottom of ice (near the contact with water); consists of numerous long crystals and hollow tubes of variable form having layered arrangement and containing bubbles of air (Muller, 1945, p. 213). Syn: Fibrous ice, satin ice.

Active layer. (*See also* Annual frost zone, active zone, mollisol, seasonally frozen ground.) 1. A layer of ground above the permafrost which thaws in the summer and freezes again in the winter (Muller, 1945, p. 213).

2. Ambiguities in the use of the term **active layer** make use of alternate terms **seasonal freezing** and **seasonal thawing** desirable. Active layer applies to ground layer affected by winter freezing or summer thawing and also to those layers subject to annual variations in temperature. Term **active layer** is sometimes applied to all strata located above the permafrost table (Khomichevskaia, 1955).

3. Term should be replaced with **seasonally thawed ground.** (Akad. Nauk SSSR, Inst. Merzlotovedeniia, 1956).

Syn: Seasonally frozen ground, annually thawed layer, frost zone, climafrost, deyatelny sloi (Russian) (Sumgin, in Dylikowa and Olchowik, 1954, p. 140), actywny pozion zmarzliny (Polish) (Jahn, in Dylikowa and Olchowik, 1954, p. 140), czynna zmarzlina (Polish) (Dylik, in Dylikowa and Olchowik, 1954, p. 140).

Active method (of construction). Method of construction in which permanently frozen ground is thawed and kept unfrozen at and near the structure (Muller, 1945, p. 213).

Active permafrost (or **active permanently frozen ground**). Permafrost which, after having been thawed due to natural or artificial causes, is able to return to permafrost under the present climate (Muller, 1945, p. 213; from Bilibin, 1937).

Active zone. (*See also* Annual frost zone, active layer, frost zone.) The entire layer of ground above the upper surface of the permafrost layer, most of which freezes and thaws every year; term distinct from **frost zone,** which is the zone subject to seasonal freezing and thawing. Where seasonal frost penetrates to permafrost or below its upper surface, the **frost zone** and **active zone** are identical (Frost, 1952, p. 226).

Agdlissartoq (Eskimo). *See* Hydrolaccolith.

Aggradation of permafrost. (*See also* Pergelation.) An increase in thickness and areal extent of permafrost. Syn: Rost vechnoi merzloty (Russian).

Air freezing index. *See* Freezing index.

Air thawing index. *See* Thawing index.

Aktywy pozion zmarzliny (Polish). *See* Active layer.

Anchor ice. Ice in the bed of a stream or upon a submerged body or structure (Langbein and Iseri, 1960, p. 4).

Annual frost zone. (*See also* Active layer, active zone, frost zone.) The top of ground subject to annual freezing and thawing. In Arctic and subartic regions where annual freezing penetrates to the permafrost table, suprapermafrost and annual frost zone are identical (Hennion, 1955, p. 107).

Annual glacier. (*See also* Icing.) The annual deposit of ice formed by the freezing of overflow water and snowdrifts saturated by the same (Maddren 1907, p. 46). Popularly referred to as glaciers.

Annually thawed layer (or zone). (*See also* Active layer.) A layer or zone in the ground above the permanently frozen ground which is alternately frozen and thawed each year (Muller, 1945, p. 213, after Leffingwell, 1919, p. 181).

Arctic. The northern region in which the mean temperature for the warmest month is less than 50°F, and the mean annual temperature is below 32°F. In general, arctic land areas coincide with the tundra region north of the limit of trees (Hennion, 1955, p. 107).

Aufeis (German). *See* Icing.

Average annual temperature. The average of the average daily temperatures for a particular year (Hennion, 1955, p. 108).

Average daily temperature. The average of the maximum and minimum temperatures for one day or the average of several temperature readings taken at equal time intervals during one day, generally hourly (Hennion, 1955, p. 108).

Average monthly temperature. The average of the average daily temperatures for a particular month (Hennion, 1955, p. 108).

Beaded drainage. The characteristic pattern of small streams in areas underlain by polygonal ground ice. The stream paths are angular owing to partial control by depressions associated with the polygonal distribution of ground ice. Small cave-in lakes occur at intervals along the stream generally at the junctions of ice wedges. The lakes, when connected by the streams, resemble beads on a string (Péwé, 1954, p. 323).

Bodeneis (German). *See* Ground ice.

Bottom ice. *See* Anchor ice.

Bulgunniakh (Russian). *See* Hydrolaccolith.

Buried ice. *See* Ground ice.

Cave-in-lake. (*See also* Cryogenic lake, thaw lake.) A lake formed in a caved-in depression produced by the thawing of ground ice (ice lens or ice pipe) (Muller, 1945, p. 214). Syn: Kettle or kettle-hole lake, thermokarst lake.

Climafrost. *See* Active layer.

Closed system. A condition in which no source of free water is available during the freezing process beyond that contained originally in the voids of the soil (Hennion, 1955, p. 108).

Combined water. Water of solid solution and water of hydration which does not freeze even at the temperature of —78°C (Muller, 1945, p. 214).

Confluent permafrost. Permafrost which is joined to the layer of winter freezing each year (Sumgin and others 1940, in translation). Syn: Merging permafrost.

Congelation. Action, process, or state, as well as the product of an alteration from a fluid to a solid state, but excluding frost processes in rocks and soils that contain only bound water (Shvetsov, 1955a, in translation).

Constant frost. *See* Permafrost.

Constant frozen ground (Russian: Postoianno marzlyi grunt, Chekotillo, 1956). *See* Permafrost.

Constant soil gelation (Russian: Postoiannoe pochvennoe promerzanie). *See* Permafrost.

Continuous-permafrost zone. 1. An area where permafrost is found everywhere under the natural surface, is relatively thick and massive, and has a temperature below 28°F (Pihlainen, 1955, p. 11).
2. A zone of thick, areally continuous permafrost in which the permafrost table lies within 4 in. to 6 ft of the land surface, and in which large lakes and rivers lie in thawed areas slightly larger than the basins they occupy. Temperature at depth of 30–50 ft is below −5°C (from Black, 1950).

Critical water period (critical period). The time, between moment of final freezing of supra-permafrost water (verkhovodka) and the start of spring thaw, in which resources rapidly diminish to nil (Tolstikhin, 1940).

Cryogenic lake. (*See also* Cave-in lake, thaw lake.) Lake in a region of permanently frozen ground produced by local thawing (Hutchinson, 1957, in Weller, 1960). Syn: Kettle or kettle-hole, thermokarst lake.

Cryokarst. *See* Thermokarst.

Cryology. *See* Kriologiia (Russian), permafrostology.

Cryophile minerals. Minerals which are solid only below 0°C (Parkhomenko, 1938, in translation).

Cryophilic rocks. *See* Permafrost, definition 7.

Cryopedology. The science of intensive frost action and permanently frozen ground including studies of the processes and their occurrence and also the engineering devices which may be invented to avoid or overcome difficulties induced by them (Bryan, 1946, p. 639–640).

Cryosphere. 1. The region of subfreezing temperatures on the earth's crust, including glaciers, ice, snow cover, and the upper layer of the atmosphere. Soils are regarded as constituents of the cryosphere even if only a part of the water is present in the solid state (from Shvetsov, 1951).
2. All the earth's surface that is permanently frozen (U.S. Air Force, Arctic, Desert, Tropic Inf. Center, in Howell, 1957, p. 69).

Cryovolcanic rocks. *See* Icing, definition 3.

Crystocrene. Surface mass of ice formed each winter by overflow of springs (Tyrrell, 1904).

Crystosphene. Mass or sheet of ice developed by a wedging growth between beds of other material (Tyrrell, 1904).

Dam, ground-water. *See* Ground-water dam.

Dauerfrostboden (or **Dauernder Frostboden**) (German). *See* Permafrost.

Deep-seated swelling. Swelling of ground caused by the freezing of freely percolating ground water (Muller, 1945, p. 215).

Degelation. Thawing.

Degradation of permafrost. (*See also* De-pergelation.) 1. Disappearance of the permafrost due to natural or artificial causes (Muller, 1945, p. 215). Syn: Degradatsiia vechnoi merzloty (Russian), ischeznovenie vechnoi merzloty (Russian).
2. Decrease in thickness or in areal extent of permafrost.

Degradatsiia vechnoi merzloty (Russian). *See* Degradation of permafrost.

Degree-day. The degree days for any one day equal the difference between the average daily air temperature and 32°F. The degree-days are minus when the average daily temperature is below 32°F (freezing degree-days) and plus when above (thawing degree-days) (Hennion, 1955, p. 108).

Degree-hour. A variation of one degree Fahrenheit from 32°F for a period of one hour. The degree-hour is negative if below 32°F and positive if above 32°F (Hennion, 1955, p. 108).

De-pergelation. (*See also* Degradation of permafrost.) The act or process of thawing permanently frozen ground (Bryan, 1946, p. 640).

Depth of attenuation of annual variations (temperature) (or **depth of seasonal change**). *See* Level of zero annual amplitude.

Detrimental permafrost (or **Detrimentally frozen materials**). A type of permafrost which, on thawing, causes differential settlement of the ground and damage to buildings, roads, and other engineering works. Generally consists of fine-textured materials which contain a large percentage of ice in the form of crystals, large and small lenses and wedges, and large and small ice masses of irregular shape (after Frost, 1952, p. 227).

Deyatelnyi sloi (also transliterated **Deiatelnyi sloi; djatel'nyi sloi**) (Russian). *See* Active layer.

Diffusivity. An index of the facility with which a material will undergo temperature change. It is numerically equal to the quotient of the thermal conductivity and the volumetric heat. The diffusivity of a soil is increased by freezing, by an increase of moisture, and by an increase in density (Hennion, 1955, p. 109).

Dilation, water of. Water in excess of water of saturation held by the ground in an inflated state (Muller, 1945, p. 215). Syn: Water of supersaturation.

Discontinuous-permafrost zone. A zone in which the continuity of permafrost is broken by unfrozen zones; most major rivers and some lakes are not underlain by permafrost, and permafrost may be absent in the tops of some well-drained low hills. Seasonal thaw penetrates 1–10 ft, and temperature at a depth of 30–50 ft generally is between −5° and −1°C (from Black, 1950).

Ditch (placer mining). System of trenches dug in unconsolidated deposits and bedrock designed to carry water from supply point in stream or lake to placer mine. Water commonly carried across gullies in pipes on trestles or by inverted siphons.

Diurnigelisol. Diurnal frozen ground (Bryan, 1946).

Dry frost. (*See also* Dry frozen ground (or dry frozen materials), dry permafrost, frost soil (or rock).) 1. Conditions in which voids are partly filled with minute crystals of ice (Wimmler, 1927, p. 64).

2. Term to be replaced by **frost soil** (or **rock**) (Akad. Nauk SSSR, Inst. Merzlotovedeniia, 1956).

Dry frozen ground (or dry frozen materials). (*See also* Dry frost, Sukhaia merzlota (Russian).) 1. Ground with temperature below 0°C, but containing no ice (Muller, 1945, p. 215).

2. Refers to condition in ordinarily well-drained granular materials in which the grains are cemented by ice, but in which ice lenses wedges, and irregular masses are lacking (from Frost, 1952, p. 226).

Syn: Sukhaia vechnaia merzlota (Russian).

Dry ice. *See* Led sushnikh.

Dry permafrost (or **dry permanently frozen ground, dry pergelisol**). 1. Permanently frozen ground with temperature below 0°C but containing no ice (Muller, 1945, p. 215).

2. Dry ground (rock, dry gravel, dry sand, etc.) which is not adfrozen and has a negative temperature (Liverovskii and Morozov, 1941, p. 35, in translation).

3. **(Dry pergelisol).** Material having the requisite mean temperature to be permanently frozen but lacking water content, or "dry" (Bryan, 1946).

Etesigelisol. *See* Seasonally frozen ground.

Ever-frozen soil (or **ever-frozen ground** or **subsoil**). *See* Permafrost.

Syn: Ever-frozen soil: Vsegda merzlaia pochva (Russian).
Ever-frozen ground: Vsegda merzlyi grunt (Russian).
Ever-frozen subsoil: Vsegda merzlaia podpochva (Russian).

Ewiger Frostboden (German). *See* Permafrost.

Earth mound. *See* Frost mound, hydrolaccolith, pingo.

Eis als felsart (German). *See* Ground ice.

Eisboden (German). *See* Frozen ground.

Entrapped water. The water trapped between the base of seasonally frozen ground and the permafrost table (from Alter, 1950a).

Eruption of soil. Probably equivalent to **Frost mound** (Muller, 1945, p. 216).

Eternal frigidness. *See* Permafrost. Syn: Postoiannoe promerzanie (Russian).

Eternal frost. *See* Permafrost. Syn: Vechnaia merzlota (Russian).

Eternal(ly) frozen ground. *See* Permafrost. Syn: Vechnomerzlyi grunt (Russian).

Fibrous ice. *See* Acicular ice.

Flood ice. *See* Icing.

Fossil ice. *See* Ground ice.

Frazil ice. 1. Composed of fine particles which when first formed are colloidal and not seen in the water in which they are floating (Langbein and Iseri, 1960, p. 11).

2. Ice formed by freezing of turbulent water. It is a mush of ice spicules and water resembling slush (Muller, 1945, p. 216).

Freezing index. The number of degree-days between the highest and lowest points on a curve of cumulative degree-days versus time for one freezing season. It is used as a measure of the combined duration and magnitude of below-freezing temperatures occurring during any given freezing season. The index determined for air temperatures at 4.5 feet above the ground is commonly designated as the air **freezing index,** while that determined for temperatures immediately below a surface is known as the **surface freezing index** (Hennion, 1955, p. 108–109).

Freezing season. That period of time during which the average daily temperature is generally below 32°F. NOTE.—The definitions for **freezing season** and **thawing season** are applicable to conditions in arctic and subarctic regions where frequent oscillations about the freezing point are uncommon (from Hennion, 1955).

Frost. *See* Frozen ground, merzlota, permafrost.

Frost action. A general term for freezing and thawing of moisture in materials and the resultant effects on those materials and on structures of which they are part or with which they are in contact (Hennion, 1955, p. 107).

Frost belt. A ditch that causes an early and rapid freezing of surficial ground forming an obstruction to percolating shallow ground water (Muller, 1945, p. 216). Syn: Frost dam.

Frost blister. A mound or an upwarp of superficial ground caused chiefly by the hydrostatic pressure of ground water (Muller, 1945, p. 216). Syn: Soil blister, gravel mound.

Frostboden (German). (*See* also Frozen ground, permafrost.) The whole zone of ground which is characterized by negative temperatures and is therefore permanently frozen (Dylikowa and Olchowik, 1954, p. 136). Syn: Frozen ground, frozen soil, le sol gelé (French), marzloc and zmarzlina (Polish), merzlota (Russian).

Frost boil. The breaking of a localized section of a highway or airfield pavement under traffic and ejection of subgrade soil in a soft and soupy condition caused by the melting of the segregated ice formed by frost action (Hennion. 1955, p. 107).

Frost dam. *See* Frost belt.

Frost heaving. (*See also* Frost thrust.) 1. The raising of a surface due to the formation of ice in the underlying soil (Hennion, 1955, p. 107).

2. The phenomenon of volume increase of moisture-saturated particles at the time of freezing that refers chiefly to upward movement of the particles, induced by the slightest pressure and associated with the existence of a capillary system and of an area of water supply (Taber, 1930b).

Frost line. The line or surface defined by the points of greatest depth at which soil freezes (from Petrica, 1951).

Frost mound. 1. A localized upwarp of the land surface caused by frost action or hydrostatic pressure (Hennion, 1955, p. 110).

2. A seasonal upwarp of land surface caused by the combined action of (a) expansion due to the freezing of water; (b) hydrostatic pressure of ground water; and (c) force of crystallization (Muller, 1945, p. 216).
Syn: Earth mound, frost blister and gravel mound (in part), ground-ice mound, hydrolaccolith (in part), ice mound, pals, peat mound, pingo (in part), suffosion complex or knob.

Frost of long duration (of many centuries, of many years). *See* Permafrost.

Frost soil (or rock). (*See also* Dry frost, frozen ground.) 1. Rocks and soils containing only bound water below the freezing point (Shvetsov, 1955, in translation).

2. A term suggested as replacement for **dry frost** (Akad. Nauk SSSR, Inst. Merzlotovedeniia, 1956).

Frost-susceptible soil. Soil in which significant (detrimental) ice segregations will occur when the requisite moisture and freezing conditions are present (Hennion, 1955, p. 108).

Frost table. A more or less irregular surface that represents the penetration of spring and summer thawing of the seasonal frozen ground (active layer). Not to be confused with permafrost table (Muller, 1945, p. 217).

Frost thrust. 1. The horizontal component of frost heaving (Eakin, 1916). 2. A lateral displacement due to frost action (Hennion, 1955, p. 107).

Frost zone. (*See also* Active zone, active layer.) Top layer of ground subject to seasonal freezing and thawing (Frost, 1952, p. 226).

Frozen formation. *See* Frozen ground.

Frozen geozone. (*See also* Permafrost.) Frozen zone of the lithosphere. Syn: Kryogeozona, kryohtonna geozona, merzla geozona (Russian).

Frozen ground (or **soil**). (*See also* Frostboden, frost soil, tjale, merzlota (Russian).) 1. Ground that has a temperature of 0°C or lower and generally contains a variable amount of water in the form of ice (Muller, 1945, p. 217). 2. The whole zone of ground which is characterized by negative temperatures and is therefore permanently frozen (Dylikowa and Olchowik, 1954, p. 136). 3. Soil, ground, or earth formation the temperature of which is below zero; thus the fact whether the soil, ground, or formation contains water or in what quantity, or whether it is entirely absent is not taken into consideration at all (Sumgin and others, 1940, in translation, p. 3–4). 4. Soil in which the change from water to ice occurs completely or in part (Shvetsov, 1955). Syn: Marzloc and Zmarzlina (Polish), le sol gelé (French), merzlyi grunt (Russian).

Frozen-ground science. *See* Cryopedology, merzlotovedenie.

Frozen zone. (*See also* Permafrost.) Zone in which soil particles remain locked in ice for several years (Sidenko, 1955, in translation). Syn: Merzlaia zona (Russian).

Frozen zone of the lithosphere. *See* Frozen geozone, permafrost.

Gefrornis (German). *See* Permafrost.

Geocryology. *See* Geokriologiia.

Geokriologiia (Russian). The science treating of the conditions of formation, development, and distribution of frozen ground or rock, their physical and mechanical properties and modifications of the latter caused by human activity. Term suggested to replace **merzlotovedeniia** (permafrostology) (Meister and Shvetsov, 1955, in Arctic Bibliography 41341).

Geotermicheskaia zonal'nost' (Russian). *See* Geothermal zone.

Goethermal gradient. The increase in depth (feet) to produce a 1°F change in temperature (Misener, 1949, p. 286).

Geothermal zone. A group of strata within which the rocks and their enclosed waters are characterized by a definite temperature interval * * *. The west Siberian artesian basin is divided into six geothermal zones on the basis of analysis of temperature of wells. (From Mavritskii, 1960, in translation.)

Glacier. (*See also* Icing, annual glacier.) 1. A body of ice and firn consisting of recrystallized snow and refrozen meltwater, lying wholly or mostly on land and showing evidence of present or former motion (Flint, 1957, p. 11).
2. Term used in Alaska to denote ground ice or sheets of surface ice formed by successive freezing of ground or river seepages, which in this report are termed icings (Muller, 1945, p. 217).
3. Ice formed directly from overflows (flood waters) in flood plains and from ground seepages (Wilkerson, 1932).

Gravel mound. *See* **Frost blister, frost mound.**

Ground frost. *See* Permafrost, seasonal frost. Syn: Gruntovaia merzlota (Russian).

Ground ice. 1. Bodies of more or less clear ice in frozen ground. Excludes ice of glacial origin (Muller, 1945, p. 217).
2. A body of ice surrounded by rocks or sediments on all sides, and keeping this state for an indefinitely long time (Obruchev, S. V., 1938, in Poiré, I. V., 1949).
3. Consists of grains or bodies of more or less clear ice in permafrost. The term generally is not applied to ice of glacial origin (Péwé, 1954, p. 323).
4. Subsurface or interstitial ice that occurs below the surface of the lithosphere. It may be formed from the freezing of either saturated or unsaturated rock or soil or from the covering of a bed of surface ice or snow by a mantle of rock debris. It may be either temporary or perennial. Functionally it is like any other solid constituent of a rock or soil, and it can therefore not properly be classed with either ground water or suspended water (Meinzer, 1923, p. 22). COMPILER'S NOTE.—Tolstikhin 1940, 1941 (quoted by Meister, 1955, in translation) includes both liquid and solid phases of water in the category of intrapermafrost water. Meister (1955, in translation) argues that ground ice should not be classed with ground water.
5. Bodies of more or less clear ice in permanently frozen ground. Deposits which are evidently only temporary features are excluded * * * and the term is not applied to deposits which seem to be on top of the ground. Stagnant earth-covered glaciers appear to fall about in the dividing line of this definition. If their glacial origin is evident, they would be excluded. The lower end of the Malaspina Glacier might be called ground ice if nothing were known of its connection with the living glacier. Any glacial ice embodied in the flat Arctic tundra, as there may be at Flaxman Island, must be included in any definition. Ice in caves and under talus in regions of unfrozen ground is excluded (Leffingwell, 1919, p. 180).
Syn: Bodeneis (German), buried ice, glacier ice (as used in Alaska), fossil ice, interstitial ice, jorbundeis (German), stone ice, subsoil ice, subsurface ice, subterranean ice, underground ice, ureis (German), steineis (German).

Ground-ice mound. *See* Frost mound.

Ground-ice wedge. *See* Ice wedge.

Ground icing. (*See also* Icing.) Surface ice formed during the winter by successive freezing of sheets of water that may seep from the ground, from the river, or from a spring (Jess, 1952).

Ground-water dam. A body of material which is impermeable or has only low permeability and which occurs below the surface in such a position that it impedes the horizontal movement of ground water, and consequently causes a pronounced difference in the level of the water table on opposite sides of it. Such a dam may be either natural or artificial (Meinzer, 1923, p. 36–37).

Heterogeneously frozen soil. A soil in which a part of the water is frozen in the form of macroscopic ice occupying a space in excess of the original voids in the soil (Hennion, 1955, p. 108).

Hoar frost. *See* Needle ice.

Homogeneously frozen soil. A soil in which water is frozen within the material voids without macroscopic segregation of ice (Hennion, 1955, p. 108).

Hydrolaccolith. (*See also* Pingo.) 1. Usually a large frost mound or an upwarp of ground produced by the freezing of water into a large lenticular body of ice—in a general way resembling a laccolith (Muller, 1945, p. 217).

2. Large swelling hummock that lasts many years and is due to the hydrostatic pressure of the ground water from below the merzlota (permafrost), or from a talik, or of the artesian ground water in general. Hydrolaccoliths always contain a frozen core that consists of frozen ground underlain by ground ice. Hydrolaccoliths are often related to the naledi (icings) Obruchev, S. V., 1938, in Poiré, 1949).

3. Large isolated mounds of peat, fine frozen soil, and pure ice in river valleys and lake depressions. They are seasonal or persistent; the largest are the hydrolaccoliths, also called pingos or bulgunniakhs, which are formed during intense, deeply penetrating, long continued freezing of the ground, possibly during early stages of formation of permafrost (Grave, 1956, in translation).

Syn: Agdlissartoq, bulgunniakh, earth mound, frost mound(large and persistent), pingorssarajuk.

Ice. *See the various types of ice:* Ground ice, needle ice, etc.

Ice content. The ratio, expressed as a percentage, of the weight of ice phase to the dry weight of soil (Hennion, 1955, p. 108).

Ice field. *See* Icing.

Ice fountain. *See* Icing.

Ice gneiss. Interlayered thin lenses and beds of ice and sediment (from Taber, 1943b, p. 1516, 1520).

Ice heap. *See* Icing mound.

Ice hillock. *See* Icing mound.

Ice lenses. Ice formations in soil occurring essentially parallel to each other, generally normal to the direction of heat loss, and commonly in repeated layers (Hennion, 1955, p. 108).

Ice mound. *See* Frost mound.

Ice pipe. Ice wedge of cylindrical shape (Muller, 1945, p. 218).

Ice segregation. The growth of ice as distinct lenses, layers, veins, and masses in soils commonly, but not always, oriented normal to the direction of heat loss (Hennion, 1955, p. 108).

Ice soil. *See* **Permafrost.**

Ice vein. Ice injected into frozen ground (Taber, 1943b).

Ice wedge. 1. A vertical wedge-shaped ice mass in permafrost usually associated with fissure polygons (Hennion, 1955, p. 108).
2. Wedge-shaped mass of relatively clear ice, oriented vertically or nearly so with its apex downward. Ice wedges range in width from a few millimeters to about 10 meters, in height from about 1 meter to 10 meters, and in length horizontally from a few meters to several tens of meters. In most places ice wedges join to form polygons whose diameters generally are on the order of a few meters to several tens of meters (Black, 1953).

Ice well. Water-filled pit with ice walls in terrain underlain by massive ground ice, the result of intense melting of the ice (Skvortsov, 1930, in translation).

Icing. (*See also* Crystocrene, cryovolcanic rocks, annual glacier, ground icing, glacier, sersineq.) 1. A mass of surface ice formed during the winter by successive freezing of sheets of water that may seep from the ground, from a river, or from a spring. When the ice is thick and localized it is called **icing mound,** and when it survives the summer it is called **taryn** (Muller, 1945, p. 218, from Sumgin, 1941, in translation).
2. A surface ice mass formed by freezing of successive sheets of water (Hennion, 1955, p. 110).
3. Naled' (Russian), a frozen sheet of water that poured over river ice, or ground, or that intruded between the two layers of ground under the pressure of the water of a dammed river or under hydrostatic pressure of the ground water (Poiré, 1949).
Syn: Aufeis (German), ice field, ice fountain, naled' (Russian), taryn (Russian).

Icing mound. A localized icing of substantial thickness but of more or less limited areal extent. May also form entirely or in part by the upwarp of a layer of ice (as in a river) by the hydrostatic pressure of water (Muller, 1945, p. 218).
Syn: Ice heap, ice hillock.

Icing process. (*See also* Naled' process.) The process of forming icings.

Intergelisol. A layer of frozen ground between the pergelisol (permafrost) and the mollisol (seasonally thawed ground) (Bryan, 1946).
Syn: Pereletok (Russian), perehodnoy sloy (Russian).

Interstitial ice. *See* Ground ice.

Intrapermafrost water. 1. Term applied to that liquid phase of water which circulates within the limits of the layer of frozen formation and to the solid phase of water—fossil ice and water-bearing horizons which once functioned and now are temporarily inactive due to the permafrost of long duration (Tolstikhin, 1940, in translation).
2. Water which circulates within the permafrost proper (Liverovskii and Morozov, 1941, p. 35, in translation).
3. Ground water in unfrozen layers, lenses, or veins within the permafrost. (Muller, 1945, p. 218).

Ischenznovenie vechnoi merzloty (Russian). *See* Degradation of permafrost.

Island permafrost. *See* Sporadic permafrost.

Istoichivaia gruntovaia merzlota (Russian). *See* Permafrost. Syn: Stable ground frost.

Jarhliche tjale (German). *See* Seasonally frozen ground.

Jorbundeis (German). *See* Ground ice.

Kettle or kettle-hole lake. *See* Cave-in lake.

Kriogeozona or Kryogeozona (Russian). *See* Frozen geozone, permafrost.

Kriohtonna (kryohtonna) geozona (Russian). *See* Frozen geozone, permafrost.

Kriologiia (Russian). The study of ice. Not restricted to the study of glaciers, but includes studies of ground, lake, river, and other forms of ice. Syn: Cryology.

Lamellar ever-frozen ground. *See* Layered permafrost. Syn: Sloistyi vsegda merzlyi grunt (Russian).

Latent heat of fusion. The number of British thermal units necessary to melt one pound of ice without a change in temperature (from Hennion, 1955, p. 109).

Layer of zero annual amplitude. *See* Level of zero annual amplitude.

Layered permafrost. Ground consisting of permanently frozen layers alternating with unfrozen layers or taliks (Muller, 1945, p. 218). Syn: Sloistyi postoianno merzlyi grunt (Russian), sloistyi vsegda merzlyi grunt (Russian).

Layered permanently frozen ground. *See* Layered permafrost. Syn: Sloistyi vechnomerzlyi grunt (Russian).

Led (Russian). Ice.

Led sushnikh (Russian). Several layers of ice divided by air layers resting on river bed in absence of water. Caused as sections of river freeze quickly and excess of water flows on leaving airspace beneath ice cover (Tolstikhin, 1940, p. 273, in translation).

Ledianie stebelki (Russian). *See* Needle ice.

Level of zero (annual) amplitude. 1. The level to which seasonal change of temperature extends into permafrost. Below this level the temperature gradient of permafrost is more or less stable the year round (Muller, 1945, p. 218).

2. A layer of rocks beneath the earth's surface at a certain depth below which the temperature of the ground does not follow the seasonal changes of temperature of the earth's surface, and is constant as long as the regime of the merzlota (permafrost) or the climate of the region remains constant (Poiré, 1949).

Level of zero annual temperature variation. *See* Level of zero (annual) amplitude.

Live water. A term used by miners in Alaska for ground water encountered in unfrozen stream beds, or commonly under hydrostatic pressure, beneath the permafrost.

Long-lasting frozen ground. *See* Permafrost.

Lower surface (of permafrost). The surface, where at a certain depth in the lithosphere the permafrost ends, and positive (above 0°C) temperatures begin. (Sumgin and others, 1940, p. 15, in translation).

Marzloc (Polish). *See* Frozen ground.

Mean annual temperature. The average of the average annual temperatures for several years (Hennion, 1955, p. 108).

Mean daily temperature. The average of the average daily temperatures for a given day for several years (Hennion, 1955, p. 108).

Mean freezing index. The freezing index determined on the basis of mean temperatures. The period of record over which temperatures are averaged is usually a minimum of 10 years and preferably 30 (Hennion, 1955, p. 109).

Mean monthly temperature. The average of the average monthly temperatures for a given month for several years (Hennion, 1955, p. 108).

Mean thawing index. The thawing index determined on the basis of mean temperatures (Hennion, 1955, p. 109).

Merging permafrost. *See* Confluent permafrost.

Merzla geozona (Russian). *See* Frozen geozone.

Merzlota (Russian). (*See also* Frozen ground.) 1. Every ground the temperature of which falls below zero (0°C) independent of the fact whether or not it contains water (Sumgin and others, 1940, in Dylikowa and Olchowik, 1954, p. 137).
2. Term used also as synonym for frozen ground that persists more than two years in which the water is predominantly in the solid state, that is, frozen as ice (from Poiré, 1949, Parkhomenko, 1936, and Tolstikhin, 1941, in translation).

Merzlotovedenie (Russian). 1. The study of frozen ground and of the processes occurring therein, as well as of the processes occurring in the zone of contact between frozen and nonfrozen rocks (from Parkhomenko, 1938, in translation).
2. Refers to the science of the development of frozen geozone (Tolstikhin, 1941, in translation).
3. A science of heat flow during cooling and freezing, heating and thawing of the upper layer of the lithosphere, together with the accompanying mechanical actions of agents inside and on the surface of the earth's crust (Shvetsov, 1951, in translation).

Merzlyi grunt (Russian). *See* Frozen ground.

Mnogoletnaia merzlota (Russian). *See* Permafrost.

Mollisol. Seasonally thawed ground above the peregelisol (permafrost), equivalent to active layer of Muller (1945) (from Byran, 1946).

Mollition. The act or process of thawing the mollisol (Bryan, 1946).

Muck. 1. Silt rich in organic material. It is gray to black when wet or frozen and fetid upon thawing. Muck in permafrost ground generally contains more ice than either perennially frozen loess or flood-plain silt (Péwé, 1954, p. 324).
2. A mixture of decayed vegetable matter and siltlike material forming the surface layer of the ground in areas of permafrost. Locally, in river valleys, muck may be as much as 100 feet thick (Muller, 1945), p. 219).

Muskeg. (*See also* Organic terrain.) A shallow, poorly drained, peat-filled depression supporting bog vegetation (Hennion, 1955, p. 110).

Naled' (Russian). (*See also* Icing, definition 3; taryn.) Term recommended only for formations on the surface of an ice cover, **taryn** being preferred for ground naledi (icings) (Akad. Nauk SSSR, Inst. Merzlotovedeniia, 1956).

Naled' process. Combination of processes: the freezing of ground or water, water migration, the formation of mounds, their cracking, the emergence of water and its freezing. The results of this process (mounds, emerging waters, ice formed from the waters) is called the naled' phenomenon (Tolstikhin, 1940, p. 276, in translation).

Needle ice. Long, thin, needlelike ice crystals appearing immediately below the ground surface during spring and fall nights; formed when air temperature falls below freezing, but while the ground is yet unfrozen. Form normal to ground surface (from Lovell and Herrin, 1953). Syn: Piprake, ledianie stebelki (Russian). Also termed **hoar frost** (Beskow, 1935), or **acicular ice** (Muller, 1945).

Non-frost-susceptible materials. Cohesionless materials such as crushed rock, gravel, sand, slag, and cinders in which significant (detrimental) ice segregation does not occur under normal freezing conditions (Hennion, 1955, p. 108).

Nonfusing permafrost or **nonmerging permafrost.** Permafrost separated from the layer of annual winter freezing by an unfrozen layer (from Sumgin and others, 1940, and Liverovskii and Morozov, 1941, in translation). Ant: Confluent or merging permafrost.

Nonperforating talik. A talik which does not entirely pierce the frozen ground (Vel'mina, 1959, in translation).

Open system. A condition in which free water in excess of that contained originally in the voids of the soil is available to be moved to the surface of freezing to form segregated ice in frost-susceptible material (Hennion, 1955, p. 108).

Organic terrain. (*See also* Muskeg.) Terrain, the surface of which is composed of a living organic mat of mosses, sedges, and (or) grasses, with or without tree and shrub growth. Underneath the surface there is a mixture of partially decomposed and disintegrated organic material, commonly known as "peat" or "muck" * * * this subsurface material is highly compressible compared to most mineral soils (MacFarlane, 1957, p. 3).

Pals (Sandinavian). (*See also* Frost mound.) Peat mound.

Passive method (of construction). Method in which the regime of the frozen ground at or near the structure is not disturbed or altered (Muller, 1945, p. 219).

Passive permafrost. Permafrost that was formed during earlier colder climates; once destroyed does not appear again (Muller, 1945, p. 219, from Bilibin, 1937). Syn: Passive permanently frozen ground, passivnaia vechnaia merzlota (Russian).

Passive permanently frozen ground. *See* Passive permafrost.

Passivnaia vechnaia merzlota (Russian). *See* Passive permafrost.

Patterned ground. A general term describing ground patterns resulting from frost action, such as soil polygons, stone polygons, stone circles, stone strips, and solifluction stripes. The most common type of polygon is known as a fissure polygon (Hennion, 1955, p. 109). COMPILER'S NOTE.—Summaries of terminology of patterned ground and references to the extensive literature may be found in Washburn (1950) and Dylikowa and Olchowik-Kolasinska (1955, 1956). These terms are generally omitted from this glossary.

Peat mound. *See* Frost mound.

Perekhednoi sloi (Russian). (*See also* Pereletok, intergelisol.) An intermediate frozen zone lying between the active layer and permafrost. Sumgin (1940) regards it as belonging to the active layer; Tolstikhin thinks it occurs in significant thickness only in the marginal areas of permafrost (from Dylikowa and Olchowik, 1954, p. 141).

Pereletok (Russian). (*See also* Intergelisol, perekhodnoi sloi.) A frozen layer at the base of active layer which remains unthawed for one or two summers. Pereletok may easily be mistaken for permafrost. (Muller, 1945, p. 219).

Perelotki merzloty (Russian). Islands of frozen ground, formed during several cold winters, that persist for several years and ultimately disappear (from Dylikowa and Olchowik, 1954, p. 141).

Perenne tjäle (Swedish). *See* Permafrost.

Perennially frozen ground. *See* Permafrost.

Perennierende tjäle (Swedish). *See* Permafrost.

Perforating talik. *See* Piercing talik.

Pergelation. The act or process of forming permanently frozen ground in the present or in the past (Bryan, 1946).

Pergelisol. Permanently or perennially frozen ground (Bryan, 1946). Syn: Permafrost.

Pergelisol table. *See* Permafrost table.

Permafrost. 1. Layers of ground (or geological formations) located at a certain depth from the surface which have a minus temperature lasting continuously from X years up to thousands or tens of thousands of years. The value of X is the length of existence of pereletok, so far not established, but approximately equal to 2, 3, or 5 years (Sumgin and others, 1940, in translation).

2. Perennially frozen ground (Hennion, 1955, p. 107).
3. Ground with negative temperature and not subject to seasonal thawing (Liverovskii and Morozov, 1941, p. 34, in translation).
4. A thickness of soil or other surficial deposits or even of bedrock, at a variable depth beneath the surface of the earth in which a temperature below freezing has existed continuously for a long time (from two to tens of thousands of years) (Muller, 1945, p. 219).
5. Permanently frozen material. It may be bedrock, muck, sand, gravel, ice, or some other superficial covering of the earth's surface which remains continually frozen for a period of two or more years (Rathjens, 1951, p. 645).
6. Permanently frozen material of varying depth existing above bedrock and below the zone of seasonal thaw (Rathjens, 1944).

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7. A special class of igneous or metamorphic rocks and sediments that contains various amounts of ice or other cryophile (those that are solid only below 0°C) minerals at a depth where they are not affected by meteorological processes. If there are no cryophile minerals, the ground cannot be called frozen, even if below 0°C (Parkhomenko, 1938).
8. The presence of a field of negative temperature located below the layer of zero annual amplitude in the upper part of the earth's crust (Redozubov, 1946, in translation).

Syn: Constant frost; constant soil gelation; Dauerfrostboden; Dauernder frostboden; eternal frigidness; eternal frost; eternally frozen ground; ever frozen soil, ground or subsoil; ewiger Frostboden; frost (in part); Frostboden (in part); frost of long duration; frost of many centuries; frost of many years; frozen geozone; frozen zone; frozen zone of the lithosphere; Gefronis; ground frost (in part); ice soil; kriogeozona; kriohtonna geozona; long lasting frozen ground; mnogoletnaia merzlota; merzla geozona; merzlota (in part); perennially frozen ground; perenne tjäle; pergelisol; permafrozen ground; permanent frost; perpetually frozen ground, soil, or subsoil; postoianno merzlyi grunt; postoiannaia gruntovaia merzlota; postoiannoe (pochvennoe) promerzanie; stable frost; stable frozen ground; stable ground frost; standiger Frostboden; tjäle; ustoichivaia merzlota; vechnaia merzlota; vechnomerzlyi podpochva; vsegda merzlyi grunt; vsegda merzlaia pochva; vsegda merzlaia podpochva.

Permafrost area. A specific section where all or only a part of the material below the earth's surface is permafrost (Rathjens, 1951, p. 645).

Permafrost table. A more or less irregular surface which represents the upper limit of permafrost (Muller, 1945, p. 219; Hennion, 1955, p. 107). Syn: Permanently frozen ground table, upper surface.

Permafrost thickness. The vertical distance at a given point between the upper surface of permafrost (permafrost table) and the lower surface of permafrost (from Sumgin and others, 1940).

Permafrostology. English translation of **merzlotovedenie,** a **Russian** term now replaced by **geokriologiia (geocryology).** *See* Merzlotovedenie, geokriologiia.

Permafrost ground or **permafrozen ground.** *See* Permafrost.

Permanent frost. *See* Permafrost. Syn: Vechnaia merzlota (Russian).

Permanent ground frost. *See* Permafrost. Syn: Postoiannaia gruntovaia merzlota (Russian).

Permanent talik. *See* Talik.

Permanently frozen ground. *See* Permafrost. Syn: Postoianno merzlyi grunt (Russian).

Permanently frozen ground table. *See* Permafrost table.

Permanent frost. *See* Permafrost. Syn: Vechnaia merzlota (Russian).

Perpetually frozen ground, soil, or **subsoil.** *See* Permafrost. Syn: Vechnomerzlyi grunt (ground, soil) (Russian), vechnomerzlyi podpochva (subsoil) Russian.

Piercing talik. A talik which entirely pierces the frozen ground. Syn: Perforating talik, taliki skvoznye (Russian).

Pingo. (*See also* Hydrolaccolith.) 1. The Eskimo name for conical hills that occur on the low, featureless Arctic coastal plain of North America from Point Barrow to east of the Mackenzie delta to the Horton River, N.W.T. Occur as two types: (a) those formed by hydraulic pressure on sloping ground and pervious soils, and (b) those formed by local upheaval due to expansion following progressive downward freezing of a body or lens of water or semifluid mud, chiefly in lake basins or beds of former lakes (Porsild, 1938).

2. Eskimo name for "conical hill." Has been used in the past as a local name for a frost mound. It is suggested that the name pingo should be restricted to frost mounds that are of longer than seasonal duration and that are, as a rule, of relatively large dimensions (Muller, 1945, p. 220).

3. A large frost mound, not uncommonly a hundred feet high or more, containing a core of ice (Hennion, 1955, p. 110).

4. A term used in the United States for long-lasting large hummocks whose origin is due to the hydrostatic pressure of ground water from below the merzlota (permafrost) or from taliki (thawed zones), or of the artesian water. In Russian, "pingos" are called hydrolaccoliths or bulgunniakhi (from Poiré, 1949).

Pingorssarajuk (Eskimo). *See* Hydrolaccolith, pingo.

Piprake (German). *See* Needle ice.

Polygonal ground (also checkered, orthogonal, tetragonal ground, tundra or Taimyr polygons). Ground with a polygonal surface pattern caused by subsidence of the surface over ground ice that is arranged in a polygonal network. Not to be confused with polygonal surface markings of small scale produced by frost heaving (Péwé, 1954, p. 323). COMPILER'S NOTE.—See Washburn (1950) and Dylikowa and Olchowik-Kolasinska (1955, 1956) for terminology of polygonal ground and polygonal markings formed by frost heaving.

Polyn'ia (Russian). 1. Areas of river channel which do not freeze in winter, generally caused by presence of ascending springs (Tolstikhin, 1940, in translation).

2. An unfrozen portion or a window in the river ice which remains unfrozen during all or part of the winter owing to a local inflow of warm water either from a subaqueous spring or from a tributary (Muller, 1945, p. 220).

Postoiannaia gruntovaia merzlota (Russian). *See* Permafrost. Syn: Permanent ground frost.

Postoiannaia merzlota (Russian). Permanently frozen.

Postoianno merzlyi grunt (Russian). *See* Permafrost. Syn: Constant frozen ground, permanently frozen ground.

Postoiannoe pochvenno promerzanie (Russian). *See* Permafrost. Syn: Constant soil gelation.

Postoiannoe promerzanie (Russian). *See* Permafrost. Syn: Eternal frigidness.

Prosloiki merzloty (Russian). Tiny lenses of frozen ground scattered in the unfrozen mass that can be seen during maximum degelation of the ground in autumn (from Dlyikowa and Olchowik, 1954, p. 141).

Pseudoisland of talik. Unfrozen ground beneath the seasonally frozen ground (active layer) surrounded and underlain by continuous permafrost (Muller, 1945, p. 221).

Pseudotalik. Talik limited from below by frozen ground (from Sumgin and others, 1940, in Dylikowa and Olchowik, 1954, p. 138). Syn: Taliki zamknutye s nizu (Russian).

Residual thaw zone. A layer of unfrozen ground between the permafrost and the annual frost zone. This layer does not exist where annual freezing penetrates to the permafrost table (Hennion, 1955, p. 107).

Rost vechnoi merzloty (Russian). *See* Aggradation of permafrost, pergelation.

Satin ice. *See* Acicular ice.

Seasonal frost. Ground having a temperature below 0°C during a definite season (Poiré, 1949).

Seasonally frozen ground. (*See also* Active layer.) The upper part of the earth's crust that is subject to seasonal freezing and thawing. The seasonally frozen ground can occur in all regions in which the temperature of the earth's surface can become negative, that is, below 0°C. The thickness of seasonally frozen ground in regions with permafrost is usually less than it would be if permafrost were absent (Poiré, 1949).

Seasonally thawed ground. Term recommended to replace **active layer** (Akad. Nauk SSSR, Inst. Merzlotovedeniia, 1956, in translation).

Sersineq (Greenland). (*See also* Icing.) Fountain ice formed by brooks originating in hot spring in Disko Bay area, Greenland (Porsild, 1925).

Sloistyi postoianno merzlyi grunt (Russian). *See* Layered permafrost.

Sloistyi vechnomerzlyi grunt (Russian). *See* Layered permafrost.

Sloistyi vsegda merzlyi grunt (Russian). *See* Layered permafrost.

Soil blister. *See* Frost blister.

Sol gelé (le) (French). *See* Frozen ground.

Solifluction. 1. The perceptible downslope movement of saturated nonfrozen soil over a base of impervious or frozen material. Movement occurs primarily when melting of segregated ice or infiltration of surface runoff results in concentration of excess water in the surface soils (Hennion, 1955, p. 109–110).

2. A process of subaerial denudation consisting of the slow gravitational flowing of masses of superficial materials saturated with water (Muller, 1945, p. 222).

Specific heat (of soil). The number of British thermal units necessary to raise the temperature of one pound of dry soil 1°F (Hennion, 1955, p. 109).

Sporadic permafrost (zone). 1. Permanently frozen ground occurring as scattered islands in the area of dominantly unfrozen ground (Muller, 1945, p. 222).

2. Permafrost found in scattered patches, of limited thickness, and having a temperature close to the melting point, 28° to 32°F (from Pihlainen, 1955, p. 11).

3. Zone of sporadic or scattered bodies of permafrost having a temperature at a depth of 30 to 50 feet higher than —1°C (from Black, 1950).

Stable frost. *See* Permafrost.

Stable frozen ground. *See* Permafrost.

Stable ground frost. *See* Permafrost. Syn: Istoichivaia gruntovaia merzlota (Russian).

Standiger Frostboden (German). *See* Permafrost.

Steineis (German). Stone ice. *See* Ground ice.

Stone ice. *See* Ground ice.

Strukturnoye ledovedenie (Russian). Term meaning cryology, a branch of study that has at its objective the analysis of the composition and structure of ice leading to far-reaching conclusions as to the conditions of ice formation in nature. Attempts to solve the problem raised by the formation and conditions responsible for the persistence of ground ice (from Shumskii, in Dylikowa and Olchowik-Kolasinska, 1955; 1956, p. 121).

Subarctic. The region adjacent to the Arctic in which the mean temperature for the coldest month is below 32°F, the mean temperature for the warmest month is above 50°F, and where there are less than 4 months having a mean temperature above 50°F. In general, subarctic land areas coincide with the circumpolar belt of dominant coniferous forest (Hennion, 1955, p. 107).

Subpermafrost water. Water which lies below the layer of permafrost. The permafrost layer serves as a ceiling for the upper portion of such waters (Tolstikhin, 1940, in translation).

Subsoil ice. *See* Ground ice.

Subsoil water. Water formed in thick alluvium above perpetually frozen ground by infiltration of precipitation and by condensation of moisture during the frostless season (Chernyshev, 1935). Syn: Suprapermafrost water.

Subsurface ice. *See* Ground ice.

Subterranean ice. *See* Ground ice.

Subwater. *See* Subpermafrost water.

Suffosion process. (*See also* Frost mound.) A process taking place in summer in which a layer of water occurs under the firm and dry crust of the surface peaty soil which frequently was found to creep down to lower levels. The pressure exerted was so great that cracks would form in the dry soil and liquid mud would pour out, or that convex mounds (suffosion knobs or mounds) would form (from Nikiforoff, 1928, p. 70).

Sukhaia merzlota (Russian). (*See also* Dry frozen ground, dry permafrost.) Dry frozen ground * * * loose rocks which do not contain a sufficient amount of water to cement the ground with ice (from Sumgin and others, 1940; in Dylikowa and Olchowik, 1954, p. 138).

Sukhaia vechnaia merzlota (Russian). *See* Dry permafrost. Syn: Dry frozen ground, dry permafrost.

Superwater. *See* Suprapermafrost water.

Suprapermafrost. The entire layer of ground above the permafrost table (Hennion, 1955, p. 107).

Suprapermafrost layer. Thickness of ground above permafrost consisting of active layer, talik, and also the pereletok, wherever present (Muller, 1945, p. 222).

Suprapermafrost water. Water on top of the layer of permafrost, which serves as a watertight foundation. It is usually encountered in the negative forms of relief, on wide water divides, less often on slopes, and mostly in Quaternary deposits (from Tolstikhin, 1940, in translation).

Suprazone. *See* Suprapermafrost layer.

Surface freezing index. *See* Freezing index.

Surface thawing index. *See* Thawing index.

Surficial swelling. Swelling of ground, usually of small magnitude (5–10 cm), caused by the freezing of meteoric waters which penetrate to a small depth below the surface (Muller, 1945, p. 222).

Swelling, deep-seated. *See* Deep-seated swelling.

Swelling of ground. Increase in volume of surficial deposits due to frost action (Muller, 1945, p. 222).

Tabetification. (*See also* Talik.) The act or process of forming tabetisol Bryan, 1946).

Tabetisol. Unfrozen ground above, within, or below the pergelisol (Bryan, 1946).

Taele (Norwegian). *See* Tjäle, frozen ground.

Talik (Russian). (*See also* Nonperforating talik, piercing, or perforating talik, tabetisol.) 1. Ground which not being perennially frozen is encircled by perennially frozen ground (Tumel' in Sumgin and others, 1940, in Dylikowa and Olchowik, 1954, p. 138).

2. A rock, no matter what its temperature, in which there is circulation of water, and, as a rule, every rock whose temperature is positive (Tolstikhin, 1941, *in* Dylikowa and Olchowik, 1954, p. 138).

3. A layer of unfrozen ground between the seasonal frozen ground (active layer) and the permafrost. Also applies to an unfrozen layer within the permafrost as well as to the unfrozen ground beneath the permafrost (Muller, 1945, p. 223).

Talik island. Unfrozen ground beneath the seasonally frozen ground surrounded on the sides by the permafrost and extending vertically to the bottom of the permafrost (Muller, 1945, p. 218).

Talik water. Water that exists within a talik, as, for example, water in the thawed zone (talik) beneath a river (from Svetozarov, 1934, in translation).

Taliki skvoznye (Russian). *See* Piercing talik.

Taliki zamknutye s nizu (Russian). *See* Pseudotalik.

Taryn (Yakut). (*See also* Icing.) 1. Icing which does not thaw completely during the summer (from Muller, 1945, p. 223).

2. Large icings in the mountains of Yakutia (Siberia) whose formation is due to the hydrostatic pressure of the ground water from below the permafrost (Poiré, 1949).

3. Term preferred for ground icings, the term *naled'* being used only for formations on the surface of an ice cover (Akad. Nauk SSSR, Inst. Merzlotovedeniia, 1956, in translation).

Tele (Norwegian). *See* Tjäle, frozen ground.

Temperature inertia (stability) of the soil. Long-lasting stability of the soil temperature at a certain depth in winter (Chekotillo, 1955, in translation); criticized by Zhukov (1958), who believes term should be eliminated from scientific terminology.

Temporary talik. A layer of unfrozen ground between the active layer (seasonally frozen ground) and permafrost, whose unfrozen state is due to an occasional warm winter or unusually early snowfall. It usually disappears with the return of the normal winter regime (Muller, 1945, p. 223).

Thaw depression. Depression which results from subsidence following thawing of perennially frozen ground (Hopkins, 1949, p. 119).

Thaw lake. (*See also* Cave-in lake, cryogenic lake.) Lake which occupies thaw depression; term includes lakes which originated in other ways but which have been considerably enlarged by thawing and caving at their margins (from Hopkins, 1949, p. 119). Syn: Kettle or kettle-hole lake, thermokarst lake.

Thaw sink. Closed depression with subterranean drainage; believed to have originated as thaw lake, (Hopkins, 1949, p. 119).

Thawing index. The number of **degree-days** between the lowest and highest points on the curve for cumulative degree-days versus time for one thawing season. It is used as a measure of the combined duration and magnitude of above-freezing temperatures occurring during any given thawing season. The index determined for air temperatures at 4.5 feet above the ground is commonly designated as the **air thawing index,** while that determined for temperatures immediately below a surface is known as the surface thawing index (Hennion, 1955, p. 109).

Thawing season. That period of time during which the average daily temperature is generally above 32°F. NOTE.—The definitions for **freezing season** and **thawing season** are applicable to conditions in arctic and subarctic regions where frequent oscillations about the freezing point are uncommon (Hennion, 1955, p. 108).

Thermal conductivity or **conductance.** The time rate of heat flow through unit area of a substance under a unit temperature gradient. Common units are British thermal units per hour per square foot per degree F per inch or foot of thickness (Hennion, 1955, p. 109) or calories per second per °C per cm of thickness.

Thermal regime. The temperature pattern existing in a body (Hennion, 1955, p. 109).

Thermal resistivity or **resistance.** The reciprocal of thermal conductivity or conductance (Hennion, 1955, p. 109).

Thermokarst. 1. Karstlike topographic features produced by the melting of ground ice and the subsequent settling or caving of ground (Muller, 1945, p. 223).

2. A process of differential settling or caving of the soil surface (Ermolaev, 1932, in translation).

3. The process of thawing of ice in the ground (except in bedrock) which is accompanied by the local settling of the soil surface and the formation of negative relief forms (Mukhin, 1960, in translation).

Syn: Cryokarst.

Tjäle (Tjaele) (Swedish). (*See also* Frozen ground.) Frozen ground without determining the duration of its frozen state * * * hence it is equivalent to frozen ground but not to perennially frozen ground (Dylikowa and Olchowik, 1954, from Högbom, 1914, and Bryan, 1951). Syn: Tele (Norwegian).

Transitory frozen ground. Ground frozen by a sudden dip of temperature and remaining frozen but a short time, usually a matter of hours or days (Muller, 1945, p. 223).

Tundra. 1. Those areas in high latitudes in which timber is lacking and the ground bears a partial or complete cover of sedges, willows, dwarf birches, mosses, and lichens (Sigafoos and Hopkins, 1952).
2. A treeless region of grasses and shrubs characteristic of the Arctic (Hennion, 1955, p. 110).

Underground ice. *See* Ground ice.

Under-river-bed stream. Suprapermafrost water or ground water (where permafrost is absent) in a riverbed which does not freeze completely in winter (Tolstikhin, 1940, in translation).

Ureis (German). *See* Ground ice.

Ustoichivaia merzlota (Russian). *See* Permafrost.

Vechnaia merzlota (Russian). *See* Permafrost. Syn: Eternal, permanent frost.

Vechnomerzlyi grunt (Russian). *See* Permafrost. Syn: Eternally frozen ground.

Verkhovodka (Russian). Suprapermafrost water lying within the active layer and freezing each season (from Tolstikhin, 1940, in translation).

Volumetric heat capacity. The number of British thermal units necessary to raise the temperature of 1 cubic foot of a material 1°F. For dry soils it is cd; for wet soils it is $d\,\frac{w}{100}$; and for wet, frozen soils it is $d\ (c+0.5\ w)$, where c is the specific heat of the dry material, d is the dry density of a soil in lb per cu ft, and w is the water content of a soil in percentage of dry weight (Hennion, 1955, p. 109).

Volumetric latent heat of fusion. The number of British thermal units necessary to melt the ice in 1 cubic foot of soil without a change in temperature ture (Hennion, 1955, p. 109).

Volumetric weight. The ratio of the weight of a unit volume of dry ground to that of an equal volume of water under standard conditions (Muller, 1945, p. 223).

Vsegda merzlaia pochva (podpochva) (Russian). *See* Permafrost. Syn: Ever-frozen soil (pochva), ever-frozen subsoil (podpochva).

Zero annual amplitude, layer of. *See* Level of zero (annual) amplitude.

Zero curtain. 1. A layer of ground between the active layer and permafrost where zero temperature (0°C) lasts a considerable period of time (as long as 115 days a year) during the freezing and thawing of overlying ground (Muller, 1945, p. 224).
2. An interval during which the temperature remains constant as the chilling of water is temporarily compensated by the latent heat of fusion (Muller, 1945, caption fig. 10).

3. According to Sumgin, expresses the resistance to heat or cold penetration in soil due to latent heat liberated on freezing, which inhibits frost penetration to a degree depending on the moisture content of the soil (Stotsenko and Ignatenko, 1957). Criticized by Zhukov (1958) who believes term should be eliminated from scientific terminology.

Zmarzlina (Polish). *See* Frozen ground.

ANNOTATED BIBLIOGRAPHY

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Large yields of potable water are found in aquifers beneath permafrost, particularly in river valleys. Temperature of the ground water is commonly high enough to prevent freezing of the distribution system. Ground water occurs in bedrock fissures, at contacts, and in structural depressions beneath permafrost.

Afanas'yev, A. N., 1958, Second conference on subterranean waters and engineering geology of Eastern Siberia (Russian): Meteorologiia i Gidrologiia, no. 11, p. 68–69.

Seventeen papers on general and methodological problems of hydrogeology, 24 on regional hydrogeology, and 18 on engineering geology and permafrost research were given at the meeting. Among papers at the plenary session were: I. K. Zaitsev's "A Multilateral Hydrogeologic Map of Eastern Siberia" (1:2,500,000) and V. G. Tkachuk's "The Mineral Waters of Eastern Siberia."—From translation 59–13328, Office of Tech. Services, U.S. Dept. Commerce.

Akademiia Nauk SSSR, 1958, Soviet coordinating commission for permafrost studies: Akad. Nauk SSSR Izv., Ser. geog., no. 4, p. 138–139, 1957 [Russian]; translated, 1958, Polar Rec., v. 9, no. 59, p. 150–151.

An interdepartmental Coordinating Commission for Permafrost Studies (Koordinatsionnaia Komissiia po Merzlotovedeniiu) has been attached to the Obruchev Institute for Permafrost Studies. A working committee to function between annual meetings consists of P. F. Shvetsov (Chairman), A. M. Chekotillo (Secretary), I. F. Nasedkin, M. V. Kim, A. L. Kalabin, V. A. Kudriavtsev, and two others.

Akademiia Nauk SSSR, Institut Merzlotovedeniia, 1956, The basic concepts and terms of geocryology (permafrostology) [Osnovnye poniatiia i terminy geokriologii (merzlotovedeniia)]: Moscow, Akad. Nauk SSSR Izd., 16 p.

A new terminology of 36 terms developed during 1950–55 by a commission of the Institute of Permafrostology, P. I. Koloskov and, later, P. F. Shvetsov, chairmen. "Permafrostology" is replaced with "geocryology"; "permanent" with phrase of "several years' standing." "Naled' " is to be used only for formations on the surface of an ice cover, "taryn" being preferred for ground naledi. "Forest soils" or "rocks" replaces "dry permafrost." "Seasonally thawed" ground replaces "active layer." *See* Glossary of terms.—From SIPRE 16349.

Akademiia Stroitel'stva i Arkhitektury SSSR, 1959, Instructions for the organization and conduct of observations on the change in the water and temperature regime of permafrost for the purpose of foundation construction [Ukazaniia po organizatsii i vedeniiu nabliudenii za izmeneniem vodno-

temperaturnogo rezhima vechnomerzlykh gruntov dlia tselei fundamentostroeniia]: Moscow, Gos. izd. literatury po stroitel'stvu, arkhitekture i stroitel'nym materialiam, 26 p.

Technical instructions for instrumentation of boreholes, including procedures for observing temperature variations in permofrost and changes in water levels.—From SIPRE 17610.

Akimov, A. T., 1935, Geophysical methods in studying permafrost [Geofizicheskie metody na merzlote]: Razvedka Nedr, v. 5, no. 22, p. 30–33.

1937, Specific resistance of frozen soils: Akad. Nauk SSSR Comptes rendus (Doklady), new ser., v. 16, no. 8, p. 405–407. [Russian.]

1959, Results of permafrost and geophysical investigations in the eastern part of the Bol'shezemel'skaya tundra [Resul'taty merzlotno-geofizicheskikh issledovanii v vostochnoi chasti Bol'shezemel'skoi tundry] Akad. Nauk SSSR, Inst. Merzlotovedeniia im. V. A. Obrucheva Trudy, v. 15, p. 5–46.

Electrometric (resistance) and geothermal investigations in the Vorkuta industrial area from 1946 to 1952 were successful in determining the location and thickness of permafrost and talik, but were not successful where the taliks were narrow and where large permafrost islands occurred among extensive areas of talik.—From SIPRE 18234.

Alaska's Health, 1951, Safe wells need careful plans: Alaska's Health v. 9, p. 7, August.

Suggestions for proper location of wells with respect to sewage disposal facilities and a detailed plan for a safe well suitable for Arctic conditions.—From Arctic Bibliography 27729.

1953, Fairbanks begins construction of unique new circulating water system in hope to foil sub-Arctic's freezing effects on mains: Alaska's Health, v. 10, p. 5.

Water for the new single-main recirculating system is to be obtained from a 24-in. drilled well.—From Arctic Bibliography 27707.

Alter, A. J., 1949, Water supply problems of the Arctic: Alaska's Health, v. 7, no. 3, p. 1–3.

A brief discussion of water supply in permafrost regions, including the utilization of ground water.

1950a, Arctic sanitary engineering: Washington, Federal Housing Adm., 106 p.

Shallow suprapermafrost water provides a seasonal supply that is easily contaminated. Rarely, water is entrapped within the permafrost in the southern part of the permafrost zone, but the yield is variable. Subpermafrost water supplies are difficult to locate, costly to develop, and commonly highly mineralized. In the Arctic, where permafrost extends into bedrock, circulation of ground water beneath permafrost is hindered by impermeable bedrock formations, and recharge through the permafrost is impossible. At Fairbanks several wells tap subpermafrost water; the warmest water is available at some distance below the base of permafrost.

1950b, Water supply in Alaska: Am. Water Works Assoc. Jour., v. 42, no. 6, p. 519–532. *See* annotation, Alter, A. J., 1950a.

1952a, Relationships of permafrost to environmental sanitation, *in* Alaskan Sci. Conf., 1st, Washington 1950, Proc: Natl. Research Council Bull. 122, p. 240–253.

Inadequate water supply, unsafe disposal of human excrement, accumulations of refuse, substandard housing, difficulties in insect control, and careless food handling are among the chief sanitation problems. Permafrost forms an impermeable substratum that prevents recharge of ground-water supplies by infiltration. Ground water above permafrost is easily exhausted and may be frozen much of the year. Wells through permafrost will freeze unless pumping is regulated.

1952b, Water supply problems in low-temperature areas, *in* Alaskan Sci. Conf., 1st Washington 1950, Proc: Natl. Research Council Bull. 122, p. 94–95; repr., 1952, Science in Alaska, Selected papers of the Alaskan Science Conference * * *: Arctic Inst. North America, p. 219–239. *See* annotation, Alter, A. J., 1955.

1953, Thermodynamic considerations in the design of Alaskan water distribution systems, *in* Alaskan Sci. Conf., 4th, Juneau 1953, Proc: Science in Alaska, p. 36–38.

Among the methods of warming the water prior to distribution is mixing surface water having a winter temperature of 32°F with warmer ground water.

1955, Low temperature problems in Alaska: Am. Water Works Assoc. Jour., v. 47, p. 763–767.

About 66 percent of Alaska lies within the permafrost zone. Permafrost prevents infiltration of water into the ground. The combination of ground-water temperatures near 32°F and below-freezing ground temperatures in wells through permafrost causes some wells to freeze. Well freezing may be prevented by controlled pumping, addition of hot water, recirculating antifreeze through a coil in the well, or by using electric heating devices.

Alter, A. J. *See also* Clark, L. K., 1956.

Ananian, A. A., 1945, Electric conductivity of frozen soils [Elektroprovodnost' merzlykh gruntov] [abs.] : Akad. Nauk SSSR, Otdel. geol. geog. Nauk, 1944, p. 124.

At positive temperatures (centigrade scale) the increase of moisture in the ground decreases its conductivity, whereas the decrease of the ice content increases its conductivity. At temperatures below freezing, the increase of moisture—that is, the increase of the ice content in the frozen ground—decreases its conductivity, whereas the decrease of the ice content increases the conductivity, and some samples of frozen ground remain sufficiently conductive for purposes of electric prospecting.—From U.S. Geol. Survey Bull. 959, p. 125, Geophys. Abs. 10075.

1952, Migration of moisture in frozen loose mountain rock soils under the influence of electro-osmotic forces [Peremeschchenie vlagi v merzlykh rykhykh gornykh porodakh pod vliianiem sil elektroomosa]: Kolloidnyi Zhur., v. 14, no. 1, p. 1–9.—*See* SIPRE U–5316.

1958, Dependence of the electrical conductivity of frozen rocks on saturation [Zavimost'elektroprovelnosti merzlykh gornykh porod ot vlazhnosti] : Akad. Nauk SSSR Izv., Ser. geofiz., no. 12, p. 1504–1509.

Electrical conductivity in finely dispersed frozen rocks is governed by the progressive advance of the not yet frozen portion of the water; it is determined by the phase relations of the water. The smaller the amount of ice and the larger amount of unfrozen water, the higher the electrical conductivity.

Conductivity of frozen rocks reaches its maximum when the moisture content approaches the lower limit of plasticity.—From U.S. Geol. Survey Bull. 1106-B, p. 173–174, Geophys. Abs. 177-142.

Ananian, A. A., and **Baulin, V. V.,** 1960, A second permafrost layer in the Salekhard region [O vtorom sloe mnogoletnemerzlykh porod v raione Salekharde]: Akad. Nauk SSSR, Inst. Merzlotovedeniia im. V. A. Obrucheva Trudy, v. 16, p. 141–149.

Geothermal investigations from 1953 to 1958 on a layer of permafrost 40–100 m thick lying at a depth of 93–152 m show that it is a relic of soil freezing that took place before the Climatic Optimum. Its temperature ranges from 0° to —0.4°C, and ground temperatures are plotted to a depth of 325 m.—From SIPRE 18324.

Andreev, V. N., 1936, Hydrolaccoliths in East Siberian tundra [Gidrolaccolity [bulgunniakhi] v Zapadno-Sibirskikh tundrakh]: Gos. geo. obschch. Izv., v. 68, no. 2, p. 186–210.

Hydrolaccoliths as much as 40 m high are caused by progressive downward freezing of water. These mounds occur in Transbaikal, the IAmal Peninsula, and in the Baidaratskaia tundra in flat, poorly drained areas near river deltas or in old lake basins. Water seeping through the fissures in the mounds is generally of a subterranean origin. Mounds fed by ground water last many years; those fed by surface water usually disappear the following summer.—From SIPRE U-3063.

Andrianov, P. I., 1927, Unfrozen water at —3°C, hygroscopic moisture and certain physical properties of soil [Voda nezamerzaiuschchaia pri —3°C, voda gigroskopicheskaia i nekotorye, fizicheskie svoistva pochvy]: Nauchn.-Agron. Zhur., v. 4, p. 307–319.

The amount of water unfrozen at —3°C increases with an increase in hygroscopic moisture and soil in solution.—From SIPRE 8618.

1946, The bound water in soil [Sviazannaia voda pochv i gruntov]: Akad. Nauk SSSR, Inst. Merzlotovedeniia im. V. A. Obrucheva Trudy, v. 3, p. 5–138.—*See* SIPRE 11880.

Anisimova, N. P., 1956, Chemical composition of the deep underground water of central Yakutia [O khimicheskom sostave podzemnykh vod nekotorykh glubokikh gorizontov na territorii tsentral'noi IAkutii]: Akad. Nauk SSSR Inst. Merzlotovedeniia, Materialy k osnovam ucheniia o merzlykh zonakh zemnoi kory, no. 3, p. 123–125.

Permafrost effects on ground-water composition were studied in two regions differing in geological and permafrost conditions. Chemical analyses were made of water obtained from depths as great as 2,015 m in the Vilyuy region and 1,400 m in the Olekma region. Permafrost caused low mineralization of the water; its content of dissolved solids remained below 0.45–0.65 grams per liter even at depths of 1,845–2,015 m.—From SIPRE 14079.

1957, Chemical composition of ground water and certain rules for its fluctuation under circulating conditions in eternally frozen ground in the central region of the lower Lena River [Khimicheskii sostav podzemnykh vod i nekotorye zakonomernosti ego izmeneniia v usloviiakh rasprostraneniia mnogoletnemerzlykh porod raion srednego techeniia R. Leny]: Akad. Nauk SSSR IAkutsk.

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Summary of results of research on application of electrical prospecting methods to study of thickness of the active layer and of permafrost thickness by Enenshtein (1947) and Petrovskii and Dostovalov (1947).

Armstrong, T. E., and Roberts, Brian, 1958, Illustrated ice glossary, part 2: Polar Rec., v. 9, p. 90–96.

Avsiuk, G. A., Markov, K. K., and Shumskii, P. A., 1956, Geographical investigations in an antarctic "oasis" [Geograficheskie issledovaniia v antarkticheskom "oazise"]: Vses. geog. obshch. Izv., v. 88, p. 316–350.

Permafrost has been found everywhere in the oasis (a glacier-free area of Antarctica); depth of thaw in summer reaches 25–40 cm in moist soil and 85–100 cm in dry soil. Icing mounds 0.5–1.0 m high and 2–3 m in diameter have been found only in depressions wet with ground water.—From SIPRE 14498.

Bader, F. F., 1935, Permafrost in southwestern Transbaikalia [Merzlota v iugozapadnom Zabaikal'e]: Gos. geog. obshch. Izv., v. 67, no. 2, p. 258–260.

The Tugnuia basin, located on the right bank of the Selenga River between long 107° 35′ and 108° 40′ E. and lat 52° 30′ and 50° 50′ N., consists of flood plains, terraces, bedrock hills, and mountains with an average elevation of 750 m above sea level. Well drilling in 1934 indicated permafrost at depths ranging from 0.25 on the flood plain of the Tugnuia River to 6.45 m on well drained terraces. The lower limit of permafrost did not exceed 11.5 m in depth. The permafrost layer was interlaced with ice, sludge, and unfrozen sand, and its thickness is estimated to be about 5 m.—From SIPRE U-1719.

Bakakin, V. P., 1959a, Characteristics of mining in permafrost areas and areas with deep winter freezing [Osobennosti gornogo dela v oblasti rasprostraneniia merzlykh porod i glubokogo zimnego promerzaniia], *in* Materialy po inzhenernomu merzlotovedeniiu: Akad. Nauk SSSR, Inst. Merzlotovedeniia, p. 129–136.

Difficulties in mining are most often encountered in the upper permafrost layers because of changes in strength of the ground and disturbance of the natural water regime. Three vertical zones are recognized, each with mechanical and hydrological characteristics that affect mining operations: (1) surface layer of Quaternary deposits, (2) zone of fissured or fractured bedrock, and (3) the transition zone to subpermafrost levels.—From SIPRE 17902.

1959b, Features of mining in deeply frozen ground [Osobennosti proizvostva gornykh rabot v meschnoi telshche merzlykh porod], pt. 1, chap. 7 *of* Osnovy geokrilogii (Merzlotovedeniia), Akad Nauk SSSR, Inst. Merzlotevedeniia, p. 219–230.—*See* SIPRE 17840.

1959c, Mine construction and exploitation in the Pechora coal basin [Usloviia stroitel'stva i ekspluatatsii gornykh perdpriatii v Pechorskom ugol'nom basseine], Sovesch. po ratsional'nym sposobam fundamentostroeniia na vechnomerzlykh gruntakh, Vorkuta 1957, Trudy: Moscow, Gosstroizdat.

Among the mining problems of the region is flooding of shafts.—From SIPRE 17991.

Bakakin, V. P., and others, 1958, Excavation and exploitation of mine shafts in the Pechora Coal Basin [Prokhodka i ekspluatsiia shakhtnykh stvolov v Pechorskom ugol'nom basseine]: Akad. Nauk SSSR, Inst. Merzlotovedeniia, Materialy k osnovam ucheniia o merzlykh zonakh zemnoi kory, no. 4, p. 195–215.

Among the mining difficulties is a peculiar distribution and circulation of ground water.—From SIPRE 18425.

Ball, D. G., and **Nichols, R. L.**, 1960, Saline lakes and drill-hole brines, McMurdo Sound, Antarctica: Geol. Soc. America Bull., v. 71, no. 11, p. 1793–1798.

A small shallow lake a few hundred yards long is underlain by 3 ft of fine-grained lake sediments which rest on glacial till and marble bedrock. The lake is dry in summer, but ground water 2 ft below the lake bed had a high concentration of NaCl, $MgCl_2$, and $CaCO_3$. After the snow melts the lake is not saline, but summer evaporation and winter freezing concentrate the salt to form a residual brine that remains unfrozen most of the winter.

A hole was drilled beneath the lake into marble. Ground temperatures in February 1958 were 32°F at the surface; 16°F at 10 ft; 3°F at 20 ft; −3°F at 30 ft; −4°F at 40 ft; and −3°F at 50 ft. At the bottom of the hole a highly concentrated brine was encountered in which the constituents were measured as follows: pH 6.4; alkalinity as $CaCO_3$ 5,500 ppm; hardness as $CaCO_3$ 128,000 ppm; Ca 27,200 ppm; Mg 14,400 ppm; and Cl 137,000 ppm. A saline solution in an earth-filled joint at a depth of 12 ft is believed to have run down into the hole, becoming more highly concentrated as it became partially frozen on its descent, until the residue had the concentration shown above. A mechanism for movement of a saline solution through an ice-filled crack in frozen ground is discussed.

Baranov, I. IA., 1934, Some notes concerning the characteristics of subterranean waters of sporadic permafrost, northern Bratsk, East-Siberian region [Nekotorye zamechaniia k kharakteristike podzemnyk vod raiona ustoichivoi merzloty sporadicheskogo tipa, S. Bratsk Vostochno-Sibirskogo Kraia]: Vodny bogatstva nedr zemli na sluzhbu sotsialisticheskomu stroitel'stvu, Pervyi Vses. Gidrolog. S"ezd, Sbornik 4, p. 181–198.

The distribution of water in the active layer and water levels in wells are tabulated.—From SIPRE U–4910.

1938, Methods of mapping permafrost [O metodike sostavleniia merzlotnykh kart]: Akad. Nauk SSSR, Kom. vechnoi merzlote Trudy, v. 6, p. 107–125. [English summary.]

Engineering and hydrogeological surveys of Transbaikalia should include semidetailed and detailed maps showing the extent, continuity, and thickness of permafrost, areas of talik and sporadic permafrost, and areas lacking permafrost. The maps are to be based on examination of test pits, drilled holes, and other conventional field methods.—From SIPRE U–1786.

1940, Ground water in the region of the southern border of permafrost [Podzemnye vody iuzhnoi okrainy oblasti mnogoletnei merzloty]; Leningrad, Sbornik Gidrogeologiia SSSR, v. 17, no. 2.

1959a, Geocryological [permafrost] map of the USSR [Geokriologicheskaia [merzlotnaia] karta SSSR,] in Materialy po obshchemu merzlotovedeniiu: Akad. Nauk SSSR, Inst. Merzlotovedeniia, p. 57–71.

The map, at a scale of 1: 5,000,000 is based on material collected over the last 25–30 yr and from the literature.—From SIPRE 17931.

1959b, Geographical distribution of seasonally and perenially frozen ground [Geograficheskoe rasprostranenie sezonno-promerziaushchikh pochv i mnogoletnemerzlykh gornykh porod], pt. 1, chap. 7 *of* Osnovy geokriologii (Merzlotovedeniia) : Alad. Nauk SSSR, Inst. Merzlotovedeniia, p. 193–218.

Permafrost is found over large areas of Eurasia, North America, Greenland, Iceland, and the North Pacific Islands, and in high mountain regions of the world, where it is considerably lower than the snow line in middle and high latitudes but is above snow line in the equatorial zone. Maps show distribution of permafrost temperature in the various geographic zones of the USSR as well as areas covered with continuous permafrost, continuous permafrost with talik, and island permafrost on each continent.—From SIPRE 17917.

1959c, The subject matter and situation of general geocryology [general permafrostology] and its immediate tasks [Soderzhanie sostoianie obshchei geokriologii [obshchego merzlotovedeniia] i ee zadachi na blizhaishee budushchee], in Materialy po obshchemu merzlotovedeniiu: Akad. Nauk SSSR, Inst. Merzlotovedeniia, p. 43–56.

Geocryology comprises the study of the composition, structure, and properties of frozen ground, the general and particular geophysical laws governing the formation and distribution of seasonally and permanently frozen ground, and the history of permafrost, and is closely related to the geological and geographical sciences. Modern geocryology suffers from slipshod work and rough empiricism, which can be corrected only by a strict approach to theoretical problems. Serious difficulties have arisen from lack of well-founded qualitative studies, so that the main theoretical problems, lacking a physical basis, are confined to the morphology and morphometry of frozen ground. The thermodynamic nature of frozen ground and cryogenic processes is most in need of study. More attention should be paid in the future to the composition and structure of frozen ground, the accumulation of unconsolidated deposits, their freezing, and physiography.—From SIPRE 17930.

1960, Certain problems of the history of permafrost on the Kola Peninsula [Nekotorye voprosy istorii mnogoletnemerzlykh tolshch na Kol'skom poluostrove] : Akad. Nauk SSSR, Inst. Merzlotovedeniia im. V. A. Obrucheva Trudy, v. 16, p. 79–80.

A discussion of the evidence for more severe permafrost conditions on the Kola Peninsula, 2,500–3,000 yr ago.—From SIPRE 18316.

Barksdale, W. L. *See* Black, R. F., 1948.

Barnes, D. F., and **MacCarthy, G. R.,** 1956, Tests of geophysical prospecting techniques in areas of sporadic permafrost in interior Alaska [abs.]: Alaskan Sci. Conf., 7th, Juneau 1956, Proc., p. 41; Geol. Soc. America Bull., v. 67, no. 12, pt. 2, p. 1805.

Tests were made of resistivity and seismic refraction techniques in prospecting for ground water near Fairbanks, Big Delta, and Tok. The seismic refraction method proved excellent for detecting permafrost and mapping its upper surface, but was not successful in mapping the lower boundary of permafrost or the upper surface of bedrock. Resistivity techniques were fairly reliable in indicating the presence of permafrost and estimating its thickness; lack of adequate interpretation curves and the effects of severe lateral variations in surface resistivity limited the accuracy of depth measurements.

Barnes, D. F., and Taylor, L. D., 1958, Some preliminary results of study of a permanently frozen lake in Greenland [abs.]: Alaskan Sci. Conf., 9th, College 1958, Proc., p. 69–70.

Anguissaq Lake, 50 miles north of Thule, has maintained a 6- to 13-ft cover of ice for at least 10 yr.

Barnes, F. F. *See* Cederstrom, D. J., 1950.

Barnes, L. C., 1946, Permafrost, a challenge to engineers: Mil. Engineer, v. 38, p. 9–11.

In this summary of permafrost conditions and the Army's program of investigation, ground water is cited as a hazard, especially if in motion, for it carries heat and may thaw frozen ground. Ground-water conditions and its effect on the thermal regime of permafrost must be carefully considered in planning construction projects.

Baskov, E. A., 1959, Underground waters of Yakutia's artesian basin and some possibilities for their practical utilization [Podzemnye vody IAkutskogo artezianskogo basseina i nekotorye vozmozhnosti ikh prakticheskogo ispol'zovaniia] Leningrad, Vses. geol. inst. Materialy, new ser., Materialy geol. geomorfol. Sibirskoi platformy, no. 24, p. 125–142.

A review of investigations and of geologic factors affecting ground water in the entire Yakut ASSR, including a schematic hydrochemical profile of the artesian basin.—From Arctic Bibliography 56776.

Baskov, E. A. *See* Maksimov, V. M., 1958.

Bateman, A. M., and McLaughlin, D. H., 1920, Geology of the ore deposits of Kennecott, Alaska: Econ. Geology, v. 15, no. 1, p. 1–80.

Temperatures in the upper levels range from 30° to 32°F in midsummer and in the two lowest levels from 31° to 32°F. Ice forms in pools and occurs as coatings on the workings and as fissure fillings. There is no circulation of water in the mines. Waters were prevented from completing oxidation of the deposits by becoming frozen during the Glacial Period to form "fossil groundwater," which occurs as ice fillings in most mine levels. In the two lowest levels of Jumbo mine and in the lowest one of Bonanza mine are open cavities and fractures, abundant dust, and considerable oxidation. It is concluded that the upper frozen ground which contains ice represents water trapped by the freezing process, whereas the dry zone (below 32°F) at depth represents ground from which the water had been drained before penetration of the freezing. The oxidation is thus prefreezing or preglacial age and took place during the period of rapid erosion that immediately preceded "Glacial" time.

Bateman, J. D., 1949, Permafrost at Giant Yellowknife: Royal Soc. Canada Trans., v. 43, ser. 3, sec. 4, p. 7–11.

Permafrost, which is not present in outcrops, extends to a depth of 280 ft where the thickness of the overlying lacustrine clay approaches 60 ft. The clay overburden is regarded as an insulating blanket that has preserved ancient permafrost, and was deposited during a late glacial or Recent high level of Great Slave Lake. The age of the permafrost, therefore, is greater than that of the overburden, and is late glacial or interglacial.—From author's conclusions, p. 11.

Baulin, V. V. *See* Ananian, A. A., 1960.

Beechey, F. W., 1831, Narrative of a voyage to the Pacific and Berring's Strait: London, H. Colburn & R. Bentley, v. 1, pt. 1 of 2 parts, 742 p.

Reexamination of the ice cliffs at Eschscholtz Bay, Kotzebue Sound Region, Alaska, shows that the ice is a surface coating formed by recrystallization of snow banked against the cliff or accumulated in hollows or formed by freezing of the water that flows over the edge of the cliffs.—From Maddren, 1907.

Beliakova, E. E. *See* Zaitsev, I. K., 1956.

Benninghoff, W. S., 1952, Interaction of vegetation and soil frost phenomena: Arctic, v. 5, no. 1, p. 34–44.

Distribution of permafrost beneath a river flood plain is sketched. Spruce-covered cut banks are underlain by permafrost at shallow depth, but river channels and bars are lacking in permafrost or have a deep permafrost table. Ground which permits the greatest degree of water penetration usually thaws to the greatest depth each summer, but root systems tend to restrict the downward penetration of water.

Benninghoff, W. S. *See also* Holmes, G. W., 1957.

Beskow, Gunnar, 1935, Soil freezing and frost heaving (Tjälbildningen och tjällyftningen): Sveriges Geol. Undersök., ser. C, no. 375, 242 p.; translated by J. O. Osterberg, with special supplement covering progress from 1935 to 1947: Evanston, Ill., Northwestern Univ., Tech. Inst., Nov. 1947, 145 p.

In this fundamental study of the freezing process in soils, the subjects discussed are mechanics of soil freezing, the process of frost heaving, hydrodynamic considerations of frost heaving, and temperatures in frozen ground.

Bilibin, IU. A., 1937, Active and passive permafrost [Ob aktivnoi i passivnoi vechnoi merzlote]: Gos. Geog. obshch. Izv., v. 69, no. 3, p. 409–411.

The author's investigations do not permit full acceptance of either of the two opposing theories on the origin of permafrost: (1) that it is a product of the climate of some distant epoch and is now gradually and constantly degrading, and (2) that it is the direct result of present-day climatic conditions. Instead permafrost is either active—corresponding to present-day climate—and is regenerated when artificially destroyed, or passive—the product of former climates—and is not reformed once destroyed. Passive permafrost is found in the southern areas of the permafrost region, and active permafrost is found in the north. Permafrost may also be divided in some areas into vertically zoned active and passive permafrost, the lower passive layer being formed during the maximum development of permafrost, and the upper active layer being that which is stable under present-day climate.—From abstract by E. A. Golomshtok; SIPRE U–801.

Billings, C. H., 1953, Protecting underground utilities located in arctic regions: Water and Sewerage Works, v. 100, no. 11, p. 441–447.

Ground water occurs above, within, or beneath permafrost; the water below permafrost is like that in other climatic regions and is the most dependable source of supply. The water within permafrost is in passages like those in limestone and is generally under pressure, because the free level of its source is likely to be that of a lake or stream above ground. The water above permafrost in summer moves by gravity, percolating down the slope of the frost table; in winter, when the water begins to freeze, it becomes confined and moves under pressure. If under sufficient hydrostatic head, the water may burst through the top of the ground to form icings.

Black, R. F., 1950, Permafrost, *in* Trask, P. D., Applied sedimentation: New York, John Wiley & Sons, chap. 14, p. 247–275.

Definitions, summaries of terminology, distribution, character, temperature, relation to terrain features, origin, and geologic, engineering, and biologic significance of permafrost are given.

Large year-round supplies of water in the continuous-permafrost zone are found only in deep lakes or large rivers which do not freeze to the bottom in winter. In the U.S.S.R. artesian water has been found beneath 700 to 1,500 ft of permafrost. In the discontinuous-permafrost zone large supplies of ground water are found perched on top of permafrost or in unfrozen zones within or beneath the permafrost. Water-supply problems in the sporadic-permafrost zone are comparable to those of the temperate regions. Quality of water is generally inferior to that of temperate regions.

1951, Permafrost: Smithsonian Inst. Ann. Rept. 1950, p. 273–301. *See* annotation, Black, R. F., 1950.

1953, Permafrost—a review: New York Acad. Sci. Trans., ser. 2, v. 15, p. 126–131. *See* annotation, Black, R. F., 1950.

1954, Permafrost—a review: Geol. Soc. America Bull., v. 65, p. 839–856. *See* annotation, Black, R. F., 1950.

1956, Permafrost as a natural phenomenon, *in* The Dynamic North: U.S. Navy, Tech. Asst. to Chief of Naval Operations for Polar Projects (OP–03A3), book II, table 1, 25 p. *See* annotation, Black, R. F., 1950.

1957, Some problems in engineering geology caused by permafrost in the Arctic coastal plain, Northern Alaska: Arctic, v. 10, no. 7, p. 230–240.

Potable ground water is absent except in the beds of larger rivers and lakes. Shallow wells have encountered only saline water within and below permafrost. Potable water is trapped on permafrost in many lakes of the coastal plain. Lakes deeper than 6 ft do not freeze to the bottom and may provide a limited supply of water throughout the year. Very limited quantities of water may be obtained in summer from the active layer and from some of the offshore bars, but the water contains organic material and dissolved salts.

1958, Permafrost, water-supply, and engineering geology of Point Spencer spit, Seward Peninsula, Alaska: Arctic, v. 11, no. 2, p. 102–116.

Point Spencer is the northern tip of a spit that separates Port Clarence from the Bering Sea and is located 69 miles northwest of Nome. Gravel and sand that compose the spit deposits are perennially frozen and cemented with ice; frozen ground underlies most of the area and extends several feet beyond the shore. In many places there is more ice than normal pore space in the sediments. The top of permafrost generally parallels topographic form. The base of permafrost determined in two wells was 12.5 and 17 ft below the surface, or 7.5 and 8 ft below sea level; the base of permafrost probably conforms roughly to topography. An icing mound 30 ft in diameter was underlain by a lens of ice 1 ft thick; polygonal patterns on the older part of the spit seem analogous to ice-wedge polygons elsewhere in the Arctic, but they were not investigated.

Fresh water is derived from rain and snow melt and is trapped as perched ground water in irregularities on the top of the permafrost. In winter much of the water is frozen. Water is most abundant in the borrow pits excavated in permafrost between the runway and Port Clarence, and in fresh-water ponds near the southern end of the runway. Permafrost rises under the barrier ridges along the edge of the spit to form a dam about 2 ft above sea level; this dam of permafrost prevents fresh water from flowing to the sea and prevents sea water from polluting the fresh water on the spit. Fluctuations in water level are as much as 1.2 ft, the higher levels following periods of relatively heavy precipitation. Decline in water levels from June to October, 1945, closely parallels the annual melting of the active layer, and resultant lowering of the frost table. Fresh water near the margins of the spit is contaminated by sea water during storms, when salt water tops the low permafrost dams under the barrier ridges; but the fresh ground water perched on permafrost in the center of the spit is generally uncontaminated. The water level in the center of the spit, however, is commonly raised during storms when outflow of fresh water is dammed by salt water along the edges of the spit.

Two wells, one 298 ft deep, do not show any source of fresh water beneath permafrost. When the bottom of the permafrost was pierced, salt water rose in the wells to approximate sea level, at depths of 5 and 9 ft, respectively. Because of strong winds, much of the snow that would otherwise replenish ground-water supplies upon melting is lost; a means for trapping the snow in protected water-supply areas should be undertaken. Construction of shallow pits bordered by earth ridges would allow water to collect beneath the pits and to be held by permafrost beneath the ridges; however, care must be taken not to allow permafrost to thaw beneath the pits.

Black, R. F., and **Barksdale, W, L.,** 1948, Terrain and permafrost, Umiat area, Alaska: U.S. Geol. Survey, Permafrost Program Prog. Rept. 5, 23 p., pub. by Engineer Intelligence Div., Office, Chief of Engineers, U.S. Army.

Umiat is on the Colville River flood plain which is bordered by a high terrace and bedrock hills. Permafrost extends to a depth of at least 911 ft in Umiat test well 1, in the bedrock hills, 4 miles northwest of Umiat. One of five seismic shotholes drilled in the flood plain west of the river between the old and new camps encountered an unfrozen waterbearing zone at a depth of 13–18 ft that may be a lateral extension of an unfrozen zone beneath the river. The extent of the unfrozen zone is unknown, but water flows throughout the winter under the river ice. The parts of the river that are more than 5 ft deep offer a good source of water, and wells in the unfrozen gravel would provide a supply free from interruption by floods and free from sediment carried during periods of high water.

1949, Oriented lakes of northern Alaska: Jour. Geology, v. 57, no. 2, p. 105–118.

Shallow unfrozen zones occur under the larger streams and below some of the deeper lakes.

Black, R. F. *See also* Wahrhaftig, Clyde, 1958.

Bobov, N. G., 1960, Pingo formations under modern conditions in the watershed between the Lena and Vilyui Rivers: Akad. Nauk SSSR Izv., Ser. geog., p. 64–49. [Russian.]

Bogdanov, N. V., 1912, Perennially frozen ground and construction on it (Vechnaia merzlota i soorusheniia na nei): St. Petersburg.

Bonchkovskii, V. F., and Bonchkovskii, IU. V., 1937, The study of the applicability of the seismic method for the determination of the depth at which the upper surface of permafrost is found (Issledovanie primeninosti seismicheskogo metoda k opredeleniiu glubiny zaleganiia verkhnego zerkala merzloty): Akad. Nauk. SSSR, Kom. izucheniiu vechnoi merzloty Trudy, v. 5, p. 131–163.

The seismic method is applicable for determining the upper surface of permafrost, especially in water-permeable ground, but is probably of little value in permafrost of rock composition.—From SIPRE U–760.

Bonchkovskii, IU. V. *See* Bonchkovskii, V. F., 1937.

Borkhov, V. S., 1950, Electrical exploration in permafrost regions [Elektrorazvedka v usloviiakh vechnoi merzloty], *in* Inzhenerno-geologicheskie issledovaniia dlia gidrolekhnicheskoga stroitel'stva, p. 179–180: Vses. Gos. Trest Gidroenergoproekt *and* Mosk. Geol.-Razveka Inst., v. 2, Moscow, Gos. Izd., Geologicheskoi literatury.

Bostock, H. S. *See* Reed, J. C., 1954.

Boyd, J. W. *See* Boyd, W. L., 1959.

Boyd, W. L., and Boyd, J. W., 1959, Water supply problems at Point Barrow: Am. Water Works Assoc. Jour, v. 51, no. 7, p. 890–896.

Attempts to utilize ground water at Point Barrow, Alaska, have been unsuccessful. Drilling during exploration for oil in the Naval Petroleum Reserve produced subpermafrost water with a salinity of several thousand parts per million. Treatment of lake water, used as a supply, is necessary because the concentration of minerals in unfrozen water increases with increased ice thickness.

Boyle, R. W., 1955, Permafrost, oxidation phenomena, and hydrogeochemical prospecting in the Mayo area, Yukon [abs.]: Alaskan Sci. Conf., 6th, College 1955, Proc., p. 74–75; Geol. Soc. America Bull., v. 66, no. 12, pt. 2, p. 1701.

Permafrost distribution in the Mayo area is patchy, depending on the elevation, hillside exposure, depth of overburden, amount of covering vegetation, and presence of moving underground and surface waters. Ice veins in faults and ore veins have been observed to depths of 300 ft or more in the mines. Much of the oxidation in some veins took place before formation of permafrost because ice veins now occupy solution channels followed by meteoric waters during early phases of the oxidation. Elsewhere, meteoric waters now circulating below areas sealed by permafrost and in areas free of permafrost are causing oxidation. The study shows that hydrogeochemical prospecting is a valid method in some permafrost areas.

Boyle, R. W., Illsley, C. T., and Green, R. N., 1955, Geochemical investigation of the heavy metal content of stream and spring waters in the Keno Hill-Galena Hill area, Yukon Territory: Canada Geol. Survey Bull. 32, 34 p.

The area described is in a region of permafrost which is patchy in its distribution, its presence depending on elevation, hillside exposure, depth of overburden, amount of vegetation, and movement of ground and surface waters. Most of the northern slopes are underlain by permanently frozen ground, but southern slopes are generally free of frozen ground. On Keno Hill, most mine workings on the summit and northern slopes were coated with frost to a maximum depth of 400 ft, but those on the southern slope encountered no permafrost. On Sourdough Hill, frost and ice veins were encountered in mine workings to a depth of 250 ft; on Galena Hill, permafrost has been reported to depths of 200 ft or more.

Melt water in the active layer and from rain and snowmelt percolating through talus deposits emerges as springs from fractures and faults in rock bluffs and at the heads of gulches. Water below permafrost seeps from veins and faults into most of the mine workings. The water in the faults and fractures probably has entered the ground where permafrost is absent. The flow of most springs depends on amount of rainfall, rate of melting of the snowfields, and rate of thawing of the active layer. Springs issuing from fractures and faults have constant flow.

The presence of permafrost does not seem to affect the common oxidation phenomena and production of soluble salts of the heavy metals; in some areas, however, the veins appear to be sealed and do not contribute heavy metal to ground and surface waters. Patchy distribution of permafrost allows oxygen-bearing water to enter the fractures at higher elevations and to issue at lower elevations, carrying dissolved heavy metal. In areas known to have permafrost, the upper part of the veins is apparently thawed sufficiently to allow circulating near-surface waters to remove traces of heavy metals.

Boyle, R. W., Pekar, E. L., and Patterson, P. R., 1956, Geochemical investigation of heavy metal content of streams and springs in the Galena Hill-Mount Haldane area, Yukon Territory: Canada Geol. Survey Bull. 36, 12 p. *See* annotation, Boyle, R. W., Illsley, C. T., and Green, R. N., 1955.

Brandon, L. V., 1960, Northern settlements; No. 1, Preliminary notes: Canada Geol. Survey Topical Rept. 28, 29 p.

A study of ground-water conditions at most of the settlements in the District of Mackenzie, Northwest Territories, was made in 1960 as part of a study of the occurrence of ground water in the permafrost regions of Canada. Most of the Paleozoic dolomite and limestone in the western Great Slave Lake region and Mackenzie Valley are aquifers containing water that is high in salt and sulfur. Precambrian rocks are satisfactory aquifers for domestic supplies only where fractured. The best aquifers are sand and gravel of alluvial and glacial deposits. Permafrost, where continuous and deep north of the Arctic Circle makes utilization of wells difficult. In relatively thin permafrost little heat is required from the water in the aquifer, or from a built-in heating unit, to keep the well open. Wells offer a potential means of supplying water where surface water has high turbidity, or requires expensive intakes, filtration, plants, or pipelines.

Bratsev, L. A., 1940, Permafrost in foreign countries [Vechnaia merzlota v zarubezhnykh stranakh]: Akad. Nauk SSSR, Fondy Inst. Merzlotovedniia im. V. A. Obrucheva. [Manuscript report.]

1945, Mine shaft construction under permafrost conditions of the Vorkuta coal basin [Shakhtnoe stroitel'stvo v usloviiakh vechnoi merzloty Vorkutskogo kamennovgolnogo basseina] [abs.]; Akad. Nauk SSSR, Otdel. geol-geog. nauk, p. 120.

In a study of 20 shafts sunk from 1937 to 1944 special attention was given to the permafrost and hydrogeological conditions of the region.—From SIPRE U-922.

Brewer, M. C., 1955a, Geothermal investigations of permafrost in Northern Alaska [abs.] : Am. Geophys. Union Trans., v. 36, no 3, p. 503.

Maximum depth of permafrost is 1,330 ft, and the minimum temperature is —10.6°C, recorded below the depth of seasonal temperature fluctuation (70–100 ft). Lakes deeper than 7 ft do not freeze to the bottom in winter and may have an unfrozen zone approaching several hundred feet in depth beneath them. Frozen ground within the upper 100 ft of depth probably does not extend outward more than a few tens of feet from the shore of the Arctic Ocean, although frozen ground may be present at greater depths.—From author's abstract.

1955b, Preliminary interpretation of ice, water, and bottom temperature data in the Arctic Ocean near Barrow, Alaska [abs.] : Am. Geophys. Union Trans., v. 36, no. 3, p. 503.

Thermal measurements were made within the ice and in the underlying water of the Arctic Ocean, and measurements were made to a depth of 310 ft below the ocean bottom. Water temperatures beneath the ice near shore do not vary by more than 0.2°C during winter. No correlation is apparent between the ice temperature and the salinity of the sea ice. Data indicate that the sediments beneath the ocean bottom at a distance of 400 ft from shore should be frozen if they contain fresh water. If the formations contain sea water, they should not be frozen even though they would be classed as permafrost by definition.—From author's abstract.

1958a, The thermal regime of an arctic lake: Am. Geophys. Union Trans., v. 39, no. 2, p. 278–284.

Permafrost underlies the shallow lakes, but an unfrozen basin several hundred feet deep may extend beneath the deep lakes.

1958b, Some results of geothermal investigations of permafrost in northern Alaska: Am. Geophys. Union Trans., v. 39, no. 1, p. 19–26.

Depth of permafrost varies with latitude, length of seasons, surface cover, proximity to the ocean, and distribution of rivers and large lakes that do not freeze to the bottom. Depth of permafrost decreases from 1,330 ft 8 miles from the ocean to indicated depths of 1,045 ft at a point 1,200 ft from the sea, and 670 ft at a point 400 ft from the ocean; the latter depths are slightly modified by nearby lakes. Permafrost temperature increases rapidly toward the ocean. At a point 390 ft from land, data suggest that permafrost is present to more than 400 ft below the sea bottom. Ocean bottom temperatures are below 0°C until ocean depths of 500–1,000 ft are reached, and therefore permafrost must extend seaward to ocean depths of 500–1,000 ft. The driller's log of the hole drilled in the ocean floor indicated no frozen material to 100 ft and the possibility of frozen ground from 100 to 205 ft and the unfrozen layers from 205 to 326 ft below the ocean floor. However, all the formations but the upper few feet have temperatures below 0°C, and are by definition perennially frozen.

Lakes are divided into two groups: (1) those that are 2–3 ft deep and freeze to the bottom in winter, and thaw to a few feet beneath their beds each summer, and (2) those that are 6–9 ft deep, do not freeze to the bottom each winter, and have much deeper thawed zones beneath their beds. Lakes having a diameter of half a mile and a depth of at least 7 ft may have thawed basins beneath them to a depth of 200 ft or more. If the lakes are underlain by sand or gravel of favorable water-bearing characteristics, they could provide a small year-

round supply of fresh water. Within 5 miles of the coast, the sediments beneath such lakes may contain saline water.

Permafrost temperatures beneath small rivers that freeze to the bottom each winter are modified by the warming action of river water. Drilling on a bar along the Shaviovik River and at sites one-quarter mile on either side of the river show that the river produced a 3°C warming of permafrost temperature to a depth of 135 ft. Temperatures of these holes are expected to converge with the normal permafrost temperature gradient at greater depth.

The best year-round water source in the Arctic is an uncontaminated lake or stream, having a minimum depth of at least 7 or 8 ft.

Brewer, M. C. *See also* Greene, G. W., 1960.

Broadwell, J. A., 1945, How CAA engineers meet construction problems north of the Arctic Circle: Pacific Builder and Engineer, v. 51, no. 4, p. 55–56.

The Civil Aeronautics Administration airstrip at Kotzebue, Alaska, is on a sandy beach ridge about 50 ft from Kotzebue Sound. Fresh water was obtained by digging a shallow well only 100 ft from the sound. Water level in the well was 5 or 6 ft below sea level. Permafrost between the site of the well and the sound formed a barrier to encroachment of salt water. Softening and chlorination of the well water was necessary. At Shungnak, Alaska, a well was dug less than 100 ft from the riverbank of the Kobuk River. The well passed from sandy soil into gravel, but it was entirely in frozen ground. No water was found at least 15 ft below the level of the river. The hole was filled with gravel and converted into a cistern into which river water was pumped.

Brodskii, A. A., 1936, Water supply investigations in eastern Siberia [Osnovnye rezultaty gidrogeologicheskikh issledovanii dlia vodnosnabzheniia 1934 i 1935 gg]: Tashkent, Za nedra srednei Azii, no. 1, p. 7–10.

Brooks, A. H., 1904, Placer mining in Alaska in 1903: U.S. Geol. Survey Bull. 225, p. 43–59.

Drift mining in high bench gravels on the divide between Anvil, Dexter, and Dry Creeks near Nome showed that the deposits, 40–200 ft thick, are usually frozen sufficiently that timbering is not required. The workings are practically dry and do not require pumping.

1907, The Circle precinct [Alaska]: U.S. Geol. Survey Bull. 314–K, p. 187–204.

On Harrison Creek the gravel deposits are not frozen, and water circulates freely throughout the year. Creek-valley alluvium along Eagle Creek is 8–20 ft thick, of which 5–15 ft is muck; the gravel is not frozen and contains freely circulating water all winter. Similar water-bearing unfrozen zones occur in the alluvial deposits on Deadwood Creek.

1908, The mining industry in 1907 [Alaska]: U.S. Geol. Survey Bull. 345–A, p. 30–53.

A discussion of developments in placer mining districts includes depths of shafts on Nolan Creek in the Wiseman area (125 ft), Gains Creek (20–31 ft), Goldhill near Tanana (119 ft), and Smallwood Creek near Fairbanks where the pay streak lay at a depth of 320 ft. On lower Deadwood Creek, Circle district, prospect pits 14–20 ft deep in unfrozen ground failed to reach bedrock. On Gains Creek, unfrozen gravel beneath the creek bed was 15–20 ft thick and contained "live water" that made prospecting difficult. Hot springs at Baker and Kuzitrin are potential sources of water for irrigating gardens and for bottled mineral water.

Brooks, A. H., 1909, The mining industry in 1908 [Alaska]: U.S. Geol. Survey Bull. 379–A, p. 21–62.

Winter prospecting on Deadwood Creek, Circle district, was hindered because seasonal frost did not penetrate to bedrock until February; until that time ground water prevented prospecting by shaft sinking. Some potential dredge ground in the Birch Creek area is 12–40 ft thick and partly unfrozen. Prospect shafts in alluvium less than 8 ft thick on Loper Creek, Preacher Creek drainage, lack permafrost.

1911, The Mount McKinley region, Alaska, with descriptions of the igneous rocks and of the Bonnifield and Kantishna districts, by L. M. Prindle: U.S. Geol. Survey Prof. Paper 70, 234 p.

On the south side of the Alaska Range the ground is generally unfrozen. North of the range it is nearly everywhere frozen beneath 1–2 ft of soil and humus. Permafrost commonly extends to bedrock in areas of undrained alluvial deposits. Where loose gravel is found, however, the material may be unfrozen.

1912, The mining industry in 1911 [Alaska]: U.S. Geol. Survey Bull. 520–A, p. 17–44.

At the Newsboy mine, located near the divide between Cleary Creek and Little Eldorado Creek, Fairbanks district, holes were drilled for water. The mill was supplied by water from the 315-ft shaft. In the Chandalar district a 286-ft shaft was dug on Crooked Creek, a tributary of Chandalar River, and another was dug 172 ft deep on Mammoth Creek.

1914, The Chisana placer district [Alaska]: U.S. Geol. Survey Bull. 592–I, p. 309–320.

Placer deposits on Little Eldorado Creek in 1913 consisted of unfrozen gravel about 4 ft thick. Attempts to dig shafts in the deep gravel deposits of Chapolda, Chatenda, and some other creeks, were thwarted by flowing ground water at depth.

1915, The Alaskan mining industry in 1914: U.S. Geol. Survey Bul. 622–A, p. 15–68.

Gravel in the channel of Otter Creek, Iditarod district, is unfrozen, but the right bank is mostly frozen, especially in its upper 5–10 ft which is composed of muck. The ground on Mammoth Creek, Circle district, consists of 12–16 ft of coarse unfrozen gravel. In the Marshall area, lower Yukon River district, shallow alluvium on Wilson Creek and other streams is generally coarse and unfrozen, but the deeper ground is frozen and is composed chiefly of silt overlying a comparatively thin gravel deposit just above bedrock. The shallow deposits are water bearing.

1916, The Alaskan mining industry in 1915: U.S. Geol. Survey Bull. 642–A, p. 16–71.

In the Koyukuk district the deep mines on Hammond Creek are wet, and until the arrival of steam pumps in 1915, mining could not be carried on.

1918, The Alaskan mining industry in 1916: U.S. Geol. Survey Bull. 662–A, p. 11–62.

Reported oil seeps in the alluvium of the Tanana Valley have proved to be iron-oxide scum associated with marsh gas; some have been encountered in placer-mining areas where shafts have been sunk below permanent ground frost.

Brooks, A. H. *See also* Collier, A. J., 1908.

Brown, R. J. E., 1956, Permafrost investigations in the Mackenzie delta: Canadian Geographer, v. 7, p. 21–26.

Permafrost underlies the entire delta and extends to a depth of several hundred feet. In July 1953 sixteen 30-ft holes at Aklavik encountered permafrost, but piles driven 60 ft in the bed of Peel Channel of the Mackenzie River in front of the settlement failed to reach permafrost. The Government decided to relocate the settlement because of the high ice content of the delta silt deposits, improper sanitation, danger from flooding, and lack of an airfield.

1960, The distribution of permafrost and its relation to air temperature in Canada and the U.S.S.R.: Arctic, v. 13, no. 3, p. 163–177.

Previous maps of permafrost distribution in Canada by Bratsev (in Sumgin and others, 1940), Nikiforoff (1928), Muller (1945), Jenness (1949), Black (1950), and Thomas (1953) are reviewed in the light of recent information. A map prepared by the National Research Council in 1959 shows the southern limit of the continuous zone and that of the dicontinuous zone. In the U.S.S.R. the latest map (Baranov, in TSytovich, 1958) shows that it is possible to contour permafrost thickness. Data in Canada are still insufficient to permit mapping based on thickness and temperature of permafrost. Attempts at correlating the southern limit of permafrost with various isotherms of mean annual temperatures and with the freezing index have been unsuccessful. Too many other factors—such as climatic, surface, and geothermal considerations—affect the occurrence of permafrost to permit explanation based solely on air temperature.

Brown, R. J. E. *See also* Pihlainen, J. A., Brown, R. J. E., and Johnston, G. H., 1956; *see* Pihlainen, J. A., Brown, R. J. E., and Legget, R. F., 1956.

Bryan, Kirk, 1946, Cryopedology—the study of frozen ground and intensive frost action with suggestions on nomenclature: Am. Jour. Sci., v. 244, p. 622–642.

A terminology is suggested for the new subscience, cryopedology, to replace the diverse and inadequate terms applied to most processes and products of frozen ground and intensive frost action. The suggested terms are given in the glossary of this annotated bibliography.

1948, The study of permanently frozen ground and intensive frost action: Mil. Engineer, v. 40, p. 304–308.

Arguments for and against adoption of the terms suggested by Bryan (1946), by Stephen Taber, R. F. Black, F. E. Zeuner, W. V. Lewis, W. K. Wilson, Jr., A. B. Cleaves, C. H. Edelman, and R. Tavernier.

1951, The erroneous use of "tjaele" as the equivalent of perennially frozen ground: Jour. Geology, v. 59, p. 69–71.

Bulmasov, A. P., 1957, The area of applicability and conditions governing the use of geophysical survey methods in permafrost areas [Oblast' i usloviia primeneniia geofizicheskikh metodov razvedki v raionakh mnogoletnei merzloty], *in* Materialy po podzemnym vodam Vostochnoi Sibiri: Irkutsk, Akad. Nauk SSSR, Vostochno-Sibirskii Filial, p. 157–163.

Seismic, electrical, gravimetric, and magnetic soundings can detect only the existence of permafrost, not its thickness. Especially large errors in establishing structural boundaries in bedrock occur in limited areas where permafrost thickness changes abruptly. The results of seismic measurements may be

improved greatly by combining them with electrical soundings, which locate structural boundaries through the different reactions of ionic and electrical conduction to freezing. But since freezing reduces this electrical differentiation, the method is unsuitable for determining horizontal boundaries within permafrost. Natural electrical currents developing as a result of the natural oxidation of ore or the filtration of water in the deposits may prove a suitable means for prospecting for ore in permafrost. The applicability of gravimetric methods in permafrost has been studied very little, but studies on permafrost density and gravimetric anomalies in Yakutia suggest a relation between the two. Magnetic methods in permafrost do not differ from those in unfrozen ground.—From SIPRE 18015.

Cairnes, D. D., 1913, The Skagway-Whitehorse-Dawson section: Internat. Geol. Cong., 12th, Ottawa 1913, Guide Book No. 10, p. 51–121.

The surface materials are perennially frozen. The thickness of the frozen ground varies considerably: it is less on the ridges than in the valleys and less on the southern than on the northern exposures. A shaft on the ridge south of Eldorado Creek in the Klondike district reached unfrozen gravel at 60 ft, whereas one in the valley of Eldorado Creek was stopped by ground water at a depth of more than 200 ft. Another shaft on the plateau between Bonanza Creek and the Klondike River passed through frozen ground at a depth of 175 ft.

1914, Upper White River district, Yukon: Canada Geol. Survey Summ. Rept. 1913, p. 12–28.

Bench gravel deposits along Burwash Creek, Kluane district, remain frozen throughout the year. Creek gravel deposits are frozen only in winter; they are frozen down to bedrock only in a few places, and elsewhere remain unfrozen below a depth of 10 or 11 ft. Near the Alaska boundary, ground bordering the White River was frozen at one place to a depth of 90 ft, where water was encountered.

1917, Scroggie, Barker, Thistle, and Kirkman Creeks, Yukon Territory: Canada Geol. Survey Mem. 97, 47 p.

In this placer-mining area near the confluence of Stewart and Yukon Rivers, the perennially frozen condition of the gravel allows drift mining to be carried on. The gravel is overlain by thin muck and is generally frozen to bedrock, except possibly under or near the stream channel, where water circulates through the unfrozen gravel near bedrock. On the benches that border the stream courses, the muck is thicker, and the deposits are generally frozen to bedrock.

Canadian Army Engineers. *See* U.S. Army, Corps of Engineers and Canadian Army Engineers, 1949.

Capps, S. R., 1911, Mineral resources of the Bonnifield region [Alaska]: U.S. Geol. Survey Bull. 480–H, p. 218–235. *See* annotation, Capps, S. R., 1912.

1912, The Bonnifield region, Alaska: U.S. Geol. Survey Bull. 501, 64 p.

Dry Creek and several smaller streams flowing north from the Alaska Range into the Tanana Valley sink into the ground as they leave the mountains.

1916, The Chisana-White River district, Alaska: U.S. Geol. Survey Bull. 630, 130 p.

Placer-mining ground on Bonanza, Little Eldorado, and Big Eldorado Creeks is generally not frozen, but patches of permanently frozen ground occur. Some frozen ground occurs on Skookum and Gold Run Creeks.

1919, The Kantishna region, Alaska: U.S. Geol. Survey Bull. 687, 118 p.

Most of the gravel deposits along the streams are unfrozen, and few placer miners have encountered difficulty with ground frost. Some of the benches, however, are permanently frozen.

1940, Geology of the Alaska Railroad region: U.S. Geol. Survey Bull. 907, 201 p.

In the lowlands in the Cook Inlet-Susitna depression, in the Matanuska Valley, and other low-altitude valleys south of the Alaska Range, there is little permanently frozen ground. However, in the adjacent mountains there is abundant permanent frost above an altitude of 3,000 ft. North of the Alaska Range permanent frost occurs even in the lowlands. The frozen zone prevents downward percolation of surface water.

Capps, S. R. *See also* Moffit, F. H., 1911.

Cathcart, S. H., 1920, Mining in northwestern Alaska: U.S. Geol. Survey Bull. 712–G, p. 185–198.

In 1906 drilling at Cape Nome encountered a strong flow of gas at a depth of 122 ft, presumably in alluvial deposits.

Cathcart, S. H. *See also* Steidtmann, Edward, 1922.

Cederstrom, D. J., 1951, Ground water in Palmer, Anchorage, and Fairbanks areas, Alaska: U.S. Geol. Survey open-file report, 6 p.

The Fairbanks area consists of a low plain underlain by silt, sand, and gravel, which is perennially frozen in the form of wedges ranging in thickness from 0 to 250 ft, and silt-mantled bedrock hills. In the plain at Fairbanks small-diameter wells, 15–250 ft deep, obtain water from above or below permafrost. The wells are constructed by the jet-drive method, and no real difficulty is experienced in keeping them in operation. Two-inch diameter wells produce as much as 40 gpm, and the large-diameter wells yield more than 800 gpm. Water quality is poor, largely because of a high-iron content.

1952, Summary of ground-water development in Alaska, 1950: U.S. Geol. Survey Circ. 169, 37 p.

This report discusses present and possible future ground-water development in a number of localities through Alaska. Substantial development of ground-water supplies is found only in Anchorage, Palmer, and Fairbanks. Elsewhere, few wells are present and possibilities of ground-water development have been almost entirely unexplored. Large quantities of ground water of good to poor quality are available in extensive areas of intermontane sandy fill and sandy glacial deposits. Nothing specific is known of possible yields in hard-rock areas, or in rocks of any kind in southeastern Alaska. Much remains to be learned about ground-water occurrence, particularly with reference to the needs of growing communities, military establishments, and some areas of potential industrial activity.

Permafrost is a factor to be dealt with in development of water supplies in many northerly localities. In the north permafrost is thick, but it thins southward and becomes more and more discontinuous until it is entirely absent. Except where thick and continuously distributed, permafrost does not preclude ground-water development, for it occurs in many places beneath permafrost or in thawed zones between permafrost. Permafrost is a serious problem north and west of the Alaska Range. Near Fairbanks permafrost is as much as 200 ft thick in the valley flat, but is discontinuous. In the vicinity of major streams and rivers permafrost is ordinarily absent, particularly on the "slip-off" side of the meander, but it is present in the steep face of cut banks on the opposite shore. Even near the cut bank, permafrost may be thin, and it is commonly absent beneath abandoned channels a half mile or more from the river. North of the Brooks Range permafrost many hundreds of feet thick makes ground-water development impracticable, except possibly along the Colville River.

Cable-tool drilling offers no special problems; frozen materials generally stand well in the hole, but casing is required to shut off thawed running sand or silt and to prevent caving due to thawing as the hole warms during the drilling. Casing will freeze to the walls of holes only where permafrost is several degrees below freezing or during periods of idleness. A productive well will not freeze if pumped regularly, and the plug of ice that sometimes forms inside the casing during idle periods can be thawed by hot water, steam, or salt.

Thicknesses of permafrost greater than 150 ft have been penetrated by 2-in. driven wells using cone-shaped drive head, above which are ¼-in. perforations and through which a ½-in. thaw line projects as much as 18 in. The thaw line delivers water at 33° to 40°F which melts sufficient permafrost to permit driving the pipe. At shallow depths skilled drillers can make 30–40 ft per day, but progress below 80–100 ft may be as little as 1 or 2 ft per day.

Shallow wells dug in materials above permafrost supply a small amount of poor-tasting water, but the wells decrease in yield or freeze completely in winter. Supplies are obtained in some places where a depression in the permafrost formed beneath stripped ground or heated buildings.

Cederstrom, D. J., 1953, Test well at Kotzebue, Alaska [abs.]: Geol. Soc. America Bull., v. 64, no. 12, pt. 2, p. 1406.

In the summers of 1949–1950 a test well was drilled at Kotzebue to a depth of 325 ft by the cable-tool method. Permafrost extended to a depth of 238 ft. Sediments encountered were largely marine clays overlying continental(?) silts. Salt water was encountered in a thawed zone at 80 ft and again below the permafrost mass between 238 and 325 ft. A gas (methane?) accumulation was present beneath the permafrost.

Difficulties encountered are evaluated, in order of difficulty, as follows: (1) logistical, (2) lack of, or excessively high cost of, local technical services and materials, (3) personnel, (4) permafrost.

Development of a shallow water zone might profitably be investigated. This would involve stripping of the tundra, melting out the upper permafrost zone by natural or artificial means, and protection of the thawed area by thick snow cover in the winter. The efficacy of the scheme in winter would depend largely upon inflow of water from any adjacent unfrozen zones that may be present between the winter frost and the permafrost.—Author's abstract.

1955, A test well at Kotzebue, Alaska: U.S. Geol. Survey open-file report, 11 p.

A test well was drilled with cable-tool machine in an attempt to find a source of water that might be used by residents and the Alaska Native Service Hospital. Shallow waters bounding the peninsula on which the town is situated are commonly fresh or only slightly brackish, owing to the discharge of the Noatak

River. Water is obtained from shallow wells occupying thawed basins in permafrost table, from ice and snow, or from distant lakes and rivers.

The well penetrated beach gravel from 0 to 19 ft, frozen blue marine clay from 19 to 79 ft, unfrozen beach gravel carrying water with 26,000 ppm of chloride from 79 to 86 ft, frozen marine blue clay from 86 to 190 ft, gravelly layer from 190 to 218 ft, possibly glacial till, marine blue clay from 218 to 226 ft, glacial till or gravel from 226 to 238 ft. All sediments from the surface to 238 ft were frozen, except the zone between 79 and 86 ft; below 238 ft the ground was unfrozen. At 238 ft an accumulation of gas (methane?) was encountered; pressure was sufficient to lift the tools 10 or 12 ft and shower mud over the area. Gas issued under pressure for an hour, but by the next day the flow subsided. The occurrence is similar to one in the Fairbanks area, at a Survey test well on Farmer's Loop Road in 1948, and at a U.S. Army well near Eielson A.F.B. in 1952. From 238 to 325 ft the well penetrated silt and fine sand of continental origin.

Static level of the salt-water aquifer between 79 and 86 ft was 15.9 ft. That of the water-saturated continental sediments below 238 ft was 42 ft below the surface; the water at depth also was salty.

The sediments encountered in the well are largely estuarine and were doubtless frozen after elevation of the land above the sea. The sediments between 79 and 86 ft were probably laid down in slightly brackish water like that of, but less well concentrated than, the ocean water that exists today. "The highly saline water may have been formed by a process of fractionation by freezing of the original slightly brackish water with which the sediments were saturated. The result would be an ice of very low chloride content and a high-chloride liquid." (See p. 5.) By this hypothesis, during freezing of the blue clay from the top down, the excess water was highly saline and was driven downward, building up pressure as freezing progressed. However, the hydrostatic pressure was apparently relieved by lateral migration of water through the permeable gravel between 79 and 86 ft, but through this migration the salinity of the water in the gravel was increased. As the freezing front drew near the gravel its temperature was probably a few degrees below 0°C, but higher than the freezing point of the saline water in the 79- to 86-ft zone. The freezing continued into the impermeable beds between 86 and 238 ft, leaving the saline water between 79 and 86 ft in the liquid state, but at negative temperature.

1959, Ground-water hydrology in Alaska [abs.]: Internat. Symposium on Arctic Geology, 1st, Calgary, Canada, 1960, Abstract of papers *in* Canadian Oil and Gas Industries, v. 12, no. 12.

Ground-water studies, begun in 1947, have been made at Fairbanks, Anchorage, Matanuska Valley, Kotzebue, Pribilof Islands, and Bethel. "The Tanana Valley, in which Fairbanks is located, with its gravelly fill was found to be one of the most prolific sources of ground water in the world. In this area permafrost is a minor problem in developing ground water, as is high iron content in the water * * * Alaska north of southeastern Alaska may be characterized as an area where great alluvial valleys contain much ground water. Northward, however, permafrost becomes more and more of a problem."

Cederstrom, D. J., Johnston, P. M., and Subitzky, Seymour, 1953, Occurrence and development of ground water in permafrost regions: U.S. Geol. Survey Circ. 275, 30 p.

Ground water in permafrost regions occurs mainly in unfrozen ground which is (a) under and adjacent to large rivers; (b) in or near the smaller streams;

(c) in or near standing bodies of water, such as lakes occupying abandoned channels or muskeg lakes; (d) in newly deposited alluvium formed on the concave side of present river meanders but not necessarily adjacent to the river; (e) in dry abandoned channel scars or lakebeds; (f) in places where insulating vegetation mat has been stripped, allowing deep thaw; and (g) on south-facing hillsides. The procedure for surveying ground-water resources follows that of Muller (1945). Description of ground-water recovery includes discussion of drilling methods, drilling fluids, and winterization of drill rigs employed by Government agencies, petroleum and mining companies, and water-well drillers in Alaska and northern Canada.

Water distribution systems and water sources are described for Fairbanks, Nome, Dawson, Yellowknife, Whitehorse, Donjek River, Kluane Lake and Fort Chemo.

Further studies of the occurrence of ground water in permafrost regions should be undertaken along the following lines: (a) Continuation of literature search; (b) establishment of a research investigation, including drilling in some area north of the Arctic Circle in Alaska to obtain data on occurrence within the continuous-permafrost zone; and (c) development of geophysical methods and use of them in alluvial valleys where geologic information and drilling information make checking of the results possible.

Cederstrom, D. J., and Péwé, T. L., 1948, Records of wells in Fairbanks, Alaska, and adjacent areas: U.S. Geol. Survey open-file report; repr., 1960, *as* ground-water data, Fairbanks area: Alaska Dept. Health, Sanitation and Engineering Sec., Water Hydrologic Data Rept. 9, 8 p., Juneau, 1958.

Tabulation of well data through 1954 for Fairbanks and vicinity; includes well number, location, owner, driller, depth, top and bottom of permafrost, water quality, and remarks.

Cederstrom, D. J., Wahrhaftig, Clyde, and Barnes, F. F., 1950, Ground water in the vicinities of Healy and Homer, Alaska: U.S. Geol. Survey open-file report, 4 p.

A terrace 350 to 500 ft above the Nenana River is 1 mile wide and about 7 miles long; the coarse terrace gravel rests on tilted, slightly cemented gravel, and on sandstone, shale, and coal of Tertiary age, which act as an impervious layer. Springs issue from the base of the terrace gravel at (1) Garner where a spring supplies the community, (2) at Healy where springs supply the town and feed a stream having a discharge of 1 cfs, and (3) Lignite where the springs are similar in size to those at Healy. A spring occurring in the gravel bed of Dry Creek, one-half mile upstream from the railroad bridge, flows at an estimated rate of 30 to 40 cfs. Recharge of ground water in the terrace deposits is accomplished by loss of water from intermittent streams that cross the terrace and by rainfall.

No springs occur at the base of the intermediate 150–300-ft terrace west of Healy and Lignite. A 480-ft terrace east of the Nenana River between Ferry and Lignite is composed of 150 ft of gravel underlain by the Nenana gravel of Middle Tertiary age. A large spring at Ferry forms icings in winter. Recharge of the ground water is from the hills to the east.

A possibility for artesian water exists at depth in the Nenana gravel and the coal-bearing formation west of Healy and near Lignite. Deposits of coarse alluvial gravel occur in the fan of Nenana River between Rex and Clear; large quantities of ground water have been found at Clear. Large quantities of water probably could be obtained from wells in or near the bed of Nenana River.

Chapin, Theodore, 1915, Auriferous gravels of the Nelchina-Susitna region [Alaska]: U.S. Geol. Survey Bull. 622–D, p. 118–130.

A shaft 180 ft deep on claim 19 below Discovery on Crooked Creek exposed 85 ft of surficial glacial capping, frozen muck, and gravel, and between 139 and 154 ft penetrated gas-bearing vegetable muck. On Daisy Creek, considerable trouble was experienced in prospecting the 12- to 15-ft deep gravel deposits because of ground water.

1918, The Nelchina-Susitna region, Alaska: U.S. Geol. Survey Bull. 668, 67 p. *See* annotation, Chapin, Theodore, 1915.

Chapman, R. M., and Sable, E. G., 1960, Geology of the Utukok-Corwin region, northwestern Alaska: U.S. Geol. Survey Prof. Paper 303–C, p. 47–167.

The water content of the layer above permafrost increases downward toward the permafrost table. Pingos, or icing mounds, occur in poorly drained tundra on the coastal plain; one is a quarter of a mile south of the village of Point Lay. All the icing mounds are less than 30 ft high.

Charles, J. L., 1959, Permafrost aspects of the Hudson Bay Railroad: Am. Soc. Civil Engineers Proc., v. 85, no. SM6, pt. 1, p. 125–135.

At Churchill a well drilled under Lake Rosabelle encountered frozen ground at a depth of 41 ft, and in the harbor no frozen ground was encountered within the limits of the low-water mark. A boring in August 1929 southeast of the lake encountered 95.8 ft of frozen unconsolidated deposits underlain by bedrock in which ice was encountered at 138 and 145 ft; the driller encountered continuous trouble with freezing of the 230-ft hole.

Chekotillo, A. M., 1940a, Icings and countermeasures [Naledi i bor'ba s nimi]: Moscow, Gushosdor NKVD, SSSR, 136 p.; edited by M. I. Sumgin, Inst. Merzlotovedeniia im. V. A. Obrucheva.

The term "icing" (naled) refers to a mass of ice formed during the winter by successive freezing of sheets of water seeping from a river, the ground, a spring, or a combination of such sources. They form irregular sheets or fields, mounds attaining large dimensions, or incrustations on slopes. Most melt during the summer and reappear the following winter; the remnants of icings that do not disappear entirely during the summer are called taryns. Conditions favorable for formation of icings are (1) ground water in the active layer, (2) low air temperature and thin snow cover during the early part of the winter, (3) proximity of permafrost table to the ground surface, and (4) thick snow cover during the latter part of the winter.

River icings are formed when the freezing of a shallow reach impedes the flow upstream, increasing the hydrostatic pressure of the water above the ice barrier. The water is forced to break through fissures in the ice or emerge along the banks as seepage; it freezes and gradually forms the icing. Ground icings are formed by freezing of ground-water seepage caused by winter frezing of the active layer to the permafrost table. Ground water from suprapermafrost or subpermafrost sources feeding springs forms icings. Some icings form mounds, in some of which the water is under such great pressure that they explode.

The earliest theory of icing by Pod'iakonov (1903), modified by Sumgin, accounts for river icing, but does not explain ground icing. Later, Sumgin accounted for formation of icings by stresses produced in the ground during freezing. Pressure in the ground is caused either by change in volume when water is converted to ice or by force of crystallization of ice. This pressure causes water to move laterally, or upward, in the direction of lesser resistance. A formula was worked out by Sumgin for the development of icing mounds. Petrov (1930) experimented with pressure measurements of icing mounds and found that from an initial stage consisting of an upper and a lower passive ice layer an application of external freezing placed the upper layer under increased pressure. Melting in the lower layer is caused by this increased pressure. To the water obtained from melting in the lower layer is added water from external sources to fill the voids left by the volume decrease on thawing. Finally, with continued penetration of freezing, a new wedge of ice is formed from the water in the lower layer, and the remains of the lower ice layer and the upper passive layer are raised to increase the height of the icing mound.

Icings are destructive to roads, bridges, buildings, and other structures. Measures against them are grouped into two categories, active and passive. The passive countermeasures are (1) removing the ice, (2) diverting the water that feeds the icing, (3) constructing barriers against the icing, (4) enlarging the cut in which the ice forms, and (5) relocating the site of the structure. The active countermeasures are (1) draining the site of the icing, (2) constructing frost belts, (3) deepening and straightening the river channels, and (4) straightening the stream channels.—From Minnesota Univ., 1950, p. 99–148.

Chekotillo, A. M., 1940b, Warming river beds to combat icings [Uteplenie rusel kak sposob bor'by s rechymi nalediami u mostov]: Stroitel'stvo Dorog, v. 3, no. 8, p. 37–39.

Classification and the theory of icing processes, subsurface hydrostatic pressure, and influence of frost belts on the icing location are discussed. Methods of preventing icings under and near bridges are outlined. The most feasible method in permafrost areas consists of insulating the bridge area. Branches, straw, dry peat, loose snow are piled in an area about 1 m off shore, 50 m upstream, and 100 m downstream from the bridge. This type of insulation prevents extensive freezing and insures a free flow of ground and surface waters under the bridge. Bridges with spans 3 m or more apart and clearance greater than 1.5 m can be readily insulated by this method.—From SIPRE U–2761.

1941, Region of the great icings; Icings of eastern Yakutia [Oblast' velikikh naledei; naledei Vostochnoi IAkutii]: Akad. Nauk SSSR Izv. Ser. geol., v. 1, p. 94–113.

The characteristics of icings of eastern Yakutia are that (1) all are of immense size, in length many km; (2) all are formed in river valleys, and none are formed by suprapermafrost ground water; (3) they are formed in the upper courses of rivers, near the base of mountains, but only rarely in plains or lowlands; (4) they appear every year at the same place, but their boundaries vary; (5) they are usually active all winter; (6) there are unfrozen water channels under the icings which enable water to reach remote parts of the icing; and (7) in summer most of the icings are thawed, but some persist to the following winter. Sources of water either from the rivers or from suprapermafrost ground water seem too small to form extensive fields of ice. Shvetsov and Sedov (1940) concluded that these icings were formed by discharge of ground water from below the permafrost; these authors observed gas-bearing springs forming icings at one point on a line 150 miles long at the base of the eastern Tas-Khaiakhtakh Range. Both the Yana and Indigirka Rivers appear to have greater discharge than is warranted by the relatively low precipitation in their drainage basins. Winter polyn'ia (ice holes where water does not freeze even at —40°C) in the ice cover may indicate emergence of warm ground water. The flourlike residue of calcium salts (50 g per m^2) deposited after the icing melts suggests that the hardness may account for supercooling of river water and nonfreezing of the springs. In an area such as this where permafrost is 200–300 m thick and where precipitation is low, these springs, possibly related to fissures in rock, may provide a suitable supply of ground water.

1945, Gigantic icings in northeastern Siberia [Gigantskie naledi severo-vostochnoi Sibiri]: Nauka i zhizn', v. 12, no. 1, p. 26–29.

Gigantic icings or naledi occur on many of the rivers of northeastern Siberia between the Yana and Indigirka Rivers, where the climate is severe continental and where permafrost is widespread and as much as 300 m thick. The largest icing, "Ulakhan Taryn," is situated on the Moma River, a right tributary of the Indigirka; it has a length of 26 km, an area of 16,000 to 18,000 hectares, and an estimated volume of 500,000,000 m^3 of ice. Investigations of the Kyra icing show that it is formed at a series of perennial springs which flow at the rate of 27,000 m^3/sec. Despite plentiful summer water supplies in the region, water is scare in winter, and development of the strong flows of ground water that form the icings may provide a dependable year-round supply for both mining and drinking.—From abstract by E. A. Golomshtok for Stefansson Collection, Dartmouth College, Baker Library, Hanover, N.H.; SIPRE U–657.

1946a, Control of icings on the Alcan Highway [Bor'ba s nalediami na avtostrade Kanada-Aliaska]: Merzlotovedenie, v. 1, p. 69–78.

In a comparison of methods of control of icings in Siberia with those encountered in 1942–44 on the Alcan Highway, it was found that the system of deep, narrow trenches and pipe networks for drainage and water warming by vapor was too expensive. The same results could have been accomplished by simple ditches covered by brush and snow to prevent water freezing, as practiced in Siberia.—From SIPRE 15892.

1946b, Measures against naledi (icings) [Bor'ba a nalediami]: Priroda, no. 1, p. 29–28.

Since icing causes deformation of buildings and other structures and renders roads impassable, precautionary measures are of importance. Such remedial action may be corrective or preventive. Ground icings may be eliminated by (1) construction of adequate drainage systems, (2) erection of permanent or temporary barriers to movement of ground water, (3) removal of the icing, (4) widening cuts, and (5) moving structures. Rivers may be deepened and straightened, and small creeks may be heated to insure free flow. Up to 1946 no effective measures had been devised to combat ice formation in railroad tunnels or on mountain slopes covered with scattered rock cutcrops. Airfield construction near large rivers is hindered by ice fields.—From SIPRE U–663.

1946c, Naleds in Alaska [O nalediakh Aliaski]: Merzlotovedenie, v. 1, p. 111–118.

Investigations on naleds in Alaska since 1904 are briefly outlined, and published conclusions on their origin are compared with data in Siberia, where physiographical conditions for naled appearance are similar. The study of naleds and methods of their control in Alaska reached maturity only when the Alcan Highway was constructed, i.e., 10–15 yr later than in the USSR. The results of Soviet experience were ignored, so that much expensive and inefficient experimentation was repeated. A uniform terminology has not been developed in the U.S. and usage varies widely. Such terms as "glacier of hillside origin," "ice fountain," "crystophene," "crystocrene," "glaciering," and "surface ice mass" have been used only by their creators. The term "icing" suggested by the U.S. Geological Committee in 1944 is successful and probably will be used in the future in the U.S.—From SIPRE 15980.

Chekotillo, A. M., 1946d, Solving the problem of "Nalyeds" in permafrost regions: Eng. News-Rec., v. 137, pt. 2, p. 724–727.

Surface ice formation (naled) is one of the acute problems of permafrost regions. Early methods of chopping or melting ice have been replaced by the following recommendations based on Sumgin's work in the 1920's: (1) Locate road and bridges in sites where naleds are not likely to form, (2) transfer the naled to a place where it will be harmless, (3) determine the direction of flow in naleds formed by ground-water emergence and intercept the flow at some distance from the road by removing insulating cover to allow a belt of deeply frozen ground to block the underground flow and induce a seepage at the desired location, (4) river naleds should be controlled by deepening the channel of ice and soil across the valley upstream from its usual place of formation. These methods were tested successfully by V. G. Petrov in 1928–29 on the Amur-Yakutsk road.

Antinaled methods are subdivided into two groups according to whether naled is formed by surface water or by ground water. The defenses against ground-water naleds are as follows: (1) Drainage of area and lowering of permafrost table (16- to 20-in. ditches used with some success); (2) freezing belts, either permanent belts in which soil and vegetation is removed, or temporary belts in which the snow cover is removed to promote deep freezing and induce icing upslope from its former position; (3) installation of surface barriers at least 60 ft from structure; (4) widening of cuts to accommodate ice naleds; (5) drainage of feeding water from subpermafrost springs and large suprapermafrost water seepages via channels protected from freezing by branches, moss, and snow; and (6) transfer of structure to new location.

Defense against naleds formed by surface water consists of (1) one or more freezing belts placed not more than 60 ft apart across the entire valley upstream from the usual site of the naled, (2) drainage of naled water by means of open or covered ditches to places where ice formation would be harmless, (3) barriers of timber or snow offering temporary protection, (4) deepening and straightening of river channels and promotion of vegetation growth on banks, (5) warmth-retaining measures, such as covering the channels with brush, branches, and snow 60 to 150 ft from the bridge (commonly the bridge or fill acts as a frost dam).

Solutions remain to be found for naled formation in tunnels, on boulder-covered slopes, and in areas of deep gravel deposits. Drainage of perennially frozen ground and use of drainage for channeling ground water have received very little study.

1947a, Current measures against icing in the U.S.A. and Canada [abs.]: Akad. Nauk SSSR, Referaty nauchn.-oissled. rabot, 1945, Otdel. geol.-geog. nauk.

In this summary of material in Canadian and American publications on measures used to combat icings, it is found that American research workers (Leffingwell, Taber, Eager, and Pryor) have worked out the general aspects of the theory of icing processes. For this reason, passive methods, directed not at the causes of icing but at the liquidation of its effects, are predominant in the efforts to combat icings. American engineers and technicians are proceeding correctly with respect to measures used against icings, but lag 15 to 20 yr behind the engineers of the USSR in this field; however, in the field of mechanization, America is more advanced than the USSR.—From Minnesota Univ., 1950, p. 95.

1947b, Permafrost in Alaska [Vechnaia merzlota Aliaski]: Merzlotovedenie, v. 2, no. 2.

1955, Soil temperature stability in winter [Temperaturnaia inertsiia pochvy v zimnee vremia], *in* Voprosy izucheniia snega i ispol'zovaniia ego v narodnom khoziaistve, p. 73–97: Akad. Nauk SSSR, Inst. geografii.

1956, Permafrostology outside the USSR as of 1955 [Merzlotovedenie za rubezhom k 1955 godu]: Materialy k osnovam ucheniia o merzlykh zonakh zemnoi kory, v. 3, p. 186–229.

This review, with 260 references is based on a study by the Institute of Permafrostology of reports published outside the Soviet Union.—From SIPRE 14085.

Chekotillo, A. M. *See also* Sumgin, M. I., 1939.

Cheng, Ch'i-p'u, 1959, Points to be considered during hydrogeological surveys in permafrost regions [Yung chu tung chieh ti ch'ü shui wen ti chih k'an ts'e kung tso chung ti chitien t'i hui]: Hsui wen ti chih kung ch'eng ti chih (Hydrogeology and engineering geology), no. 11, p. 13–15.

The water regime in the permafrost area along the route of survey of a 1,000-mile long railroad in Manchuria and recommendations for hydrogeological field work are given. The depth to the permafrost table along the route generally is between 0.3 and 0.5 m, but sometimes reaches 3–5 m. The thickness of permafrost is usually 1–2 m, but occasionally reaches 40 to 50 m.—From SIPRE 18289.

Chernukhov, P. S. *See* Grave, N. A., 1947.

Chernyshev, M. IA., 1928, Icings and frost heaving [Naledi i pucheniia]: Zheleznodorozhnoe Delo, Put', v. 5, no. 7–8, p. 7–9.

Conditions causing the formation of these phenomena are analyzed and diagrammed. The accumulation of ground water and summer precipitation over the waterproof permafrost causes frost heaving by expansion during freezing. The penetration of subpermafrost water through fissures in frozen soil and subsequent freezing near the surface result in the formation and growth of icings (naledi). Icings reach a thickness of 3 m at some points in eastern Siberia.—From SIPRE 9340.

1933, Search for underground waters in the permanently frozen ground [Poiski podzemnykh vod v raione vechnoi merzloty]: Sanitarnaia Tekhnika no. 2, 9–12, Moscow. *See* annotation, Chernyshev, M. IA., 1935.

1935, Search for underground water in perpetually frozen areas: Am. Water Works Assoc. Jour., v. 27, p. 581–593.

Finding water in perpetually frozen ground offers difficulties, and the methods used to find it are different from those ordinarily used. They are closely associated with common geologic practice and with the climate in a given region and are difficult to use in other regions. Three types of water occurrence are considered.

1. *Subsoil* water found in thick alluvium above perpetually frozen ground is the result of infiltration of precipitation and condensation of moisture during the frost-free season. Because of underlying permafrost the subsoil water is not a source of large supplies, and tends to be erratic in quantity and to dry up toward

the end of winter. In winter, when the water-bearing layer is compressed between the downward penetration of winter freezing and permafrost, the water under hydrostatic pressure breaks through to the surface at the weakest point in the seasonally frozen layer. The water forms an icefield; under heated buildings the water can emerge with less difficulty and may inundate the building, freezing and filling the structure with ice. Subsoil water trapped between the seasonal frost and the permafrost is not an abundant and dependable supply of water, and the springs formed are not dependable. It is best developed by erection of shallow wells with timbered frames or underground drain galleries; however, withdrawal of water may exhaust the water-bearing layer and permit freezing of the galleries; so the wells and galleries should be protected from freezing air temperatures, possibly by an earth embankment around well or gallery. The water in regions of perpetually frozen ground is characteristically soft, and sometimes contains high amounts of iron.

2. *Springs* are a more constant and abundant supply of water, which rises from very deep strata through the permafrost. They occur in the cracks of the scarps and are common in areas underlain by granite and crystalline schists. Springs are of either fresh or mineral water; some hot and warm waters are of the nitrous-acid type, most cold waters are of the carbonic-acid type. Springs are common on sunny slopes and even on mountaintops; their waters saturate the soil downslope, providing sufficient moisture for growth of thickets of trees (some tilted) on ice hillocks. Some springs, when localized, form "ice-volcanoes" at the surface; others, composed of warm water, form open-water channels that pass downslope into icefields. The best time to search for springs is February or March, when they can be recognized by icefields, or "heaps," and because at this time of year a flow probably indicates a spring origin, not an origin in subsoil water.

Investigation of a spring should be a reconnaissance in March to fix its limits, and detailed exploitation and concentration of the water in the summer. During the reconnaissance a topographic survey of the outlet is made, and the icefield is sketched. Velocity of the running water is measured. Where the outlet is under water, the highest temperature measurement will be closest to the spring outlet, and measurement of the direction of currents in an icefield may enable location of the outlet. Shallow borings and excavations to locate the deepest thawed ground and rise of ground temperatures toward the source of water also show the position of the spring outlet. Heads of springs commonly form ice cones in late winter. Definition of the limits of the funnel within which the spring occurs is done during the detailed investigation by a system of "chessboard" borings and pits made near the outlet. From these excavations and borings, geologic maps with notations of permafrost and ground-water level can be made. In the center of the funnel in permafrost, an excavation is made suitable for pumping water. Where the spring outlet is discovered, the whole thawed layer and outlet may be intersected at several points by a collection gallery. Where there are several outlets separated by permafrost, each outlet is blocked and its water diverted to the lowest. Pumping tests and water-level observations should be made, and the waste water led away by way of gutters downslope; at the beginning of pumping the water yield is always more than that established later.

3. *Artesian water* from beneath the permafrost comes generally from horizons in alluvium in which impermeable confining layers are above and below the water-bearing layer and cause hydrostatic pressure (head). Artesian water occurs, in some places, in perpetually frozen ground, and may also consist of

juvenile water; artesian water is found only in comparatively young sedimentary and volcanic formations (Jurassic and Tertiary) and in volcanic formations of Jurassic, Cretaceous, and Tertiary age.

Investigation of artesian water requires detailed geologic examination and deep boring. Temperatures of perpetually frozen ground and of the water are measured to insure that the water passing through the borehole in permafrost will not freeze. Water should be kept flowing through the borehole rapidly to enable the water to warm the pipes and thaw sufficient frozen ground around the pipes. It is also advisable to heat the hole, at the beginning of work, by steam through pipes from the boiler. Further special heating measures are generally not required.

Chirikhin, IU. D., 1934, Permafrost in the basin of the Indigirka River [Vechnaia merzlota basseina reki Indigirki]: Akad. Nauk SSSR, Komi. izuch. vechnoi merzloty Trudy, v. 3, p. 21–39.

Ice mounds and icings (naledi) are closely related to orography, depth of snow cover, and temeprature. As the river-ice cover thickens, the shallowest reaches freeze to the bottom and water is limited to the deep places. The water is under pressure which causes it to overflow. Icings are formed under the following conditions: (1) Freezing of rivers, (2) complete freezing of river deposits, and (3) conditions favoring accumulation and discharge of ground water, that is, high summer precipitation, favorable soil, steep gradient of the stream. The Moma icing is 26 km long, 6–7 km wide, and 3–4 km thick. Ice mounds are formed over deep pools as the ice thickens and expands, and the pressure cannot be relieved against the frozen riverbed up and downstream. Thus, the ice surface is arched. Where the deep pools are fed by ground water which lacks an outlet, additional pressure is exerted on the surface ice.

The water level does not rise significantly in the spring because of the frozen riverbed and light precipitation, nor does thawing of the ground to a depth of 30–40 cm in summer feed the river to any great extent. Atmospheric precipitation feeds the river, and the rapidity of changes is similar to that of a mountain stream. In early winter the river is fed by ground water found between the frozen upper soil and the upper level of permafrost. As this intermediate layer freezes, the Indigirka presumably stops flowing altogether, because no water is being supplied.—From abstract by E. A. Golomshtok; SIPRE U–382.

Clark, A. C., 1943a, The Alaska Highway—Effects of climate and soils on design: Civil Eng., v. 13, no. 5, p. 209–212.

An estimated 100 miles of frozen ground occurs along the route of the highway in Yukon Territory, less in Alaska. "Glaciering" is the building up of ice formations during the winter. The water may seep from side slopes and cause continuous buildup of ice. Locally, bridges on the highways are reportedly engulfed by ice which may be as much as 50 ft thick in stream channels by spring.

1943b, Design problems presented by soil and climatic conditions on the Alcan Highway: Pacific Builder and Engineer, v. 49, no. 3, p. 38–45. *See* annotation, Clark, A. C., 1943a.

Clark, L. K., 1953, Some aspects of sanitation and water supply in the Arctic, p. 287–309 *in* Report of the Symposium on advanced base water supply and sanitation: Port Hueneme, Calif., U.S. Navy, Oct. 7–9, 1953.

A brief review of current practices at military and civilian installations.

Clark, L. K., and **Alter, A. J.**, 1956, Water supply in arctic areas; design features: Am. Soc. Civil Engineers Proc., Jour. Sanitary Eng. Div. v. 82, no. SA-2, Paper 931, p. 931-1—931-11.

Ground water obtained from wells through permafrost is subject to freezing in the withdrawal pipe from underpumping and to freezing in the aquifer from overpumping. Well and pump installations are subject to damage by frost heaving. Ground water is warmer than surface water in winter and requires less heating before distribution. Water levels fluctuate, reaching the lowest level in late winter and early spring; in some places, well supplies have been entirely depleted at this time of year. Test pumping during the spring low water period will aid in determining reliability of yield.

Cleaves, A. B. *See* Schultz, J. R., 1955.

Collier, A. J., 1902, A reconnaissance of the northwestern portion of Seward Peninsula, Alaska: U.S. Geol. Survey Prof. Paper 2, 70 p.

Serpentine Hot Springs emerges in the center of a broad mound along the creek above flood level. The water is sulfur-bearing and has a temperature of 212°F. Budd Creek, in the upper American Creek basin, North Fork Kugruk River, and Igloo Creek flow underground where they cross limestone beds and emerge as springs farther downstream. A large mineral spring from which carbonic acid escapes is located at the base of Noxapaga Butte. The water is cold and has a taste resembling that of soda springs.

1903a, Coal resources of the Yukon basin, Alaska: U.S. Geol. Survey Bull. 213, p. 276-283. *See* annotation, Collier, A. J., 1903b.

1903b, The coal resources of the Yukon, Alaska: U.S. Geol. Survey Bull. 218, 71 p.

Frozen ground in the Cliff Creek mine, 9 miles downstream from the village of Fortymile, Yukon Territory, Canada, extends to a depth of 150 ft. In the Nation River mine, in American territory, part of the coal was frozen, and the distribution of thawed zones in the frost is attributed to circulation of water through the coal. Lack of gas in the mines along the upper and lower Yukon may be due to the fact that the workings have not penetrated beyond the zone of perpetual frost.

Collier, A. J., Hess, F. L., Smith, P. S., and **Brooks, A. H.**, 1908, The gold placers of parts of Seward Peninsula, Alaska: U.S. Geol. Survey Bull. 328, 343 p.

Perennially frozen gravel and bedrock occur throughout the area. The frozen ground gives a maximum surface runoff and a minimum loss of ground water. Large bodies of gravel deposits have been found always free of ice; these gravels rest upon a porous bedrock that permits the ground water to drain away more rapidly than is possible in the surrounding areas of frozen ground. Water can be heard trickling through the limestone which underlies 18 ft of partly frozen gravel in mine shafts in Grass Gulch, a tributary of Dexter Creek.

Snowflake Mine on the south slope of King Mountain near Nome has a paystreak at 130 ft and another in a buried channel at a depth of 230 ft. The ground is perennially frozen from the surface to a depth of 90 ft, but the underlying gravel is dry, water percolating only down the mine shaft. Along Solomon River near the mouth of Big Hurrah Creek, a dredge encountered frozen gravel beneath the river bed. Kasson Creek, a tributary of Shovel Creek, Solomon district, loses most of its water into limestone beds. On Ophir Creek, Council district, holes dug in limestone beneath the creekbed encountered open crevices filled with slow-moving water at a depth of more than 6 ft; it is reported that the sinking of water into underground channels has decreased since the creekbed has been filled with silt from mining operations and that the creek carries more water than formerly.

Collins, F. R., 1958, Test wells, Umiat area, Alaska, *with* Micropaleontologic study of the Umiat field, northern Alaska, by H. R. Bergquist, *and sections on* Temperature measurement studies, by M. C. Brewer, *and* Core analyses, Umiat test well 9, by G. L. Gates: U.S. Geol. Survey Prof. Paper 305–B, p. 71–206.

The Umiat area is underlain by permafrost about 900 ft thick, except near the Colville River where permafrost is about 770 ft thick, possibly because of the warming effect of the river. The deepest record of permafrost is 1,055 ft in Umiat test well 9. Test wells 5 and 6 are located close to one another, and during rotary drilling of well 5 an increase in temperature was noted in well 6 at the downdip end of a sandstone bed at about 600 ft. Presumably the temperature increase was caused by warm fluids heated and driven downward from well 5 toward well 6 by the drilling mud. This relationship suggests that unfrozen fluids are present within permafrost, although at a temperature below 0°C.

A formation test in sandstone at 1693–1816 ft in Umiat No. 1 was unsatisfactory because of leakage in the packer and valve. The first 6 hr of bailing lowered the water level from 500 to a depth of 1,100 ft, and the next 4 hr lowered the level to 1,200 ft; but the level could not be lowered below 1,200 ft. Fresh water was moving into the hole at a rate of 10 gphr, and the bailing was stopped at 13 hours with the water level at 1,100 ft. Permafrost in this well extended to a depth of 920 ft.

1959, Test wells, Square Lake and Wolf Creek areas, Alaska, *with* Micropaleontology of Square Lake test well 1 and the Wolf Creek test wells, northern Alaska, by H. R. Bergquist: U.S. Geol. Survey Prof. Paper 305–H, p. 423–484.

Wolf Creek test well 2 encountered water at depths of 961 to 1,185 ft; its flow was as great as 20 gphr and its salinity was 9,400 ppm.

Collins, F. R. *See also* Robinson, F. M., 1959.

Cook, F. A., 1955, Near surface soil temperature measurements at Resolute Bay, Northwest Territories: Arctic, v. 8, no. 4, p. 237–249.

Little moisture migration occurs in shattered rock and gravel, but considerable migration takes place in clay. Upward migration of moisture to form ice lenses in the clay left the lower part of the clay relatively dry. Lowering of temperature in moist ground does not proceed at a uniform rate because the loss of heat is temporarily compensated by the latent heat of fusion given off, until all the water is converted to ice. Hydrostatic pressure developed in the unfrozen material lowers the freezing point of the soil; this pressure is due to downward squeezing between the advancing frostline and the permafrost table and to an increase in volume of the moisture as the temperature of the water is lowered. The maximum "zero curtain" occurs just above the permafrost table where the water cannot escape.

Coulter, H. W. *See* Muller, E. H., 1954.

Cox, Allan. *See* Wahrhaftig, Clyde, 1959.

Cressey, G. B., 1939, Frozen ground in Siberia: Jour. Geology, v. 47, p. 472–488.

A summary of knowledge through 1937, which includes discussion of distribution, types, zonation, depth, research history, relationship to glaciation and present climate, origin of permafrost. Mentions well at Igarka (where permafrost is 57.5 m thick) that obtains 800 buckets of water per day from an unfrozen lens in the frozen ground.

Cronkwright, A. E., 1947, Water supply problems of the Arctic: Public Works, v. 78, no. 8, p. 18–20.

In Arctic and subarctic regions abundant surface water of good quality can be obtained from rivers and lakes in summer; but in winter surface water is scarce, for rivers freeze nearly to the bottom and have restricted flow, and only the deeper lakes have water beneath the ice cover. At an unspecified Army post on Baffin Island plans were made for obtaining winter water supply from a river that in summer was one-quarter mile wide and 10 to 20 ft deep. Restricted streamflow, thick ice, and drifting snow on the access road rendered these plans impracticable, and water that was mineralized and of high color was obtained from a lake. Permafrost extends into bedrock at least 100 ft below the ground surface at this base and is hard to drill. The possibility of using high-speed rock drills in frozen rock should be investigated. At a large subarctic base, water was distributed by pipelines laid on the surface in insulated boxes. At small bases, a location close to water, such a deep lake, is required or else snow and ice can be melted for camp use.

Crowley, F. A., and **Hanson, R. E.,** 1956, Seismic measurements in permafrost areas of interior Alaska [abs.]: Alaskan Sci. Conf., 7th, Juneau 1956, Proc., p. 54; Geol. Soc. America Bull., v. 67, no. 12, pt. 2, p. 1086.

Extensive refraction seismograph measurements near Fairbanks succeeded in mapping the upper surface of permafrost. Dispersion of flexural waves was noted, but lack of adequate theoretical models prevented their use for thickness measurements. Long distances required for dispersion measurements do not permit sufficient resolution for prospecting applications.

Crumlish, W. S., 1948, Exploratory well drilling in permafrost, Fort Churchill, Manitoba, Canada, July–November, 1947: Report on Project 8–75–01–001 submitted to Office of Chief of Engineers, U.S. Army, by Water Supply Branch, Engineer Research and Development Laboratories, Fort Belvoir, Va., Apr. 23, 1948.

A program of exploratory drilling, using a Failing 314–C rotary-drilling machine (wells 1 and 3) and a Star 71SK percussion-drilling machine (wells 2, 4, and 5), was conducted to obtain information on well drilling, well development, and ground-water sources in permafrost areas and to obtain a supplemental ground-water supply for Fort Churchill. Preliminary resistivity studies indicated permafrost to be, at most, 40 ft thick and ground-water possibilities poor, except for the south end of a gravel ridge in the south camp.

Well 1 penetrated 7 ft of gravel, 3 ft of clay, and 25 ft of coarse sand, clay and gravel. Permafrost was encountered at 10–12 ft and a cave-in of frozen ground at the bottom of the uncased hole caused the bit to hang up; efforts at recovery of the bit failed when the sub, 7 ft from the surface, sheared. Besides the fishing operations, blasting, excavation with a clamshell, steaming inside the drill pipe, and lifting the drill tools by an A-frame and tractor all failed, and the hole was abandoned.

Well 2 penetrated 5 ft of gravel, 15 ft of sandy gravel, 3 ft of sand and clay, 17 ft of clay and gravel, 23½ ft of glacial moraine, 27½ ft of clay, sand and gravel, and 1½ ft of sand, bearing salt water (32.5 ft below sea level). Permafrost was encountered at 15 feet; the uncased hole caved badly to a depth of 20 ft, and permafrost thawed between 25 and 27 ft. Temperature of the salt water in the sand at 91 ft was 28°F. An attempt to drive the 8-in. casing inside the 10-in. casing was unsuccesful because of freezing of surface seepage down the hole into the permafrost zone, a broken segment of 10-in. casing at the 20-ft level, and crushing of the 8-in. drive shoe at a depth of 33 ft. Further drilling was discontinued because of inability to case the hole.

Well 3 encountered 20 ft of clay and gravel; 11 ft of clay, gravel, and organic matter; 10 ft of clay and gravel; 10 ft of clay; 21.7 ft of clay, gravel, and organic matter; 0.8 ft of boulder limestone; 4.1 ft of gravel; 2 ft of sand (salt water); 8.4 ft of clay and gravel; 3 ft of gravel; 34 ft of creviced dolomite; 4 ft of soft dolomite; 28 ft of clay and dolomite; and 37 ft of soft dolomite, Attempts to bail the water seeping in from the sand at 77.6–79.6 ft resulted in caving until the uncased hole was filled to within 15 ft of the surface. The hole was redrilled before and after arrival of casing.

Well 4 penetrated 5 ft of gravel; 15 ft of sandy gravel; 3 ft of sand and clay; 17 ft of clay and gravel; 23.5 ft of glacial moraine; 27½ ft of clay, sand, and gravel; and 25 ft of sand bearing salt water. The hole was drilled less than a foot from well 2.

Well 5 encountered 14 ft of gravel, 10 ft of sandstone, 5 ft of clay and gravel, 22 ft of sand and gravel, 3.6 ft of sandstone, 21 ft of sand containing brackish water; 4 inches of sand was encountered at 20 ft. The yield of the water sand when pumped with a 60 gpm Peerless deep-well Hi-Lift pump installed at a depth of 62.5 ft was only 3 gpm at maximum drawdown. Three sticks of 60 percent dynamite were exploded in the bottom of the well (63.5 ft); the well was bailed and drilled to 70 ft, at which point nine sticks of dynamite were exploded at 67 ft. After explosion of the charge and bailing, the static water level was 13 ft 11 in. from the ground surface. After several hours of test pumping the yield was still 3 gpm at maximum drawdown. After exploding a charge of 20 sticks of dynamite and bailing the well, drilling was continued to 75 ft, at which point compressed air at 75 psi was used to surge the well for 2 hr; after surging, the well was drilled to 75 ft 6 in, at which depth solid rock was hit and drilling suspended for fear of hitting salt water. After 9 hr of pumping on Oct. 23 and 8 hr on Oct. 24, the yield of the well was 4 gpm at a 60-ft drawdown.

The results of the exploratory drilling show that (1) salt or brackish ground water is present beneath Fort Churchill, (2) presence of ground water in permafrost areas can best be determined by drilling, (3) drilling in permafrost at Fort Churchill can be done with either rotary or percussion machines, (4) percussion machine is more adaptable to drilling in permafrost than the rotary, (5) modifications to both machines would make them more efficient, (6) additional tools and equipment would insure more efficient drilling operations. Further drilling in permafrost areas should be undertaken to determine what additional modifications to standard drilling equipment are needed, what additional equipment is needed, and what techniques are necessary to insure development of ground water in permafrost areas.

Dall, W. H., 1870, Alaska and its resources: Boston, Mass., Lee & Shepard, 627 p.

Reports that many springs along the coast near St. Michael and some to the northeast near the village of Ulukuk remain unfrozen and flow all winter.

Those near St. Michael have a temperature of 28° to 30°F, and those near Ulukuk are 32° to 34° F.

Dall, W. H., 1881, Notes on Alaska and the vicinity of Bering Strait: American Jour. Sci., v. 121, p. 104–111.

Description of exposures of frozen ground and ground ice in coastal bluffs from Return Reef to Barrow to Kotzebue Sound, including discussion of the origin of the ice at Elephant Point, Eschscholtz Bay.

D'Appolonia, E. *See* Hardy, R. M., 1946.

Davis, T. N., 1958, Yakutat and Huslia earthquakes of 1956 [abs.]: Alaskan Sci. Conf., 9th College 1958, Proc., p. 94–95.

Several thousand sand flows as much as one quarter of a square mile in area were associated with the Huslia earthquake of Apr. 7. The sand apparently flowed upward from old lake and stream beds currently covered with vegetated dunes. Flowage was locally accompanied by collapse of the sand dune layer.

Davydov, L. K., 1953, Hydrography of the USSR, part I, General hydrology [Gidrografiia SSSR, chast' I, Obshchaia karakteristika vod]: Leningrad, Leningradskogo Univ. Izd. 184 p.

The results of hydrological research are outlined. Annual variations in run-off and its dependence on physiography are analyzed. Ice conditions in lakes and rivers are described. The characteristics of anchor ice, sludge, pyatry, and naledi (icings) are given, and various conditions attending their appearance and favoring their development are discussed. Distribution of ground water in the USSR, particularly in permafrost regions, is described.—From SIPRE 10346.

Demchinskii, B. N. *See* Sumgin, M. I., 1940.

Demenitskaia, R. M., 1939, Prospects of seismic survey by the method of refracted waves in the region of the Ust-Eniseisk Port: Problemy Arktiki, no. 5, p. 81–92. [Russian.]

Dementiev, A. I., 1945, Action of the suprapermafrost stream during winter soil freezing [Aktivnoe deistvie nadmerzlotnogo potaka v period zimnego promerzaniia gruntov]: Akad. Nauk SSSR Vestnik, v. 15, no. 9, p. 75–76.

Water percolating in unfrozen ground above permafrost is subject to hydrostatic pressure which increases as the depth of the upper frozen soil increases. A case is described demonstrating the magnitude of such hydrostatic pressure. The active layer under a cabin was thawed by the heat of a stove. The pressurized ground water rose to the surface and overflowed the cabin to the window level. The water flowed from February to April, when weather conditions completely thawed out the active layer.—From SIPRE U–1581.

Dementiev, A. I., and Tumel', V. F., 1946, Civil engineering in frozen soil, U.S.S.R.: Canadian Geog. Jour., v. 32, no. 1, p. 32–33.

Yakutsk is an example of the types of ground-water problems solved in engineering practice. The city obtained its water in the form of broken ice from the Lena River in winter because it was too costly to build a main in the permafrost. The water of the Lena is not suitable for drinking and requires filtration; the shifting channels would require constant shifting of the pumping stations. Tolstikhin proposed using wells to tap the artesian water below the 700-ft layer of permafrost, and in 1940 a test well was bored to 1,600 ft which yielded a sufficient quantity of water of good quality. At Irkutsk, in 1944, a larger well was drilled to a depth even greater than the one at Yakutsk. Possibilities of using artesian wells are good in other parts of Yakutia.

Dickens, H. B., 1959, Water supply and sewage disposal in permafrost areas of northern Canada: Polar Rec., v. 9, no. 62, p. 421–432.

Permafrost restricts the movement of ground water and limits its use. Supplies obtained from above or within the permafrost are of variable quantity and of doubtful purity. Wells drilled through permafrost are costly and may require controlled pumping or auxiliary heat to prevent freezing of the well. Overpumping may result in freezing of the aquifer.

1960, Construction in permafrost; obstacles of soil and climate: Canadian Consulting Engineer, v. 2, no. 1, p. 33–37.

An exposition for the engineer of the basic properties of permafrost, including discussion of the problems of water supply and sewage disposal.

Dickens, H. B. *See also* Legget, R. F., 1959.

Dobrovol'skii, V. P., 1959, Certain characteristics of the interpretation of electrical sounding curves obtained during investigations of permafrost thickness [Nekotorye osobennosti interpretatsii krivykh VEZ poluchennykh pri issledovanii tolshchi mnogoletnemerzlykh gornykh porod]: Nauchn. Doklady Vysshei Shkoly, Geol.-geog. nauki, no. 2, p. 127–133.

Dostovalov, B. N., 1945, Method of examining rock formations using electromagnetic waves and its use in permafrost regions [abs.] [Metod prosvechivaniia gornykh porod elektromagnitnymi volnami i ego primenenie v raionakh vechnoi merzloty]: Akad. Nauk SSSR, Referaty nauch.-issled. rabot, 1944, Otdel, geol.-geog. nauk, p. 131, Moscow.

1947, Electrical characteristics of frozen ground formations [Elektricheskie kharakteristiki merzlykh porod]: Akad. Nauk SSSR, Inst. Merzlotovedeniia Trudy, v. 5, p. 18–35.

1956, Electrical prospecting of permafrost with the resistance method [Elektrorazvedka merzlykh porod metodam soprotivlenii), *in* Tezisy i plany dokladov * * * k soveshchaniiu 1956 po merzlotovedeniiu]: Akad. Nauk SSSR, Inst. Merzlotovedeniia, no. 2, p. 41–42.

The use of the electric resistance method in permafrost is based on the dependence of the resistance of frozen soil and rock on their ice content and temperature and on the increased heterogeneity of resistances along horizontal and vertical planes; it is governed by the necessity of accounting for permafrost conditions (primarily geothermal) together with geological conditions in interpretation of results.—From SIPRE 17052.

1959a, Permafrost survey by the resistance method in northwestern Siberia [Merzlotnaia s"emka metodom soproptivenii v usloviiakh severo-zapadnoi Sibiri]: Akad. Nauk SSSR, Inst. Merzlotovedeniia im. V. A. Obrucheva Trudy, v. 15, p. 47–80.

Studies were made in 1948 along the Poluya River, a right tributary of the Ob' River to determine permafrost distribution and thickness and to test the applicability of the method. The method is satisfactory for distinguishing between permafrost and talik, determining their distribution, and, under favorable conditions determining permafrost thickness.—From SIPRE 18235.

1959b, Permafrost investigations by the resistance method along the lower reaches of the Indigirka River [Issledovanie merzlykh porod metodom soprotivlenii nizov'e reki Indigirki]: Akad. Nauk SSSR, Inst. Merzlotovedeniia im. V. A. Obrucheva Trudy, v. 15, p. 81–112.

Driatskii, V. M., and **others,** 1960, Development of the Arctic geophysical studies for the period of 40 years: Problemy Arktiki i Antarktiki, no. 4, p. 97–110. [Russian.]

Dubakh, A. D., 1940, Ground water in peat bogs [Gruntovaia voda v torfianom bolote]: Gos. Leningradskogo Univ., Uchenye Zap. 50, Ser. geog. nauk, no. 2, p. 58–66.

* * * a bog may be considered a lake in which the ground water is bound by organic matter. Fluctuations of the ground-water table are related to air temperature and precipitation, with maximum elevations in the spring and fall and minimum elevations in the summer and winter.—Geol. Soc. America, Bibliography and Index of Geology Exclusive of North America, v. 13, 1948, p. 73, 1949.

Dunbar, Moira, 1958, Curious open-water feature in the ice at the head of Cambridge Fiord: Internat. Union Geodesy and Geophysics, Assoc. Sci. Hydrology Gen. Assembly, Toronto 1957, v. 4, p. 514–519.

A circular pool in the fast ice of the fiord in northeastern Baffin Island was first discovered in aerial photographs in April 1951. When first observed the pool was 312 ft in diameter and near shore where the coast makes a right angle, its center being 600 ft from the shore on either side of the angle. Each year the pool was observed in exactly the same place and varied in diameter from 156 to 229 ft. In mid-February through mid-March 1953 no pool was seen, but it had reappeared at the time of the next observation flight in April. No relation could be found between the formation of the pool and meteorological conditions. The origin of the pool may be attributed to the existence of a narrow column of water welling up from under the ice and most probably produced by underground water in the form of either a hot or cold spring. Many faults in the hard rock of the area suggest that the springs from below the permafrost are not improbable and would provide the narrow even column of water required to produce such a pool. A possible explanation for the opening of the pool in late winter is that freezing of the active layer reaches a stage at this time of year that in some way affects the hydrostatic pressure and increases the flow of the spring.—From SIPRE 16959.

Dylikowa, Anna, and **Olchowik, Julia,** 1954, Frozen ground—general terms [Zmarzlina—projecia orolne]: Poland, Lodzkie Towarz. nauk., Biul. Peryglacjalny 1, p. 136–141. [Translated from Polish by T. Dmochowska.]

Dylikowa, Anna, and **Olchowik-Kolasinska, Julia,** 1955–56, Processes and structures in the active zone of perennially frozen ground, parts I and II (Procesy i struktury w strefie cznmej zmarzliny, czesc I, II): Poland, Lodzkie towarz. nauk., Biul. Peryglacjalny 2, p. 197–203, 1955; no. 3, p. 119–124, 1956. [Translated from Polish by T. Dmochowska.]

Dzens-Litovskii, A. I., 1938a, Mineral lakes in the region of permafrost conditions [Mineral'nye ozera v usloviiakh vechnoi merzloty]: Akad. Nauk SSSR, Trudy kom. vechnoi merzlote, v. 6, p. 79–105.

The hydrogeologic regimen of mineral lakes is very different in the permafrost region from that elsewhere. In the Transbaikal, the lakes are rich in mirabilite, sodium chloride, and soda. These lakes have never been connected with the sea, and they are connected with a degradation of permafrost that developed sinks and karst funnels as the ice melted. These thaw lakes widened under the action of waves and freezing and thawing. Some of the lakes disappear as permafrost degrades, permitting the water to drain underground. In frozen-

ground regions where snowfall is light, surface waters are usually rich in salts. The salts are a product of intensive winter weathering of the rocks. These salts are carried by streams into the lake basins. Within the basins the 0.5- to 2-m aquifer just above the permafrost is important in the balance of the lakes. Mirabilite or soda deposited at low temperature in winter is partially dissolved again in summer, and in some lakes the permanent salt deposit is as much as 3 m thick. During freezing when the sulfates precipitate out, lake temperature suddenly rises 5° to 6°C, but later freezes to the bottom; in spring there is an absorption of heat during solution of the sulfates. In some places soda is precipitated on the ice surface during freezing; this material is commonly blown away by the wind. The lake-bottom mirabilite deposits may be worked like mines on firm land because the lakes freeze down to permafrost in winter.—From author's English summary.

1938b, Mineral lakes of the USSR, their types and geographical distribution: Priroda, no. 11–12, p. 37–51.

1945, Kempendian deposits of ice salt [Kempendiaiskoe mestorozhdenie ledianoi povarennoi soli-"Ledianki"]: Priroda, v. 34, no. 6, p. 41–44.

Mineral lakes in Yakut ASSR produce large amounts of Glaubers salt and NaCl. Salt is extracted from brine by the freezing method near the Kempendian deposits in the Viliui River basin. Salt mounds are formed from icing mounds through the action of underground waters percolating through deposits of salt and rising to the surface through hydrostatic pressure caused by frost action. The processes by which icing mounds develop into salt mounds are described.—From SIPRE U–3782.

1951, Permafrost on the bottom of Lake Razval at Sol'-Iletsk [Mnogoletniaia merzlota na dne ozera Razval v Iletskoi Zashchite]: Lab. gidrogeol. problem Trudy, v. 10, p. 130–141.

The physiography of the region is described, including the extensive deposits of rock salt near Lake Razval. The heavy salt content of the water prevents its freezing. The upper layers of the lake are cooled to −20.5°C or lower by winter air temperatures that drop to the vicinity of −40°C. Water temperatures near the bottom remain below freezing even in summer and reach a maximum of −5° to −10°C in August.—From SIPRE 9042.

1954, Hydrogeological and geological factors in the formation of saline icings [Gidrogeologicheskie usloviia formirovaniia solianykh naledei]: Moskovskogo obshch. ispytatelei prirody Biull., Otdel. geol., v. 29, no. 3, p. 99–100.

Saline icings (naledi) are widespread in areas with NaCl deposits in the permafrost zone of Yakutia. Severe freezing causes the formation of saline icings in the Tien Shan, the Urals, Western Siberia, and Kazakhstan. The icings are formed from surface and ground water and are either perennial or seasonal phenomena. Hydrostatic pressure in the ground from the freezing of the salt water causes severe ground deformation. The ice formed usually consists of less than 1.5 percent NaCl.—From SIPRE 12069.

1956, Hydrogeological peculiarities in the formation of the cryosphere of natural brine and salt lakes [Gidrogeologicheskie osobennosti formirovaniia kriosfery prirodnykh rassolov i solianykh ozer], *in* Tezisy i plany dokladov * * * k soveshchaniiu 1956 merzlotovedeniiu: Akad. Nauk SSSR, Inst. Merzlotovedeniia, no. 2, p. 32–34.

The characteristics and formation of a new type of permanently frozen matter (brine), often found south of the permafrost line is described. Two types of saline permafrost are distinguished: frozen silt at the bottom of salt lakes and frozen brine above, within, below, and at the margins of underground salt deposits. The survival of these layers in the frozen state is explained by the fact that as the salt concentration increases by sedimentation, the layers lose the properties common to fresh water and become similar to ordinary matter in which no convection currents take place. The surface water of salt lakes becomes supercooled in winter (down to —21.5°C) and gradually settles to the bottom, where it freezes. Brine found in the vicinity or within salt deposits freezes only at below —21.5°C, forming both at the surface and in the ground special forms of naleds, salt cones, etc. Natural frozen brine also promotes the formation of saline thermokarst in salt-bearing areas.

Dzens-Litovskii, A. I., and Tolstikhin, N. I., 1936a, Balneological resources of natural waters of USSR, their geographic distribution and methods of calculation: Problems of Soviet Geology, v. 6, no. 7, p. 641–642, July. [Russian.]

1936b, Hydrogeological investigations of mineral waters of Russia (O gidrogeologicheskikh issledovaniiakh mineral'nykh vod) : Razvedka Nedr, no. 11, p. 1–6, Moscow.

1937, Mineral springs and muds of the Soviet Union: Priroda, no. 10, p. 104–124; 1939, Geol. Soc. America, Bibliography and Index of Geology Exclusive of North America, v. 6, 1938, p. 73. [Russian.]

1948, Geographic rules of distribution of natural mineral water in the USSR [Geograficheskie zakonomernosti raspredeleniya prirodnykh mineral'nykh vod SSSR]: Vses. Geog. S"ezd, 2d, Trudy, v. 2, p. 264–266.

Outlines the distribution of mineralized ground waters and mineral lakes in the USSR. Three main types of ground waters (including springs) are distinguished—carbonate waters associated with the zone of Alpine folding and with Tertiary-Quaternary volcanic zones, soda-bearing, sulfate-bearing, chloride-bearing, and hydrocarbonate-bearing waters found in the peripheral zone of Alpine folding, and chloride and sulfate waters occurring in platform regions.—Geol. Soc. America, Bibliography and Index of Geology Exclusive of North America, v. 18, 1953, p. 116, 1954.

Dzens-Litovskii, A. I. *See also* Gladtsin, I. N., 1936; Tolstikhin, N. I., 1938.

Eager, W. L., and Pryor, W. T., 1945, Ice formation along the Alaska Highway: Eng. and Contract Rec., v. 58, no. 12; Public Roads, v. 24, no. 3, p. 55–74, 82.

Water that emerges at the surface and forms icings on or near the highway comes from one or more of the following sources: (1) surface water flowing in rivers, creeks, and small streams; (2) spring water from fissures and porous strata at a definite point on or near the road; and (3) percolating water or seepage from muskeg swamps, talus slopes, alluvial fans, bedrock strata, and sloping ground with heavy vegetation cover. Between Whitehorse, Yukon Territory, and Big Delta, Alaska, 28 percent of the road is built on permafrost, and 68 percent of the icings occurred in the sections on permafrost. Icings are most common above an elevation of 2,100 ft in rugged topography where numerous small watercourses with steep gradients are intercepted by the highway, and where temperature fluctuates more widely than in the lowlands.

Eakin, H. M., 1912, The Rampart and Hot Springs regions [Alaska]: U.S. Geol. Survey Bull. 520–I, p. 271–286.

In the Gold Mountain district, west of Tanana, prospect shafts on Grant Creek are 30–135 ft deep; they have been abandoned because of the presence of moving ground water. On Illinois Creek, a 133-ft shaft was abandoned before reaching bedrock for similar reasons.

1913a, A geologic reconnaissance of a part of the Rampart quadrangle, Alaska: U.S. Geol. Survey Bull. 535, 38 p.

Except where unusual factors operate, the ground below a slight depth is permanently frozen. It remains unfrozen about Hot Springs because of the heat of the springs, and on some of the creeks where the gravels are unusually permeable to circulating ground waters.—Author's report, p. 12.

In the Gold Mountain area prospect shafts were abandoned without encountering bedrock because of the difficulties with moving ground water in unfrozen ground at depths ranging from 30 to 135 ft.

1913b, Gold placers of the Innoko-Iditarod region [Alaska]: U.S. Geol. Survey Bull. 542–G, p. 293–303.

Prospecting by means of shafts in the flood plain of Gaines Creek is hindered because of thawed ground and the danger of flooding by ground water.

1914a, The Iditarod-Ruby region, Alaska: U.S. Geol. Survey Bull. 578, 45 p.

Extremely permeable gravel deposits are usually thawed, owing to the circulation of ground water. Alluvial deposits of Yankee Creek are unfrozen where being mined for gold. In most of the placer mines in the Ruby district the ground is frozen to bedrock. However, on Quartz Creek, a tributary of Solatna River, the placer deposits are 50–180 ft deep and the valley fill is frozen to bedrock in all but the deepest places.

1914b, Placer mining in the Ruby district [Alaska]: U.S. Geol. Survey Bull. 592–J, p. 363–369.

On Long Creek some of the deeper prospect shafts have encountered thawed ground, and ground water has hindered prospecting. The use of a drill is recommended in this type of prospecting.

1915a, Placer mining in Seward Peninsula [Alaska]: U.S. Geol. Survey Bull. 622–I, p. 366–373.

A possible method of thawing the coastal-plain deposits more cheaply by means of ditch water is suggested by the results of an artificial drainage project in the vicinity of Nome. A drainage ditch was dug across the tundra at a short distance from one of the natural watercourses and parallel with it. In places the excavation penetrated through the muck and into the surface of the underlying gravels. After a time it was noted that considerable water was lost from the ditch by seepage, presumably through the gravels toward the natural watercourse, along which there was a zone of thawed ground. Later the thawed strip of gravel along the stream was dredged, and it was found that the area between the ditch and the stream was also thawed and available for dredging. Apparently the ditch water seeping through the gravels eliminated the ground frost to progressively greater depths, until the circulation affected the whole thickness of the gravels down to bedrock. The depth of thawing the first summer exceeded the depth of winter frost of the following season, so that the second summer's thawing was added to that of the first, and so on to bedrock. It is estimated that the surface of ground frost was lowered about 20 ft a year.

This occurrence accords with the laws of ground-water circulation as developed by Slichter and applied by Van Hise. The waters do not move in straight lines between the point of entrance into the gravels and the point of their withdrawal,

but tend to follow a number of divergent paths from the former and of convergent paths near the latter. The coastal-plain gravels, where thawed, are fairly homogenous and offer a nearly uniform degree of permeability to ground waters. The ideal circulation would be modified at the inception of the process by the high level of the surface of ground frost. As this surface was lowered by the influence of the relatively warm ditch waters the circulation would take on more and more of the ideal form. The rate of circulation of ground water is affected by the difference in elevation between the points of entrance and exit, being more rapid under a higher head. The depth of gravels affected would depend somewhat on the horizontal distance between these points.—Author's report p. 368–369.

Eakin, H. M., 1915b, Mining in the Fairbanks district [Alaska] : U.S. Geol. Survey Bull. 622–G, p. 229–238.

Claim 1 below on Cleary Creek has 6–12 ft of muck covering gravel and bedrock that lies 16–22 ft deep. Most of the ground is thawed, and only isolated patches of frozen ground occur. Downstream from claim No. 10 below, however, and in the Chatanika Flats the alluvium is 34–140 ft thick and is perpetually frozen.

1915c, Mining in the Hot Springs district [Alaska] : U.S. Geol. Survey Bull. 622–G, p. 239–245.

On the Midnight Sun claim, one-quarter mile northwest of Tofty, the placer ground is 50 to 65 ft deep and most of it is perpetually frozen. The mine became flooded when workings penetrated unfrozen gravel containing ground water.

1916, The Yukon-Koyukuk region, Alaska: U.S. Geol. Survey Bull. 631, 88 p.

Except on creeks where gravels are permeated by circulating ground water and near hot springs, the ground below a slight depth is permanently frozen in places to depths of 130 ft or more.—From author's report, p. 18.

Eakin, H. M. *See also* Smith, P. S., 1910, 1911.

Eardley, A. J., 1938a, Unconsolidated sediments and topographic features of the lower Yukon valley : Geol. Soc. America Bull., v. 49, p. 303–341.

1938b, Yukon channel shifting : Geol. Soc. America Bull., v. 49, no. 3, p. 343–358.

Eckhart, R. A. *See* Moxham, R. M., 1956.

Efimov, A. I., 1944, Regime of ground water in deeply frozen ground under heated buildings [Glubokoe promerzanie gruntov i rezhim nadmerzlotnykh vod pod teplymi zdaniiami] : Akad. Nauk SSSR, Inst. Merzlotovedeniia im. V. A. Obrucheva Trudy, v. 4, p. 205–225.

The relationship between the depth of seasonal frozen soil and the ground-water level was investigated under two heated buildings during the winters of 1941–43 in the southern part of a permafrost area. The permafrost was 4–15 m thick with an active layer of 3–4 m, had temperatures of −0.2° to −0.3°C and moisture contents of 17–40 percent. The ground-water level began to increase when seasonally frozen soil reached the water layer. The ground-water level varied between 2.2 m in March and 3–5 m in November–December. The temperature of the ground water was high enough under buildings to cause thawing of the permafrost. The indications are that the permafrost will be completely thawed within 5–8 yr.—From SIPRE U–5568.

1945a, Hydrological observations under permafrost conditions: Acad. Sci. USSR, Div. Geol. and Geog. Sci., Work of the Obruchev Inst. Permafrostology, 1944, p. 114–132. [Russian.]

1945b, The Yakutian artesian basin of underground waters below the permanently frozen ground [IAkutskii artesianskii bassein podmerzlotynykh vod]: Akad. Nauk SSSR Izv., Ser. geol., no. 4, p. 128–140.

Geologic investigation of the central Yakutian artesian basin, near the city of Yakutsk, indicated that the ground waters came from beneath permafrost and occurred in sandstone and conglomerate of Lower Jurassic age, which forms a slightly inclined trough of large size. Permafrost is 216 m thick and of continuous extent, but thawed ground may exist beneath the Lena and Aldan Rivers, which may feed the underground waters. Near Yakutsk the waters beneath permafrost occur in the interval between 320 m and 500 m, or deeper, and are under sufficient pressure to rise to a level only 78 m below land surface. The temperature of the waters is 2.8°C at a depth of 500 m. Chemical analysis of the water shows a total of 1,352.7 mg per liter, including 365.7 mg per liter Na+K, 142.5 mg per liter Cl, 257.6 mg per liter SO_4, and 550.8 mg per liter HCO_3^-.—From Russian, p. 135; author's English summary, p. 140.

1946, Subpermafrost waters of the central Yakut region [Podmerzlotnye vody tsentral'noi IAkutii]: Priroda, v. 35, no. 7, p. 50–53.

Permafrost is as much as 200 m thick at Yakutsk, where subpermafrost waters had to be utilized because of inadequate shallow water supplies. The subpermafrost waters occur 320–500 m below the surface and rise in drill holes to a depth of about 80 m. Springs of subpermafrost waters near Yakutsk are sterile and have a low mineral content. Because of low temperatures in the ground, the flow of water must be continuous and may even require some heating to prevent freezing.—From SIPRE U–824.

1947a, Character of suprapermafrost waters underneath warm buildings [abs.] [Rezhim nadmerzlotnykh vod vnutri konturov teplykh zolanii]: Akad. Nauk SSSR, Otdel. geol.-geog. nauk, p. 158–159.

Near Chita, in eastern Transbaikal, water-bearing gravelly Quaternary deposits are underlain by perennially frozen, massive clay of Jurassic age. During the winter partial freezing of the upper part of the water-bearing deposits to a depth of 4 or 5 m establishes pressure. Beneath heated buildings, where there is no seasonal freezing, the level of the pressurized water in the suprapermafrost layer rises 1–1.5 m during the period from January to May. The unfrozen ground under the structure where the water level rises extends throughout the entire area of the structure and sometimes even beyond it. The periodic wetting and drying of the ground under the foundations due to seasonal variation in the level of the suprapermafrost water is one factor that weakens the bearing capacity of the ground supporting the foundations. Complicated measures are needed to prevent the rise of water level, and it is best to avoid using areas that develop a semifreezing suprapermafrost layer for erection of large heated structures.—From Minnesota Univ., 1950, p. 74.

1947b, Formulation of thermokarst lakes in Yakutia [abs.]: Akad. Nauk SSSR, Referaty nauch.-issled, rabot, 1945, Otdel. geol-geog, nauk,

Permafrost and hydrogeological studies made in 1945 of the Churapcha region on the Lena-Amginsk divide shows that ground ice in the form of layers 15 to 20 in. thick is widespread. Melting of the ground ice in local areas results in formation of a large number of thermokarst lakes, which are classifiied as follows: (1) lakes of river origin which are basically old riverbeds, (2) thermokarst lakes having a short annual contact with surface streams, (3) thermokarst lakes which have no contact with surface streams because the streams have been dry for several years, (4) lakes of thermokarst origin having no contact with streams and feeding on water flowing down mountain slopes, (5) thermokarst lakes outside the range of surface flow, generally located on flat or elevated topography. The latter group can be subdivided into (a) lakes being formed, (b) existing lakes, and (c) drying lakes. The final stage is represented by a dry depression. The dry climate (precipitation 200 mm, evaporation about 350 to 400 mm) causes drying of lakes that are not replenished by surface water. Lakes of all groups except 2 and 3 have a high mineral content; even those lakes that are replenished by surface waters are not suitable for water supplies for large centers of population, in which case it is necessary to plan for utilization of the waters under the permafrost layer.—From Minnesota Univ. 1950, p. 73–74.

Efimov, A. L., 1947c, Suprapermafrost conditions: Acad. Sci. USSR, Div. Geol. and Geog. Sci., Collected works of the Obruchev Inst. Permafrostology, 1945, p. 152–173, [Russian.]

1952, Non-freezing fresh water springs of the Ulakhan icing in central Yakutia [Nezamerzaiushchii presnyi istochnik Ulakhantaryn v tsentral'noi IAkutii]: Akad. Nauk SSSR, Sbornik Issled. vechnoi merzloty v IAkutskoi Respublike, no. 3.

1954, Water supply of central Yakutia [Istochniki vodosnabheniia tsentral'noi IAkutii]: Akad. Nauk SSSR, Materialy o prirodnyk usloviiakh i sel'skom khoziaistve tsentral'noi IAkutii.

1957, Certain characteristics of the use of ground water under various hydrogeologic conditions in southern and central Yakutia [Nekotorye osobennosti ispol'zovaniia podzemnykh vod pri razlichnykh gidrogeologicheskikh usloviiakh v iuzhnoi i tsentral'noi IAkutii], *in* Materialy po podzemnym vodam Vostochnoi Sibri; Irkutsk, Akad. Nauk SSSR, Vostochno-Sibirskii Filial, p. 172–176.

Permafrost and hydrogeological conditions of southern and central Yakutia are described, and the problem of water supply is considered. The thickness of permafrost in the region increases in the direction of the main tectonic structure of the east portion of the Siberian plateau and not from south to north. Within the Aldan-Olekminsk highland, permafrost is 100–150 m thick and occurs in conjunction with large water bearing taliks found under rivers, in tectonic disturbances, composite fissured sedimentary or metamorphic rock, and karst areas. In southwestern Yakutia, permafrost reaches a thickness of 100–120 m and thawed areas are found in tectonic disturbances or karst. North of the Aldan highland permafrost reaches a thickness of 200–500 m and thawed ground is rarer than in the south.—From SIPRE 18017.

1959a, Certain characteristics of the formation of ground water in southern and central Yakutia [Nekotorye osobennosti formirovaniia podzemnykh vod v predelakh iuzhnoi i tsentral'noi IAkutii]: Akad. Nauk SSSR, Inst. Merzlotovedeniia, Materialy obshchemu merzlotovedeniiu, p. 128–137.

Perforating taliks play the most important role in the relation between surface and ground water, their existence and that of thawed ground being determined by erosion, the size, permanency, and depth of water bodies, the composition of the ground underlying water bodies, chemical processes in the ground, and the circulation of infiltrating and ground water. Considerable areas of thawed ground are found near water bodies in the Aldan-Olekminsk highlands, where permafrost is 100–150 m thick, together with numerous permanent springs. In

southwestern Yakutia permafrost is discontinuous, reaches a maximum thickness of 100–200 m, and taliks occur in river beds. In the lowlands north of the Aldan highland, permafrost reaches a thickness of 200–250 m and its continuity is more rarely interrupted, perforating taliks being found only under large rivers. In central Yakutia, permafrost reaches a thickness from 200–600 m, or more, and taliks are encountered under water bodies. Permafrost in western Yakutia reaches a thickness of 200 m and is generally continuous, while south of the Lena-Vilyui lowland it is estimated to be 300–400 m or more thick, and taliks are possible only under the Lena River. The sources of supply of ground water in the various regions are discussed, and the possibility of exploiting the water is considered.—From SIPRE 17938.

1959b, Hydrogeologic features of diamond deposits of the pipe "Mir" area in southwestern Yakutia [Gidrogeologícheskie osobennosti mestorozhdeniia almazov trubki "Mir" v iugo-zapadnoi IAkutii]: Moskovskoe obshch. ispytatelei prirody Biull., new. ser., v. 64, Otdel. geol., v. 34, no. 3, p. 150–151.

Describes reserves, temperature, mineralization, and occurrence of ground water in the border zone of the Tunguska and Vilyuy synclines. Data are given on ground water conditions and temperature at depths of 12–15 m and at 170 m. Ground water from these depths cannot be used for diamond-producing enterprises, and a suitable supply should be obtained from unfrozen basic rocks at a depth of approximately 400–450 m.—From Arctic Bibliography 57826.

Efimov, A. I., Kachurin, S. P., and **Solov'ev, P. A.,** 1947, Permafrost hydrogeological sketch of surroundings of Churapchi settlement in Yakut ASSR [abs.] [Merzlotno-gidrogeologicheskii ocherk okrestnostei poselka Churapchi v IAASSR] Akad. Nauk SSSR, Referaty nauchn.-issled, a rabot 1945, Otdel. geol.-geog. nauk, p. 159–160.

An aerial survey of the Lena-Amgin divide was made to locate sources of water supply. The aerial photographs on a 1:60,000 scale indicated that 65 percent of the area was free of cave-ins, and 33.5 percent of the land contained cave-ins ranging from 5 to 18 m in depth. Thermokarst lakes were found on 1.4 percent of the area and erosion lakes on 0.1 percent of the land surveyed. The upper 70 m layer of the soil was analysed. Its composition from the surface downward is as follows: 2–5 m of clay and sandy loam, ground ice of firn origin, clay soils with ground ice, interstratified clay and sandy loam, and coarse, gravel-like sand. There was no suprafrost water. It is suggested that the ground ice might be utilized as a source of water supply by the artificial creation of thermokarst lakes.—From SIPRE U–1649.

Efimov, A. I., Mel'nikov, P. I., and **Solov'ev, P. A.,** 1945, Water below the permanently frozen ground in the region of the town of IAkutsk [Podmerzlotnye vody raiona IAkutska]: Akad. Nauk SSSR, Referaty nauchn.-issled. rabot, 1944, Otdel. geol.-geog. nauk, p. 130,

Review of special investigations in the Yakutsk region during 1938–44. The measurement of the earth's temperature at depths to 500 m is given. In this area the under layer of permafrost occurred at a depth of 204 m.—Meteorol. Abs. and Bibliography, March 1951, v. 2, no. 3, p. 226.

Ellsworth, C. E., 1910a, Placer mining in the Yukon-Tanana region [Alaska]: U.S. Geol. Survey Bull. 442–F, p. 230–245.

Difficulties were encountered on Treasure Creek in 1909 in attempting to work deep placers by underground methods because of the presence of ground water.

A reservoir of ground water that limited mining on claims 8, 9, and 10 below Discovery on Cleary Creek had to be drained by constructing a tunnel. Presence of thawed gravel and underground water channels which flood mine workings hindered development of rich placer ground on Little Minook Creek near Rampart. In the Hot Springs mining district, near Eureka Creek, a churn drill hole 200 ft was suspended for lack of casing; the purpose of the well was to obtain artesian water, and drilling was to have been continued during the winter of 1909–10. In the Salcha-Tenderfoot area, drift mining on Caribou and Butte Creeks was hindered by ground water in thawed ground.

Ellsworth, C. E., 1910b, Water supply of the Yukon-Tanana region [Alaska], 1909; U.S. Geol. Survey Bull. 442–F, p. 251–283.

Impermeability of the frozen ground prevents significant underground storage of water and makes uniform distribution of the total runoff impossible. Water derived from thawing of frozen ground during summer is of minor importance.

Ellsworth, C. E., and **Parker, G. L.,** 1911, Placer mining in the Yukon-Tanana region [Alaska]: U.S. Geol. Survey Bull. 480–G, p. 153–172.

Ground water occurred in thawed ground in placer workings on Engineer Creek, Fairbanks district.

Enenshtein, B. S., 1947, The results of the application of electromagnetic investigations by direct current in the region of permafrost [Result'taty primeniia elektrorazvedki metodom postoiannogo toka v raionakh vechnoi merzloty]: Akad. Nauk SSSR, Inst. Merzlotovedenie Trudy, v. 5, p. 36–86.

The object of the study is to show that the theory that permafrost is a nonconductor is false, that it is a semiconductor instead, as demonstrated by laboratory and field investigations. Electrical resistance of unfrozen formations is influenced by (1) porosity, form and size of the pores, (2) degree of saturation of the pores by ground water, (3) character, chemical content, and concentration of salts and acids in the water, (4) temperature of the electrolyte which fills the pores, (5) structure of the formations, (6) geologic factors, such as weathering, and (7) state of the water in the pores. The resistance is in inverse proportion to the porosity, in direct proportion to the resistance of pore water, and in inverse proportion to the degree of concentration of the solution. Resistance decreases with increase in temperature of the electrolyte, and in well-laminated formations the tendency is to conduct current along and across the laminae. Weathered formations have less resistance, but an increase in degree of cementation increases resistance.

In the Tolba River area of Yakut ASSR, exploration for oil was made in terrain underlain by a layer of clay sand, a 1–m layer of crystalline ice, and a permafrost layer. The presence of the ice distorted the electrical cross section and prevented determination of the position of the thawed and frozen layers. The presence of the ice both in the permafrost and on its surface could be determined by electric methods. Permafrost layers under natural conditions, even at a temperature of —3° to —4°C, act as a conductor of electrical current.

Investigations at Nordvik at the mouth of Khatanga Bay were hampered by the presence of as much as 20 m of fossil ice, but were aided by the presence of concentrated salt solutions within the formations. At Amderma the permafrost extends from a depth of 0.5–2 m down to more than 300 m. Salt sea water had infiltrated into the permafrost and numerous layers of thawed ground as much as several meters thick occurred. The presence of salt water and thawed zones may have affected the results of electric conductivity studies.

Studies along the Baikal-Amur railway showed that (1) direct current can be used for electric sounding under the type of permafrost conditions that exist in the Far East, (2) when the upper thawed layer is heterogeneous, the upper layer of permafrost cannot be determined accurately, and (3) the chart of resistances based on the profiles does not give sufficient information for mapping the distribution and limits of the ice incrustations.

The electric sounding method was employed to determine the top and bottom of permafrost in the Bukachacha coal region, but it was not possible, because of permafrost, to permit electrodifferentiation of geological layers in the permafrost-free zone. In the study of Sarasun region the electric sounding method was used to show the position of the base of permafrost, and the results were checked by borings; under favorable conditions in this region the methods could be used also in the search for mineral waters. Work at the Lenin and Krutoy gold mines in the Lapa-Vytim region showed that permafrost, even at —3°C, acts as a conductor for electrical current. At Igarka the electrical method was used to determine the thawed zone, the upper and lower limits of permafrost, as well as the depths of the basic formation.—From abstract by E. A. Golomshtok for Stefansson Collection, Dartmouth College Baker Library, Hanover, N.H.

Engineering and Contracting, 1922, Methods and cost of thawing frozen gravel by means of cold water: Eng. and Contracting, v. 57, p. 157–158.

In experiments at Candle, Alaska, frozen gravel was thawed by blocking off the area to be dredged, sinking a shaft to bedrock, and then pumping water from a nearby creek through the active zone of the gravel. Layers of muck were thawed with cold-water points so that a seepage of water from the creek to the shaft was maintained. The frost line gradually descended to the bottom level of the shaft, and an area 790 by 235 ft and 60 ft deep was thawed by 80 hrs of pumping.—From SIPRE U-398.

Engineering and Mining Journal, 1915, Koyukuk placer-mining district: Eng. Mining Jour., v. 99, p. 1021–1023.

An inclined shaft 80 ft deep encountered water on Discovery claim 1½ miles above the mouth of Hammond River. Claim 3 above has thawed ground, consisting of large boulders and gravel, resting on bedrock, at a depth of 95 ft. A shaft on claim 5 above was flooded out. The lower Hammond River is known for the occurrence of "live water" in the gravel above bedrock. Prospecting on Rye Creek, a tributary of Flat Creek in the Wild River drainage, has been hindered by the presence of ground water. A deep gravel-filled channel on Marion Creek has not been worked because of the presence of ground water above bedrock.

1917, Ground frost in Alaska: Eng. Mining Jour., v. 104, no. 11, p. 491.

Alluvial deposits in the Klondike district are frozen to a depth of around 200 ft. Those at Fairbanks are frozen to depths of more than 200 ft, and in one shaft 318 ft of frozen alluvium was encountered. On the Seward Peninsula many holes encounter more than 75 ft of frozen alluvium, and one was dug in more than 200 ft of frozen material. Some ground is not frozen. Underground channels of water raise havoc with mining operations, but occur in only a few places.

Engineering News-Record, 1940, Army builds an arctic air base: Eng. News-Rec., v. 125, no. 17, p. 558–559.

Drilling during the winter of 1939–40 at Ladd AFB (now Fort Wainwright) encountered 80 ft of permanently frozen ground beneath which lay water-bearing gravel. Two wells, 18 and 24 in. in diameter, drilled to a depth of 100 ft yield 3 mgd.

Erman, Adolph, 1838, Notes on the frozen soil in Siberia: Royal Geog. Soc. [London] Jour., v. 8, p. 212–213.

The well at Yakutsk was observed when at a depth of 50 ft; temperatures measured by inserting a thermometer in the frozen clods of earth being thrown from the hole were —6° Reaumur. On the basis of calculations of the geothermal gradient, a thickness of 500–600 ft of frozen ground was expected.

Ermilov, I. IA., 1934, Influence of permafrost on relief (O vliianii vechnoi merzloty na relef) : Gos. geog. obshch. Izv., v. 66, no. 3, p. 377–388.

Ground water in regions of permafrost plays a double role; it works as a destructive agent, and it also favors the constructive processes. The action of freezing temperature contributes to the formation of the following features; polygons, hummocky slopes, sharp ridges separating the gullies, swelling hummocks and spots in tundra, hummocks in peat bogs, and cemetery hummocks. Large swelling hummocks and ridges whose height reaches tens of meters, naledi, and taryny are related to the deep ground water and artesian water. Melting of ground ice causes the formation of karst funnels, underground streams, disappearing rivers, and other features characteristic of karst regions.—From unpublished translation and emendation by I. V. Poiré, 1949.

1947, Hot springs in the Mukunga River valley [Termal'nye istochniki na r. Mukunge] : Vses. geog. obshch. Izv., v. 79, p. 657–658.

The physiography of hot springs along the upper Bureya River (Khabarovsk area) was studied in 1946. The penetration of warm water through fissures in permafrost at one point has caused thawing of the permafrost and the formation of a swamp about 75 m in diameter, and of many smaller swampy spots in the vicinity. Some hot springs in the valley of the Solon' River have caused the formation of icings.—From SIPRE 9326.

Ermolaev, M. M., 1932, Geological and geomorphological outline of Bolshoi Lyakhov Island [Geologicheskii i geomorfologicheskii ocherk ostrova Bol'shogo Liakhovskogo]: Soveta izuch. proizvoditel'nykh sil, Trudy, Ser. IAkutskaia, v. 7, p. 147–228.

Ernshtedt, A. V. *See* Tolstikhin, N. I., 1937, 1938.

Essoglou, M. E., 1957, Piling operations in Alaska: Mil. Engineer, v. 49, p. 282–287.

This article gives a detailed description of subsurface exploration at the U.S. Air Force installation 3 miles west of Bethel. A test well, 290 ft deep, was drilled in a draw on the south slope of the 180 ft hill on which the installation is located and 1,500 ft to the south. The well encountered no permafrost except for a 4-ft layer at a depth of 45 ft.

Fagin, K. M., 1947, Drilling problems in Alaska: Petroleum Engineer, v. 19, no. 1, p. 180, 182, 184, 186, 188, 190.

In northern Alaska permafrost ranges from 600 to 1,000 ft thick. Isolated islands of unfrozen ground have been found in riverbeds and other places.

Fal'kovskii, N. I., 1948, Water supply and sanitary engineering in the USSR [Vodosnabzhenie i sanitarnaia tekhnika v SSSR]: Moscow, Ministry Communal Economy, USSR, 108 p.

Development and recent achievements in the field of water supply and sanitary engineering, including some statistical data.

Fernald, A. T., 1959, Geomorphology of the Upper Kuskokwim region, Alaska: U.S. Geol. Survey Bull. 1071–G, p. 191–279.

Wells at McGrath on the flood plain of the meandering Kuskokwim River provide subsurface data on frozen ground in the lowland. On the older parts of the meander scrolls 5 wells passed through the bottom of permafrost at depths ranging from 15 to 40 ft, and 6 wells at depths of 40–50 ft. Wells on the newer parts of the meander scrolls, including the 262-ft Federal Aviation Agency well, are free of permafrost. At Farewell Federal Aviation Agency airstrip a 360-ft well passed through a zone of permafrost the bottom of which is reported as both 12 and 125 ft by different sources.

Filatov, K. V. *See* Lange, O. K., 1947.

Filosofov, G. N. *See* Ponomarev, V. M., 1960.

Flint, R. F., 1957, Glacial and Pleistocene geology: New York, John Wiley & Sons, 553 p.

Fotiadi, E. E., ed., 1940, Geophysical methods of prospecting in the Arctic: Leningrad, Arctic Inst. of Chief Administration of Northern Sea Route Trans., no. 151, 104 p. [Russian.]

Application of gravimetric, electrical, and seismic methods under arctic conditions, including a discussion of geophysical work at Nordvik, Ust' Port, and the Yukorsk Peninsula and in the Adicha-Yansk region.—From U.S. Geol. Survey Bull. 932–A, p. 29, Geophys. Abs. 5964.

Fraser, J. K., 1956, Physiographic notes on features in the Mackenzie delta area: Canadian Geographer, no. 8, p. 18–23.

Associated with landslide debris on the slopes of low hills bordering the eastern margin of the Richardson Mountains, near Aklavik, Northwest Territories, are three pingolike features. Pingos, according to most workers, are formed by hydrostatic pressure in a subsurface layer of unfrozen soil confined by frozen layers. This pressure forces a mixture of water and fine materials upward through a rupture in the upper permafrost layer; their formation appears to require fine homogeneous material saturated with water, as, for example, occurs in shallow ponds or old lake beds. The pingos on the slopes of Mount Goodenough (Black Mtn.) are (1) a conical hill 60 ft high containing a crater with a pool 25 ft across, (2) a circular pool 40 ft across in which the ice was cracked and arched, with mud showing in the crack, and (3) a circular crater about 85 ft in diameter contained by a low rim about 18 ft high and breached downslope. Two theories of origin are advanced: (1) that they are of thermokarst origin, and (2) that their formation is similar to that of pingos.

Frost, R. E., 1950, Permafrost: Ann. Road School, 36th, Apr. 10–13, Proc., Purdue Univ., Eng. Bull., v. 34, no. 3, p. 101–111.

1952, Interpretation of permafrost features from airphotos: Natl. Acad. Sci., Natl. Research Council, Highway Research Board, Frost action in soils, a symposium, Spec. Rept. 2, p. 223–246.

Pingos are of three types: (1) true pingos or frost mounds, the result of upheaval of the earth's crust from pressure of ice beneath the surface, (2) isolated dome-shaped terrace remnants which are made conical as a result of the peculiar arctic erosion and dissection, and (3) mounds formed by upward flow of water and (or) soils to the surface through some type of orifice. An example of a mound constructed by upward flow of water and (or) soil occurs in the Copper River valley near Gulkana. The mound is locally called a mud volcano, and the surrounding trees are still being buried by material moved down the slopes. Also cited is a mound in the Ruby district in which earth material is brought up by a spring. Various theories of origin are discussed.

Gal'tsov, A. P., 1958, New research program on the problem of the hydrothermal regime of the earth's surface, its role in the dynamics of natural phenomena, and methods of modifying it for practical purposes [Novaia programma issledovanii po probleme teplovogo i vodnogo rezhima zemnoi poverkhnosti, ego roli v dinamike prirodnykh iavlenii i metodov preobrazovaniia dlia praktcheskikh tselei]: Akad. Nauk SSSR Izv., Ser. geog., no. 6, p. 3–15.

Individual problems needing studying to assess the role of hydrothermal regime at the earth's surface in the formation of climate and regional geographical characteristics are discussed, and various methods of investigations are outlined. The research problems on the program include: radiational heat exchange at the earth's surface; turbulent heat and moisture exchange between the ground and the atmosphere, surface runoff, soil-water movements; and heat and moisture exchange between different geographical regions; the formation, dynamics, and thermal regime of snow cover and the hydrothermal regime of the subtended soil; the formation and dynamics of continental glaciers—those of seasonally and permanently frozen ground and those of surface and ground water and denudation processes.—From SIPRE 17062.

Garmonov, I. V., 1956, Hydrochemical zones of ground water [Gidrokhimicheskaia zonal'nost' gruntovykh vod]: Priroda, v. 45, no. 3, p. 83–86, March.

The effects of permafrost, climate, and other factors on chemical composition of ground water in European Russia are discussed, and four hydrochemical zones are discerned. The lowest mineral content is characteristic of the tundra zone where the permafrost table is located at depths from 0.25 m in peat soil to 3 m in alluvium and diluvial deposits. The mineral content is usually not more than 0.1–0.15 gm per liter. Ground water in permafrost contains numerous acidic organic substances, and hydrocarbonates prevail as anions. The cation content varies considerably with physiography and soil composition.—From SIPRE 13649.

Geniev, N. N. *See* Sumgin, M. I., 1939.

Gersht, E. P., 1957, The use of radioactive isotopes in meteorology and hydrology [Ob ispol'zovanii radioaktivnykh izotopov v meteorologii i gidrologii]: Meteorologiia i Gidrologiia, no. 8, p. 62–64.

The principles of measurements with radioactive isotopes and their application to hydrometeorological problems are discussed. Measurements of scattering of nuclear radiation can be used to determine the moisture content of frozen ground.—From SIPRE 16097.

Ghiglione, A. F., 1951, Problems of icing on roads and airfields: Paper delivered before Am. Soc. Civil Engineers, New York, Oct. 23, 1951.

Icings are common in the permafrost region at springs or seepages exposed by excavation, at drainage facilities where lack of insulation causes ice formation, and at fills where frost dams obstruct subsurface or surface flow. A rainy period before freezeup increases the flow of ground water in winter and causes more numerous and heavier icings. An early heavy snow insulates the ground and tends to minimize ice formation. Prolonged freezing weather with little snow causes considerable icing. A severe winter with long periods of extreme cold freezes back and stops the flow of ground water which causes the seepage icings, but increases the formation of river icings; a mild winter may have the opposite result.

1956, Highways, bridges, and protection from ice damage, *in* The Dynamic North, U.S. Navy, Tech. Assistant to Chief of Naval Operations for Polar Projects (OP–03A3): book 2, table 11, 7 p.

Among the highway maintenance problems are icings, termed "glaciers" by maintenance men. Effluent-seepage icings are formed where ground water emerges at the surface and freezes in winter. River icings, formed where a stream freezes to its bed, are found where the stream flows over permafrost and are largely limited to interior Alaska.

1957, Subarctic highway construction and maintenance: Science in Alaska, Alaskan Sci. Conf., 5th, Anchorage 1954, Proc: p. 16–21.

Permafrost, estimated to underlie 80 percent of Alaska, impedes subsurface drainage and permits formation of a glide plane lubricated by water that favors creep and viscous flow of the active layer over permafrost. Surface icing is commonly associated with permafrost. Icings form where springs and seepages are intercepted by construction work and at places where change in slope forces subsurface water to the surface. Frost dams formed by deep frost penetration beneath roads force water to emerge upslope to form icings, which fill ditches and culverts and overflow the road. In some places as much as 20 ft of ice is built up behind the fences placed between the road and the seepage.

Gibson, Arthur, 1914, Third beach line at Nome, Alaska: Mining and Sci. Press, v. 108, p. 686–688.

The Third beach at Nome is 3 miles north of the town and is buried beneath younger sediments; the pay streak lies at depths of 20–124 ft below the present land surface. Where the pay streak was found intact and the original stratification of the beach deposits preserved, the ground was found to be frozen all the way from the surface to the bedrock, independent of depth. Where the original pay streak has been washed by water in channels, the ground, with a single exception, was unfrozen and waterlogged, requiring heavy timbering and large pumps.

Gladtsin, I. N., 1938, Geomorphological outline of Transbaikal [Geomorfologicheskii ocherk Zabaikal'ia]: Inst. fiz. geog. Trudy, v. 29, p. 117–195.

Permafrost is evident in the region through relief, hillocks, ground water in unusual places, and mounds and small mud volcanoes on the banks of lakes. Mud mounds (puchi) with underground icings as much as 4 m thick and 160 m wide are observed on the slopes; they contain ice blocks 3 m thick which melt into streams flowing through the cracks in the mounds.—From SIPRE U–6552.

Gladtsin, I. N., and Dzens-Litovskii, A. I., 1936, Frost mounds and hydrolaccoliths of the Doronin Lake region [Merzlotny "sal'zy" i gidrolakkolity raiona Doroninskogo sodovogo ozera]: Gos. geog. obshch. Izv., v. 68, no. 4, p. 449–459.

Doronin Soda Lake is located 140 km southwest of Chita in a depression between the Cherskii and IAblonovyi Ranges. Bordering the lake is a terraced and undulating plain 16–18 km wide. There is evidence that the lake was once much larger and that the mineralization of the lake water is due to concentration of the mineral matter of the former large body of water. Smaller soda lakes northeast of Doronin Lake also are remnants of the former large lake. A group of oval fresh-water lakes 5–200 m in diameter lie southwest of Doronin Lake; these lakes, no more than 25–30 m deep, are fed by ground water and are drained by streams. Some of the fresh-water lakes resemble sinkholes (suggesting thermokarst origin) and are bordered by concentric cracks along the shore.

Ground water from above permafrost forms hummocks, marshes, and bogs because of impermeability of the frozen layer. Some hummocks are pingos; others are mud volcanoes 0.45–0.75 m high and 1–2 m in diameter formed of gray hard mud. Openings in the tops of the mud volcanoes are filled with dark fluid mud with black to coffee-colored water. Bubbles of gas, chiefly methane, issue from the craters. The gas originates from slow decomposition of organic matter. A solid bottom of permafrost or lenses of ice lie beneath the cones at depths of 0.5–1.5 m.

Larger hummocks are as much as 4 m high and 10–20 m in diameter and alternately appear and disappear. In some places slightly alkaline water issued from cracks in the hummocks, and on occasion a hummock will burst and water will rise many meters in height, forming a stream which will flow for several hours, and leaving a lake in the top of the hummock. These hummocks, also formed in the bottom of Doronin Lake, are probably formed in winter. Some hummocks may be pierced with a stick, and yellowish-gray mud accompanied by gas will pour out. Temperatures of the mud in the volcanoes taken in July 1929 were 15°C at the surface, 4°C at a depth of 0.2 m, 1.5°C at a depth of 0.5 m, and 0° at 1 m. The formation of hummocks and other features occurs in March and April when active layer and permafrost merge. Even larger mounds (pingos) are 7–8 m high and 40–50 m in diameter. The smaller mounds are apparently related to processes within the active layer, but the large mounds are related to ground water within the permafrost. Similar features are reported from the shores of Selengin Lake.—From unpublished condensation and emendation by I. V. Poiré.

Glazov, N. V., 1936, Certain effects of tectonics and permafrost on ground water [Gidrogeologicheskie osobennosti tektonicheskikh kontaktov i vechnoi merzloty]: Razvedka Nedr, v. 7, no. 21, p. 22–24.

The results of an analysis of the distribution of about 1,000 springs in the southeastern Transbaikal are discussed. The number of springs was found to be considerably greater in areas of fissured bedrock and no pemafrost. Permafrost in the area occurs in valleys and on north slopes, while about 75 percent of the springs studied were found in southwest, southeast, and south slopes.—From SIPRE 10074.

Gokoev, A. G., 1939, Frost mounds and hydrolaccoliths in the Kazakh steppe [O bugrakh vspuchivaniia i gidrolakkolitakh v kazakhskoi stepi]: Vses. geog. obshch. Izv., v. 71, p. 541–546.

Frost mounds 1 m high and 10 m in diameter at the base contain ice lenses at a depth of 0.5 m even in July and August. The ice is overlain by a layer of semiliquid clay. Underground water penetrates into the upper soil layers through fissures and freezes there in winter to cause the heaving that forms the hydrolaccoliths. These conditions are similar to those described by N. I. Tolstikhin for Siberian permafrost.—From SIPRE 9010.

Golab, Josef, 1956, Ice-wedges as ground-water conductors [Kliny zmarzlinowe jako drogi przewodzace wod gruntowych]: Poland, Lodzkie towarzy. nauk., Wydzial 3, sec. 3, Biul. Peryglacjaly 3, p. 61–63. [Translation from Polish by J. Rulikowska, p. 135–137.]

A discussion of the suitability of filled ice-wedge casts for allowing rainwater to infiltrate through relatively impermeable materials to a permeable horizon below.

Goliatin, V. K., 1951, Compilation of the Hydrological Year Books, V. V. Ukhanov, editor [Sostavlenie gidrologicheskikh ezhegodnikov]: Pod red. V. V. Ukhanova, Leningrad, Gidrometeorol. Izd., 223 p.

Textbook for hydrological technical colleges, approved by the Main Administration of Hydrometeorological Service. General information and instructions for securing coordinated data from hydrometeorological posts and stations, and for analysis and preparation of data for inclusion in hydrological yearbooks (Gidrologicheskii ezhegodnik—these have not been seen). Yearbooks of 1945 and later published in new enlarged form; data assembled on standard bases comprise daily information on water levels, ice conditions, air, water, and ground temperatures, ice thickness and that of its snow cover, variation in water flow and discharge, amount of suspended and transported sediments daily, monthly, seasonal and annual average data, physical characteristics of deposits and chemical composition of the water, etc. Nineteen hydrological yearbooks have been published annually, with data for 9 major regions of USSR, including basins of White and Barents Sea, west and east Kara Sea (v. 6–7), Laptev, east Siberian and Chuckhi Seas (v. 8), and basin of Pacific Ocean (v. 9) with the sea of Okhotsk, Bering Straits, and Kamchatka drainage areas.—From Arctic Bibliography 45166.

Gorbatskii, G. V., 1933, Buried glaciers in the Krestovaia Bay area, Novaia Zemliia [Iskopaemye ledniki krestovoi guby na Novoi Zemle]: Arktika, v. 1, p. 41–65.

Relief of the strandflat between Krestovaia Bay and Sul'menevaia Bay is transformed by melting or underground glacier ice. Immediate results of the degradation are the gradual lowering of the water table, and a temporary increase of the ground-water supply fed by melting ice.—From SIPRE U–1659.

1952, Methods for the physiographical study of the Arctic [O putiakh fizikogeograficheskogo izucheniia arkticheskoi sushi v sviazi s ee osnovnymi prirodnymi osobennostiami]: Uchenye Zapiski Leningradskogo Univ., Ser. geog. nauk, no. 152 (8), p. 159–182.

The negative annual heat balance and the presence of permafrost are important factors in physiographical processes in the Arctic. Deep penetration of moisture into the soil is prevented by permafrost which increases the moisture near the surface. Runoff exceeds precipitation in the Arctic and in permafrost zones is two to three times higher than that in neighboring Western Siberia and Kazakhstan.—From SIPRE 7159.

Gordeev, D. I., 1954, Progress of hydrogeology in the USSR [Osnovnye etapy istorii otechestvennoi gidrogeologii]: Akad. Nauk SSSR, Lab. gidrogeol. problem Trudy, v. 7, 382 p.

Historical review of hydrogeological research in Russia from the 17th century, with emphasis on that during the last 40 years. Recent studies on ground water are surveyed (p. 219–224) in relation to permafrost regions (zones of fossil ice, continuous permafrost, permafrost with thawed spaces, and permafrost islands). Railroad construction in Siberia at the end of the 19th century and extensive construction in permafrost areas after 1925 resulted in the development of permafrost study from the engineering viewpoint, and a new science—permafrostology. The Commission (from 1930), Committee (from 1936), and Institute (from 1939) of Permafrostology of the Academy of Sciences of the USSR, numerous permafrost stations, and six All-Union conferences on permafrost during the prewar period aided in the development of the new science.—From SIPRE 13052.

Gorodkov, B. N., 1924, The west-Siberian expedition of the Russian Academy of Sciences and the Russian Geographical Society [Zapadno Sibirskaia Ekspeditsiia Rossiskoi Akademii Nauk i Russkogo Geograficheskogo Obshchestva] : Priroda, v. 13, no. 7, p. 8–32.

In the permafrost region between Surgut on the Ob' River and Taz Bay, the southern boundary of permafrost in areas with abundant ground water is characterized by hillocky tundra with large peat mounds.—From SIPRE 8678.

1928, The geographical distribution of peat bogs with large mounds [Krupnobugristye torfianiki i ikh geograficheskoe rasprostranenie] : Priroda, v. 17, p. 599–601.

The irregular distribution of ground water and snow cover are the principal causes of mound formation in peat. The main factors in mound growth are the thickness of the peat layer and the depth of the permafrost table. Mound size varies directly with active-layer thickness. Large mounds are especially characteristic of sporadic permafrost.—From SIPRE 8741.

Grainge, J. W., 1958, Water and sewer facilities in permafrost regions : Municipal Utilities Mag., v. 96, no. 10, p. 29, 62–67.

Water in permafrost regions may be obtained from wells, rivers, lakes, ice, and the ocean. River water can be exploited by standard methods or with portable pumps where permafrost, unstable soil conditions, or the problem of ice erosion of river banks exist. Water can be obtained from lakes by extending intake pipe out into the lake. It can be obtained from just below the ice of the Arctic Ocean near the mouths of rivers because the fresh river water floats on the heavier salt water.—From SIPRE 16893.

Grave, N. A., 1946, A new hypothesis by Taber on fossil-ice formation [Novaia gipoteza Tabera ob obrazovanii iskopaemykh l'dov] : Merzlotovedenie, v. 1, p. 83–84.

A review of Taber's (1943b) article on origin of ground ice, in which Taber is criticized for rejecting Tyrrell's (1904) hypothesis on the ground-water origin of naledi in the Klondike.—From SIPRE 15895.

1956, Archaeological age of hydrolaccoliths in the Chukotki Peninsula [Ob arkheologicheskoi datirovke vozrasta nekotorykh gidrolakkolitov na Chukotke] : Akad. Nauk SSSR Doklady, v. 106, p. 706–707. [Translated from Russian by E. R. Hope, Canada, Directorate of Defence, Sci. Inf. Service, Defence Research Board, June 1956, Translation T218R.]

Hydrolaccoliths are large isolated mounds formed of peat, fine frozen soil, and pure ice that occur in river valleys and lake depressions. They are seasonal or persistent and are also called pingos or bulgunniakhs. They are formed during the intense deeply penetrating long-continued freezing of the ground that characterizes the early stages of permafrost formation.

A 15- to 20-m high hydrolaccolith on the plain near Chirovoye Lake, on the Anadyr Plateau of Chukotke Peninsula, can be dated. Its lower age limit is equivalent to that of the terrace deposits on which it rests and is Climatic Optimum. The upper age limit is determined from the age of artifacts found in soil that fills cracks on its surface; the artifacts were Yakutian upper Neolithic, or more than 2,000 yr old. Therefore, the hydrolaccolith formed during the cool period that followed the Climatic Optimum.

Still other mounds only 10–12 m high, located downstream near Stalino had craters containing a pond; around the craters and on slopes are angular lumps of sod and earth as much as 0.7 m in diameter. These lumps were overgrown with turf, and their excellent state of preservation suggests that the small mounds are younger that the large hydrolaccolith described above.

Grave, N. A., and **Chernukhov, P. G.,** 1947, Some observations on the permafrost, geology, and hydrogeology in the Khal'mer-IU River region [abs.] [Nekotorye nabliudeniia nad vechnoi merzlotoi, geologiei i gidrogeologiei v raione r. Khal'mer-IU]: Akad. Nauk SSSR, Referaty nauch-issled. rabot, 1945, Moskva 1947, Otdel. geol.-geog. nauk, p. 157.

The discovery of coking coal deposits in the extreme northeastern part of European USSR prompted an investigation of permafrost and hydrogeological conditions existing in the region, and a parallel study of Quaternary formations. Data obtained indicated that the permafrost layer was about 118 m thick, and that the subpermafrost waters were under high pressure. The geological structure of the area was morainic in character with many lakes formed during the peak of the postglacial period.—From SIPRE U-1546.

Green, R. N. *See* Boyle, R. W., 1955.

Greene, G. W., Lachenbruch, A. H., and **Brewer, M. C.,** 1960, Some thermal effects of a roadway on permafrost: U.S. Geol. Survey Prof. Paper 400-B, p. B 141-144.

A larger seasonal range of surface temperature and a proportionately greater range at depth characterize the ground beneath highways as compared to adjacent areas. The depth of seasonal thaw increases and the active layer encroaches on permafrost. The ground beneath the road is more subject to random climatic variations, and deep thaw is accentuated during abnormally warm seasons. If the excess water produced by melting the ice in the surface layers of permafrost can drain off, the thickened active layer will be drier and more easily thawed in later years. This will result in settling of the roadway where the deep thawing occurs. Water will migrate into the thawed trough beneath the road until it is either trapped or can escape. When trapped in a basin, such as a swale or large culvert, the water is refrozen, and frost heaving may be expected.

Greene, G. W. *See also* Lachenbruch, A. G., 1960.

Grigor'ev, A. A., 1946, The Subarctic, an essay on the principal types of its physico-geographic features [Subarktika, opyt kharakteristiki osnovnykh tipov fiziko-geograficheskoi sredy]: Moscow-Leningrad, Akad. Nauk SSSR, Inst. geografii, 172 p.

This general geographic study includes sections on hydrogeomorphic processes (p. 29-45) and formation of pingos and ground ice (p. 111-116).

In the northern Pechora delta a boring 12 m deep failed to locate permafrost beneath the riverbed. The depth to the permafrost table is greater beneath river beds and alluvial-sand terraces than in other types of ground bordering the streams.

Grigor'ev, N. F., 1959, The influence of water bodies on the geocryological conditions in the coastal lowland of the Ust'Yansk region of the Yakutian ASSR [O vliianii vodoemov na geokriologicheskie usloviia primorskoi nizmennosti Ust'Anskogo raiona IAkutskoi ASSR], *in* Materialy po obschemu merzlotovendeniiu: Akad. Nauk SSSR, Inst. Merzlotovedeniia, p. 202-206.

Anomalous geocryological conditions observed near water bodies are discussed. Water temperature measurements reveal that the greatest heat loss occurs when the water freezes. This heat loss increases the mean annual air temperature near the water, affects the thermal regime of the upper permafrost layers, and promotes the formation of taliks under the water. Around lakes which do not freeze to the bottom, anomalous temperature conditions occur, the greatest rise in temperature (4°C) being experienced by permafrost in the immediate vicinity of the water. In certain cases, when the water line moves toward the center as a lake dries, permafrost forms in the areas vacated by the water. Taliks under water bodies are confined to the area covered with water and are limited in depth, depending not so much on size of the water body as on the geological structure of the bottom and the geocryological conditions of the area.—From SIPRE 17943.

Grigo 'ev, N. F., 1960, Geocryological conditions under the lake reservoirs in East Antarctica, *in* Second Continental Expedition 1956–58, Glaciological Investigations, The Soviet Antarctic Expeditions: Arctic and Antarctic Inst., v. 10, p. 318–320. [Russian.]

Gryc, George. *See* Miller, D. J., 1959.

Gurovich, M. A. *See* Zaitsev, I. K., 1956.

Hanson, R. E. *See* Crowley, F. A., 1956.

Hardy, R. M., and D'Appolonia, E., 1946, Permanently frozen ground and foundation design: Eng. Jour., v. 29, no. 1, p. 4–12.

At a repeater station near the intersection of the Alaska Highway and the Alaska-Yukon boundary, permafrost was logged in a well from 2 to 42 ft.

Harrington, G. L., 1918a, The Anvik-Andreafski region, Alaska (including the Marshall district): U.S. Geol. Survey Bull. 683, 70 p.

Near Marshall placer ground on upper Wilson and Disappointment Creeks is 10–12 ft deep. On the lower reaches of Disappointment Creek holes failed to reach bedrock at a depth of 35 ft and were abandoned because of the flow of ground water that entered. Mineral springs of water containing calcium, bicarbonate, and iron and carbon dioxide gas occur 7 miles up the Yukon from Marshall and half a mile from the Willow Creek landing. The springs flow a few quarts per minute and appear to issue at the contact between Quaternary lavas and older greenstone.

1918b, Gold placers of the Anvik-Andreafski region [Alaska]: U.S. Geol. Survey Bull. 662–F, p. 333–349. *See* annotation, Harrington, G. L., 1918a.

1919, The gold and platinum placers of the Kiwalik-Koyuk region [Alaska]: U.S. Geol. Survey Bull. 692–G, p. 369–400.

Fifty feet above the west bank of Spring Creek, a tributary of Sweepstakes Creek, Koyuk River drainage, is a hot spring. The spring rises along the contact between diorite and andesite, carries SO_2 and CO_2 gas and has a temperature of 105°F. The spring is believed fed by meteoric waters descending through joints and fissures on upper slopes of Granite Mountain to a depth where it acquires heat. The water then ascends to emerge as hot springs.

1921, Mineral resources of the Goodnews Bay region [Alaska]: U.S. Geol. Survey Bull. 714–E, p. 207–228.

The creekbed placers of Kowkow, Wattamus, and Bear Creeks are generally unfrozen. Most of the auriferous stream gravel and overburden lies within reach of circulating water in the streams.

Harrington, G. L. *See also* Mertie, J. B., Jr., 1916.

Harwood, T. A., 1955, Geology and physiography of the arctic region of north continental America and Greenland: Canada, Defence Research Board, Arctic Rept. 1/55, 31 p.

A discussion of the origin of patterned ground, pingos, and frost mounds is given. Pingos and frost mounds are formed by freezing of percolating waters between the frozen active layer and permafrost. Freezing leads to an increase in hydrostatic pressure between the active layer and permafrost, and the ground is forced upward at points of local weakness. In permafrost areas overlain by deep silts, such as the Arctic coastal plain of Alaska and certain Canadian Arctic islands, supplies of ground water are difficult to obtain. Subsurface water has been found in unfrozen layers or talik within the permafrost.

Heide, H. E., and **Sanford, R. S.,** 1948, Churn drilling at Cape Mountain tin placer deposits, Seward Peninsula, Alaska: U.S. Bur. Mines Rept. Inv. 4345, 14, p.

Most of the drill holes beneath or near the streambed on lower Cape, Boulder and Village Creeks were in unfrozen ground, but elsewhere were in frozen ground.

Hemstock, R. A., 1952, Permafrost problems in oil development in northern Canada: Canadian Mining and Metall. Bull., v. 45, no. 481, p. 280–283.

Location of reliable supplies of good water is difficult, and such supplies can be obtained from large lakes and rivers and from wells drilled below permafrost or into talik.

Hennion, Frank, 1955, Frost and permafrost definitions: Natl. Research Council, Highway Research Board Bull. 111, p. 107–110.

Henshaw, F. F., 1909a, Mining in the Fairhaven precinct [Seward Peninsula, Alaska]: U.S. Geol. Survey Bull. 379–F, p. 355–369.

Springs at the head of Inmachuk River furnish a constant flow of about 8 cfs. Placer mines in the 7-mile reach of Inmachuk River below the mouth of Pinnell Creek are in a gravel flat in which depth to bedrock is 15–30 ft. The river-channel deposits are thawed to bedrock in summer, and there is a large underflow of ground water which hinders opencut work. In winter the river is filled with ice formed by overflow of water from springs. The Fairhaven ditch leads from Imuruk Lake through the 17-mile upper section across the top of the lava to the divide between Wade Creek and Pinnell River. At the divide the water is dropped into a channel leading to a sinkhole in the lava which is connected by an underground passage to Wade Creek, and is diverted to Pinnell River by the middle section of the ditch. Glacier Creek, 25 miles south of Candle, is fed by springs flowing from limestone and schist bedrock; the springs form an icing as far as 1 mile downstream from the springs during the winter.

1909b, Water-supply investigations in Seward Peninsula [Alaska], 1908; U.S. Geol. Survey Bull. 379–F, p. 370–401.

Some streams in southern Seward Peninsula are regulated by springs in limestone which occur on Hobson, Moonlight, and Canyon Creeks, and Solomon and Grand Central Rivers. Springs in central Seward Peninsula occur in limestone on Glacier Creek (Kiwalik basin) and on upper Inmachuk River and in lava on Kugruk, Pinnell, and Goodhope Rivers. When the channel of Kugruk

River was cut off from Imuruk Lake by construction of the dam for Fairhaven ditch, most of the river discharge came from springs in the lava above the canyon in the summer of 1908; the flow at the mouth of the canyon was 31 cfs.

Henshaw, F. F., 1910a, Mining in Seward Peninsula [Alaska]: U.S. Geol. Survey Bull. 442–I, p. 353–371.

In 1909 experiments were carried out to test artificial freezing as a means of checking the flow of water from unfrozen ground into underground placer mine workings. An ice machine was used in a mine on Bourbon Creek to freeze a barrier of gravel in order to shut off a flow of approximately 0.2 cfs. A steam point driven into the flooded workings of an adjoining claim caused a rush of water into the Bessie Mine (Mining and Sci. Press, 1909). Drill holes were sunk every few inches across the drift in which the water had been encountered, and small ammonia-filled pipes inserted inside the casings. The refrigeration system formed a solid wall of ice across the drift and stopped the flow of water.

In the Council area, drilling on Ophir Creek shows that the streambed is generally unfrozen. The bed of Iron Creek near the Iron Creek-Kruzgamepa River tunnel is wet and unfrozen. Some of the gravel deposits of the Kugruk River flood plain are frozen.

1910b. Water-supply investigations in Seward Peninsula [Alaska] in 1909: U.S. Geol. Survey Bull. 442–I, p. 372–418.

The presence of frozen ground near the surface prevents water from being stored in the ground and causes immediate runoff and rapid fluctuations of river stage. Springs in limestone occur on Glacier Creek, in the Kiwalik basin, on the upper Inmachuk, and in the lava on Kugruk, Pinnell, and Goodhope Rivers. The springs produce a steady flow, and the accumulated ice formed by freezing of winter overflow adds to the water supply during the early summer.

Herrin, Moreland. *See* Lovell, C. W., Jr., 1953.

Hess, F. L., 1906a, The gold placers, *in* Prindle, L. M., and Hess, F. L., The Rampart gold placer region, Alaska: U.S. Geol. Survey Bull. 280, p. 26–50.

"Surficial deposits are always frozen, and the limit of the frozen ground has not yet been reached, but there are channels in the frozen gravels through which water circulates freely at all seasons. Large masses of ground ice often occur in the muck, though none are found in the gravels. The depth of the alluvial deposits sometimes exceeds 100 feet, but it is generally less than one-fifth of that amount * * *. In some cases the presence of water interferes very seriously with the drift mining and renders gravels otherwise workable comparatively valueless." (p. 27). Live water in the creek alluvium has hampered placer mining operations on Hoosier Creek, Ruby Creek, Gold Run, Omega Creek, and Hutlina Creek. "Gophering," or sinking shafts without system, has rendered some of the mining ground on Little Minook Creek practically worthless because the old shafts have filled with water. The water has frozen from the top and sides, but remains liquid for several years in the center of the shaft; thawing of the ice in these old shafts during construction of new workings causes floods.

1906b, The York tin region [Alaska]: U.S. Geol. Survey Bull. 284, p. 145–157.

In the Lost River and Cassiterite Creek area most of the deposits encountered in tunneling for lode tin and in prospecting for placer tin were frozen. However, in a few places water has been encountered in tunnels. A water well

was reported in progress during the 1905 season at Tin City; the prospects for finding water in this region were described as "not hopeless." At Eagle, water was found beneath 50–60 ft of frozen ground, and at Rampart a hole 225 ft deep did not penetrate the frost. In the Nome area some places have no frozen ground, whereas others have more than 100 ft of frost. Because of the shorter season and colder climate at Tin City, the frost probably will be deeper than at Nome.

Hess, F. L. *See also* Collier, A. J., 1908.

Hill, J. M., 1933, Lode deposits of the Fairbanks district [Alaska]: U.S. Geol. Survey Bull. 849–B, p. 29–163.

The ground is frozen to great depth. Certain alluvial deposits are reported frozen to a depth greater than 300 feet below the surface. "Differences in material, however, and in the position of the material with reference to drainage have some extent governed the distribution of frozen ground, and considerable areas of alluvial deposits are unfrozen." (See p. 35.) Ground water circulates within deposits of unfrozen gravel.

The Newsboy mine at an altitude of 1,752 ft on the divide between Cleary and Last Chance Creeks was reopened in 1931; at that time it was necessary to clear ice which had filled the shaft to a depth of 70 ft; below the 160-ft level the shaft was under water in 1931. A well at the mill of the Tolovana Mining Co. at a 1,300-ft elevation on Willow Creek, tributary to Cleary Creek, provided water for the mill in winter. A crosscut tunnel with its mouth at the level of the west fork of Wolf Creek, at elevation 1,500 ft is the lower limit to which mining can be extended without encountering heavy flow of water. The mill of Eva Quartz Mining Co. on Moose Gulch, tributary to Ester Creek, has a well that provides water. A section of the upper tunnel near the entrance of Mohawk Mine on upper St. Patrick Creek was half full of ice when visited in 1931.

Hogbom, Bertil, 1914, On the geologic work of frost [Uber die geologische Bedeutung des Frostes]: Geol. Inst. Upsala Bull., v. 12.

Holmes, G. W., and **Benninghoff, W. S.,** 1957, Terrain study of the army test area, Fort Greely, Alaska: U.S. Geol. Survey, Mil. Geology Br., for U.S. Army Corps of Engineers, Waterways Expt. Sta., Vicksburg, Miss., 2v.

Permafrost beneath the airfield and military base lies at considerable depth. The water table occurs at a depth of 9 ft near the confluence of the Tanana and Delta Rivers, 108 ft at Delta Junction, and at a maximum of 215 ft at Fort Greely. The aquifer is outwash or alluvial gravel. Test pumping at 1,000 gpm was continued at the base for several days with no measurable depression of the water table. Tabulated well data show permafrost in water wells at Bert and Mary's, mile 277.6 Richardson Highway, from 0 to 40 ft; at Fort Greely at well 4, Bldg. 117, from 24 to 88 ft, and from 96 to 108 ft; at well 6, Bldg. 300, from 40 to 118 ft; and at well 8, Bldg. 625, frozen to 217 ft. In each of these wells, water was found beneath the permafrost. In the other wells, as deep as 120 ft along the Richardson Highway and 270 ft on the post, no permafrost was logged.

Hooper, C. L., 1881, Report of the Cruise of the U.S. Revenue Steamer *Corwin* in the Arctic Ocean in 1880: U.S. Treasury Dept.

1884, Cruise of the Revenue Steamer *Corwin* in the Arctic Ocean in 1881: Washington, U.S. Treasury Dept. Doc. 601, p. 79–82.

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Hopewell, H. T., 1945, Asphaltic concrete operations at Big Delta: Pacific Builder and Engineer, v. 51, no. 8, p. 44–45.

During construction of the airstrips at Big Delta, little permanent ground frost was found. Well drilling showed a ground-water level of about 200 ft below the surface. Freezing of water and sewer lines was prevented by construction of 3 x 4-ft utility ducts through which lines were routed underground.

Hopkins, D. M., 1949, Thaw lakes and thaw sinks in the Imuruk Lake area, Seward Peninsula, Alaska: Jour. Geology, v. 57, no. 2, p. 119–131.

Drill-hole data and comparisons with areas having a similar climate indicate that permafrost ranges from 50 to 300 ft in depth. Thawed zones within the deeper part of the permafrost are suggested by occurrence of subsurface drainage; these thawed zones suggest that the deepest part of the permafrost is unstable and is gradually thawing in present climate, and that the present climate is capable of producing only a much smaller thickness of frozen ground than now exists. "Subterranean drainage is possible only if ice is absent from the open spaces which act as drainage channels. Small streams entering the ground during the summer probably are capable of maintaining open channels in rocks in which the temperature remains below freezing throughout the season; with falling discharge in the fall, however, channels in subfreezing zones can be expected to be clogged with ice; when flow ceases, the channel should be completely filled." (See p. 130–131.) Thaw sinks may be used as indicators of the presence of thawed zones in which some ground water may occur.

Hopkins, D. M., Karlstrom, T. N. V., and others, 1955, Permafrost and ground water in Alaska: U.S. Geol. Survey Prof. Paper 264–F, p. 113–146.

Distribution of ground water in Alaska affects and is affected by permafrost distribution. Regional climatic differences result in a transition from thick continuous permafrost in the north to permafrost-free terrain in the south. Local differences in topography, lithology, and drainage cause sharp local differences in the character and distribution of permafrost that tend to obscure the regional zonation. Frozen ground formed during past cold periods persists to the present in many areas, so that the distribution pattern is not exclusively the product of present-day climates. The ancient frozen ground is locally thawing today, and recently frozen ground thaws where the thermal regime is disturbed; thus, both old and modern permafrost are interrupted by horizontal and vertical thawed zones through which water may circulate. Conditions favoring active circulation of water promote thawing of permafrost and retard formation of new permafrost. Thus, potential aquifers are similar in charatcer, but more restricted in size and abundance in permafrost areas than in areas of no permafrost.

On the Arctic Slope (described by R. F. Black) in the continuous permafrost zone, permafrost is 600–1,300 ft thick and generally at least 1,000 ft deep in wells near Barrow. Permafrost is deep or possibly absent under large rivers, such as the Colville and beneath large lakes. Ground water is available only beneath large streams and lakes and from springs. Low-ground temperatures indicate little chance of finding ground water within permafrost. The Shublik Springs emerge at a rate of about 1,000 gpm from the contact between the Lisburne limestone and the overlying Sadlerochit sandstone. Water temperature is 43–48°F, and the springs flow all winter. Sadlerochit Springs are about the same size, but may be warmer. Other much smaller springs are reported on the Sagavanirktok, Shaviovik, and Okpilak Rivers. The floodplain icings on the trunk streams suggest that water continues to flow after fall freezeup; the water may originate in the channel, within the streambed, in terrace gravel, in gravel fill associated with lakes, or from springs in bedrock. Areas upstream from these icings are favorable sites for prospecting for ground water. The Lisburne limestone and Sadlerochit sandstone are the most likely reservoirs of ground water beneath permafrost. Beneath the coastal plain, however, the subpermafrost water probably has a salinity of several thousand parts per million.

On the northern Seward Peninsula (described by D. M. Hopkins) in the continuous permafrost zone, subsurface materials are frozen nearly everywhere except beneath and near lakes, perennial streams, some ocean beaches and hot springs. Permafrost averages 200 ft in thickness and ranges from 15 to more than 260 ft. Unfrozen zones in lava flows of Quaternary age are indicated by springs and closed depressions having interior drainage. Unfrozen zones are more common in mountains because of the insulating effect of past glaciations, steepened thermal gradients due to orogenic heating of rocks at depth, steep slopes, coarse-grained soils and sediments, and more abundant supply of surface water from precipitation and melting snow. Unfrozen zones near and beneath channels of large streams provide the most dependable source of ground water. Flood-plain icings are closely associated with perennial springs or form in reaches where shallow bedrock forces ground water to the surface. Limited supplies may be found in unfrozen zones in terrace and flood-plain gravel in uplands and mountains. Unfrozen zones in alluvial-fan deposits provide large summer water supplies, but small supplies in winter. Small supplies are available from thawed zones beneath lakes. Locally, large springs occur along the young fault zone and may be highly mineralized. Unfrozen crevices, lava tubes, and interstratified flow breccias in basalt and fracture zones and solution cavities in marble are promising sources of ground water in upland and mountain areas.

In the southern Seward Peninsula (described by D. M. Hopkins) in the discontinuous zone, permafrost is a few feet to more than 350 ft thick, but in most places is 100–200 ft thick. Thawed zones are localized by conditions that favor ground-water circulation. Upland and mountain ridges, unlike northern Seward Peninsula, are generally unfrozen, and the thawed zones beneath streams are more extensive. Alluvial fans, ancient beaches, spits, bay bars, young raised-beach deposits, and older gravel deposits near the coast are generally unfrozen, or contain unfrozen zones. Ground water is more widely available in the southern Seward Peninsula than in the northern part because of less extensive permafrost and greater precipitation to the south.

In the Yukon Flats (described by J. R. Williams) the best sources of ground water are the unfrozen gravel beneath beds and slip-off slopes of major streams, beneath some large lakes, and in local unfrozen zones in gravel of the large alluvial fans. Permafrost was encountered by drilling near Fort Yukon near the surface and extended deeper than 89 ft in sand and gravel; it occurs to a depth of 40 ft in an island on the Yukon near Eagle.

The middle Tanana Valley (described by T. L. Péwé) near Fairbanks lies in the discontinuous zone of permafrost. Ground water in the Tanana flood-plain circulates freely below permafrost, though unfrozen channels within and above permafrost, and above permafrost wherever the top of frozen ground lies below the water table. Domestic wells 15–30 ft deep draw water from above or within permafrost and yield as much as 40 gpm; other wells 100–250 ft deep draw water from below permafrost and yield as much as 3,000 gpm with a drawdown of 10–15 ft. On the alluvial plain separating the flood plain from the hills and in valleys of the Yukon-Tanana Upland, wells on lower slopes must penetrate 100–200 ft of permafrost to obtain water. Some of these wells encountered artesian water in aquifers beneath permafrost; one well flowed at the rate of more than 40 gpm. Quality of ground water in the flood plain and in the upland is commonly poor because of high organic and iron content obtained as it percolates through organic deposits. South of the Tanana River the gravel outwash plains are sources of water of good quality. Springs occur at the north end of the outwash plain, and depth to water increases upslope at a rate of 15 ft per mile to a depth of 200 ft halfway to the end moraine.

Ground-water conditions in the discontinuous zone of permafrost in the Upper Kuskokwim Valley (described by A. T. Fernald) are known only at McGrath, where shallow household wells obtain water from sand and gravel in the flood-plain alluvium and from beneath permafrost in older alluvium at depths of 40–50 ft, and at Farewell where the water table is 338 ft beneath the land surface. A deep well at McGrath encountered bedrock at 262 ft. Water level in the wells terminating in unfrozen sediments fluctuates with changes in level of the Kuskokwim River. Ground water is also available beneath flood plains of braided streams, in alluvial-fan deposits, and in outwash deposits on piedmont slopes.

In the Bristol Bay region (described by E. H. Muller) in the sporadic zone of permafrost, frozen ground is limited to silt, glacial till, and fine sand, and occurs most commonly in swampy lowlands. Layers of frozen fine-grained sediments thicker than 10 ft are encountered at depths as great as 175 ft in some wells, interbedded with unfrozen sand and gravel. Ground water throughout the lowlands is available at 100–600 ft, and domestic supplies are available in most places at depths of 5–50 ft. Water in the lowlands is generally under hydrostatic presssure. At Koggiung, 20 miles north of Naknek, an artesian flow of water with 5,800 ppm dissolved solids was encountered at a depth of 600 ft; water at less than 300 ft had a lower mineral content and was potable.

In the Kenai Peninsula (described by T. N. V. Karlstrom) isolated occurrences of relic permafrost are restricted to black spruce islands in bog flats in the northern Kenai lowland.

A map showing the boundaries between the zones of permafrost is superimposed on a map of forest cover in figure 11.

Hopkins, D. M., and **Sigafoos, R. S.,** 1951, Frost action and vegetation patterns on Seward Peninsula, Alaska: U.S. Geol. Survey Bull. 974–C, p. 51–101.

In the northern part of Seward Peninsula perennially frozen ground is 50 to at least 300 ft deep, except near lakes, large streams, and warm springs where it is absent. Intensive frost action in areas of perennially frozen ground produces microrelief features in soil, such as cottongrass tussocks, frost scars, peat rings, tussock rings, and tussock-birch-heath polygons.

Surface runoff is impeded by vegetation, and downward circulation of surface water is prevented by the impermeable soils and the presence of perennially frozen ground at shallow depths. High moisture content of soils is maintained, also, by a low rate of evaporation and the melting of seasonally frozen ground. Moisture content of the soils varies inversely with depth of seasonal thaw and degree of slope. In some places ground water circulates more readily in peat than in the less permeable silty material that lies above the frost table.

Hopkins, D. M. *See also* Péwé, 1958; Sigafoos, R. S., 1952.

Howell, J. V. chm., 1957, Glossary of geology and related sciences: Am. Geol. Inst., NAS–NRC Pub. 501, 325 p.

Hudson, H. B., Jr., ed. *See* Abu-Lughod, J., 1957.

Hutchins, J. P., 1908, Prospecting and mining gold placers in Alaska: U.S. Geol. Survey Bull. 345–A, p. 54–77.

Permanently frozen ground benefits drift mining by eliminating the need for timbering the workings and pumping seepage water. Frozen ground is generally found in the beds of small streams and may be present in irregular patches in the beds of large streams. It is common in river flats adjacent to the riverbeds of streams carrying several hundred cubic feet per second of water. On Seward Peninsula the growth of willows is generally, but not always, an indication of unfrozen ground.

Depth to ground water and distribution and character of perennially frozen ground are of great importance in placer mining, particularly in evaluating the suitability of the ground for dredging.

Hyland, W. L., and **Mellish, M. H.,** 1949, Steam heated conduits—utilidors—protect service pipes from freezing: Civil Eng., v. 19, no. 1, p. 27–29, 73.

Churchill, Manitoba, Canada, obtains its water by way of pipeline from a lake; the subsoil is not suitable for wells. At Fairbanks, Alaska, individual domestic wells are as deep as 200 ft; the sandy and gravelly soil is perennially frozen, but is water-bearing below and between layers of permafrost.

Hyland, W. L., and **Reece, G. M.,** 1951a, Water supplies for army bases in Alaska: New England Water Works Assoc. Jour., v. 65, no. 1, p. 1–16.

Near Fairbanks, shallow lakes and streams, deep freezing in winter, flat terrain, and high suspended load of some streams make development of surface-water supplies impracticable. Adequate supplies of ground water are found below permafrost at depths of 60–180 ft. The water is about 35°F and does not meet the U.S. Public Health Service standards for iron and manganese content. The high iron and manganese content seems characteristic of permafrost regions. Because of the high cost of shipment of dry chemicals, and because base regulations required 0.4 ppm chlorine in the treated water, the chlorine method was found most practicable for removing the iron and manganese and at the same time adding chlorine to the water. Chlorine is applied to the water and is followed by settling and sand filtration.

1951b, Arctic conditions complicate supply problems in Alaska: Water Works Eng., v. 104, p. 378, 414–415. *See* annotation, Hyland, W. L., and Reece, G. M., 1951a.

IAkupov, V. S., 1959, Determination of the thickness of Recent unconsolidated deposits by the vertical electrical sounding method in regions of low-temperature permafrost [Opredelenie moshchnosti sovremennykh rykhlykh otlozhenii metodom vertikal'nogo electricheskogo zondirovaniia v raionakh s mizkoi temperaturnoi mnogoletnemerzlykh porod]: Akad. Nauk SSSR, Inst. Merzlotvedeniia im. V. A. Obrucheva Trudy, v. 15, p. 144–183.

The theory of the method is based on the principle that frozen unconsolidated deposits have a much higher apparent resistance than the original rock. A representative geoelectrical profile through permafrost is described and analyzed mathematically. Examples are given for frozen unconsolidated deposits which are not more than 10 m thick and are lithologically homogeneous along the vertical, for deposits consisting of four strata, and for talik. The influence of sloping and vertical boundary layers and the applicability of the sounding methods to other problems in permafrostology is discussed.—From SIPRE 18239.

Ignatenko, K. Z. *See* Stotsenko, A. V., 1957.

Il'ina, E. V., 1959, Hydrogeology of the Yakutian artesian basin [Gidrogeologiia IAkutskogo artezianskogo basseina]: Leningrad, Vses. neft. nauchn.-issled. geol. Inst., Materialy geologii i neftenosnosti IAkutskoi ASSR, p. 183–233.

Outlines the extent, permafrost conditions, chemical properties of ground waters and gases of the Yukutian artesian basin. Ground waters in the Quaternary, Cretaceous, Jurassic, Silurian, Ordovician, and Cambrian rocks are described, and their chemical characteristics tabulated. Gases are analyzed. Borings in Yakutia are listed, and regionalization of the ground waters is outlined.—From Arctic Bibliography 58824.

Illsley, C. T. *See* Boyle, R. W., 1955.

Iseri, K. T. *See* Langbein, W. B., 1960.

IUganson, V. E., 1951, On the hydrogeologic regions of the USSR [O gidrogeologocheskom raionirovanni SSSR]: Voprosy geografii Sbornik 26, p. 73–79.

IUrev, B. N., 1935, Permafrost [Vechnaia merzlota], *in* IUrev, B. N., Ust'e reki Pechory: Sevgosmoraraokhodstvo, Archangel, p. 118–119.

1938, Fresh ground-water resources in sand layers along the shore of the Barents Sea (O zapasakh presnykh gruntovykh vod v peschanykh fatsiiakh neritovykh formatisii Barentsova moria): Problemy Arkitki, 1938, no. 3, p. 29–41.

Fresh water is obtained in shallow wells near Indiga Bay and on the Kanin Peninsula, and in the form of icings near the Pechora estuary.—From Arctic Bibliography 7855.

Ivanov, K. E., 1958, Variations of the level of ground water in swamps during winter [Kolebaniia urovnei gruntovykh vod na bolotnykh massivakh v zimnii period], *in* Ivanov, K. E., Gidrologiia bolot: Leningrad, Gidrometeorologicheskoe Izd., p. 171–177.

The relation between ground water levels and frost penetration is discussed, and representative data are graphed. Variations in the water table in winter are caused primarily by filtration runoff and depend on frost penetration and thawing. When the water table drops more rapidly than frost penetrates, frost penetration has little effect on water-level variations. If frost penetration is more rapid than the drop of the water table, the freezing and water levels meet; excessive hydrostatic pressure develops under the frozen layer, and water filters under pressure. Pressure filtration continues until the water-table drop rate exceeds the speed of frost-penetration (which tapers off with depth), and the water table is again below the freezing level. The freezing and ground-water regimes are determined by air temperatures, snow-cover depths, swamp microrelief, the initial position of the water table, and thawing periods in winter.—From SIPRE 17244.

Ives, J. D., 1960, Permafrost in central Labrador-Ungava: Jour. Glaciology, v. 3, no. 28, p. 789–790.

Studies by McGill University and Iron Ore Co. of Canada show extensive permafrost south of 55th parallel; its thickness locally exceeds 80 m. Much of the permafrost in the hills above 680 m elevation is not relic, but compatible with the climatic regime of the last few decades. Only thin and patchy permafrost (including some relic masses) separated from seasonally frozen ground by a talik occurs below 680 ft beneath the forest cover, where snow cover is thick. The relic permafrost probably formed after retreat of the glaciers (about 4000 B.C.) and before establishment of the present forest.

Jaillite, W. M., 1947, Permafrost research area: Mil. Engineer, v. 39, p. 375–379.

St. Paul District, Corps of Engineers, U.S. Army drilled two 165-ft dry holes through permafrost at the permafrost research station at Steese Highway and Farmer's Loop Road north of Fairbanks, Alaska. A third well, only 108 ft deep, encountered water under such great hydrostatic pressure that the water rose 3 ft above the land surface and stones as much as 2 in. in diameter were brought to the surface. The drill hole was not cased beyond 6 ft because of the resistance of the frozen ground to casing. When the water began to rise, however, 110 ft of 4-in. well casing was quickly dropped into the hole. But the water began rising along the outside of the casing because of its loose fit in the hole, caused partly by thaw of permafrost during drilling. The flow inside the pipe decreased, while that outside continued to increase until the depth of thaw extended the length of the hole. First a cubic yard of gravel was dumped into the hole, and then 40 sacks of cement grout was pumped down through the casing so it would rise on the outside of the pipe. This stopped the flow on the outside for only a few hours.

Next, a 40,000-gphr capacity pump was connected to the casing, and by continuous pumping the flow on the outside of the casing was stopped. Then, 2 yd of high-early-strength concrete was placed outside the casing and allowed to set. Pumping was relaxed and leakage appeared on the outside of the concrete plug. After pumping was resumed, a short 4-ft section of 6-in. pipe was placed through the concrete beside the casing, and 4 cu yd of concrete was placed around the pipe to form a slab 10 ft square. The pump was stopped and water flowed through the 6-in. pipe with only minor leaks around the edge of the slab. These leaks were patched with driller's mud and cement. By this time the entire flow was moving through the 6-in. pipe, and only by pumping or bailing could water be obtained from the 4-in. casing. Other attempts to grout the hole around the casing were unsuccessful and only sealed off the bottom of the casing. To reopen the casing, it was dynamited at a depth of 90 ft. Soundings were made and it was learned that a large cavity had been melted and washed out. Gravel was then poured through the short 6-in. pipe until it filled the cavity to a point just above the new opening in the 4-in. casing at 90 ft. The rest of the cavity from 90 ft to the surface was filled with concrete through the short 6-in. pipe, and the leakage was stopped. Six cubic yards was required for this. Flow continued from the 4-in. casing but at a much decreased rate.

Jenness, J. L., 1949, Permafrost in Canada: Arctic, v. 2, no. 1, p. 13–27.

The bed of the Mackenzie River near Norman Wells is unfrozen. Wells 100 ft, 200 ft, and 350 ft from the water encountered permafrost thicknesses of 60 ft, 135 ft, and 267 ft, respectively. The beds of Great Bear, Great Slave, and other lakes are unfrozen.

Two theories may account for the presence of an unfrozen zone separating the permafrost from the active layer: (1) that the permafrost below the unfrozen zone is a relic of past harsher climate and that the present climate is not severe enough to form permafrost, and (2) that the unfrozen zone may be a recent aquifer developed on or near the top of permafrost; freezing of the active layer may compress the aquifer, giving rise to hydrostatic pressure that prevents its water from freezing even when its temperature falls below 0°C. The second theory is unlikely because it is hard to imagine that ground water could force its way through already-frozen soil to form such unfrozen zones. However, some unfrozen zones may result from the failure of permafrost to form in aquifers having a high mineral content. A map shows the distribution of permafrost in Canada.

Jenness, J. L., 1952, Erosive forces in the physiography of western Arctic Canada: Geog. Rev., v. 42, no. 2, p. 238–252.

Permafrost provides the impervious base that prevents surface water from seeping into the ground deeper than a few feet, and its presence below the active layer induces a much greater subsurface flow within the active layer than would otherwise take place. Lakes and ponds are fed not only by surface runoff but by large quantities of ground water moving downslope through the active layer. Such a concentration of water near the surface creates a shear or slip plane above permafrost on which the materials in the active layer can move downslope.

Jess, Arthur, 1952, Some aspects of ground-ice control on Alaskan Highways: Alaska Sci. Conf., 3d, Mount McKinley Park 1952, Proc., p. 25–26.

The term "ground-icing" is applied to "surface ice formed during the winter by successive freezing of sheets of water that may seep from the ground, from the river, or from a spring." Pressure of ground water in the active layer, low air temperature, thin snow cover in early winter, proximity of permafrost to the ground surface, and thick snow cover during late winter favor development of icings.

Joesting, H. R., 1941, Magnetometer and direct-current resistivity studies in Alaska: Am. Inst. Mining Metall. Engineers Tech. Pub. 1284, 20 p.

Thick unconsolidated overburden in interior Alaska raises problems in (1) location of buried placers, (2) determination of depth and areal distribution of permanently frozen and thawed unconsolidated deposits, and (3) location of water-bearing beds under unconsolidated deposits. These problems can be attacked by magnetic and direct-current resistivity methods which are not only simple, rapid, and inexpensive, but well suited to the study of the problems. A vertical Schmidt-type magnetometer was used; the direct-current resistivity instrument was similar to those in use by the Geophysics Branch, U.S. Geological Survey.

Determination of depth and areal distribution of permanently frozen and thawed overburden was attempted with the direct-current resistivity method. Some 400 measurements were obtained where conditions were known, and in general the variations in moisture content caused a wide variety in resistivity; below the upper 5 ft moisture variations were less pronounced and the resistivity more uniform. Thawed, moist gravel has higher resistivity than thawed silt. Water-bearing gravel has higher resistivity than moist gravel, probably because there is a lower concentration of salts in materials with unrestricted circulation of water, and because the moist gravel appears to have a higher silt content than water-bearing gravel. The resistivities of frozen unconsolidated deposits are higher than the same materials in the thawed state, and traverses using the direct-current method can distinguish the areal distribution of permanently frozen ground, whereas depth profiles can show its approximate depth.

Investigations of ground water are practicable near Fairbanks, where within the thick silt and gravel deposits the gravel is more likely to be thawed (and water-bearing) than the silt. The resistivity traverse offers a rapid means of locating thawed areas within areas of frozen ground like that near Fairbanks, and the depth profile can be used for locating water under frozen deposits by determining the depth at which thawed ground is encountered. Locating ground water within entirely thawed ground by the direct-current resistivity method is more difficult because of the smaller difference in resistivity caused by differences in moisture content, compared to the difference between thawed and frozen ground.

1954, Geophysical exploration in Alaska: Arctic, v. 7, nos. 3 and 4, p. 165–175.

Early geophysical exploratory work on permafrost problems was conducted in the Fairbanks gold placer mining district by U.S. Smelting, Refining & Mining Co. Electrical resistivity and potential-drop-ratio methods used in 1933 to determine areas of permafrost and thickness of unconsolidated material over bedrock were not successful because of the complex stratigraphy and permafrost relations of the partly frozen overburden. In 1938 the company engaged L. D. Leet and H. G. Taylor to make experimental seismic refraction surveys; results showed that the schist bedrock could not be mapped because seismic velocities in the frozen gravel were almost at high as in bedrock, and bedrock underlying frozen muck could not be mapped because of variations in velocities in the rock and in the muck.

Later studies by United Geophysical Co. in Arctic, Alaska, showed that velocities in continuous permafrost range between 8,000 fps in frozen alluvium to 13,500 fps in frozen Tertiary sediments, and that vertical velocities are slowest. Barnes in studies at Fairbanks showed horizontal velocities in frozen alluvium to be comparatively high (7,000–13,000 fps) and that a high seismic velocity is almost a sure sign of frozen ground and can be misinterpreted as bedrock. Frozen alluvium was found markedly anisotropic to propagation of seismic waves. Resistivity studies by Matthews and Joesting showed that resistivity of frozen rocks is higher than that of comparable thawed material; the methods were generally not satisfactory in determining depth to bedrock in discontinuous permafrost, but the contrast in resistivity between frozen and unfrozen unconsolidated deposits could facilitate the search for ground water. Swartz and Shepard, working in 1944 in Northway, Fairbanks, and Galena, found that the top of permafrost could be determined by both seismic and resistivity methods and that areas of frozen and thawed ground also could be distinguished; however, the bottom of permafrost could be determined by resistivity and not by seismic refraction. Ice lenses could be indicated by the resistivity method. Further resistivity studies by Swartz at Fairbanks in 1948 substantiated earlier conclusions. MacCarthy and others in 1952 made a study of electrical and seismic methods in the search for ground water in permafrost regions.

In 1953, U.S. Air Force Cambridge Research Center studied the thickness of continuous permafrost along Farmers Loop Road near Fairbanks by measuring the frequency dispersion of flexural waves propagated through the permafrost.

Geothermal studies in permafrost in northern Alaska were begun in 1949 by the Geological Survey; they have been made also by Boston University near Umiat and in the Fairbanks area by the Corps of Engineers and U.S. Geological Survey.

Johnston, G. H. *See* Pihlainen, J. A., 1956.

Johnston, P. M. *See* Cederstrom, D. J., 1953.

Johnston, W. A., 1930, Frozen ground in the glaciated parts of northern Canada: Royal Soc. Canada Trans., ser. 3, v. 24, pt. 1, sec. 4, p. 31–40.

A summary of observations of permafrost that are scattered through the literature. A shaft on Eldorado Creek, Klondike district, was stopped by running water beneath permafrost at a depth of over 200 ft. Creek gravel along Burwash Creek, Kluane district, is frozen only in winter, and at most places it is unfrozen all year below a depth of 10 ft. In the upper White River valley near the Alaska border, water was encountered beneath 90 ft of permafrost. Wells along the Mackenzie River are described, including one at Fort Simpson that passed through frozen ground between 5 and 40 ft. Borings at Churchill, Manitoba, are described; the deepest was 230 ft deep and was located 1,000 ft southeast of Lake Rosabelle; pockets of water occurred at 32.5 ft and from 95.8 ft to bedrock, but ice occurred in cracks in the bedrock. Two borings were made in the bed of Lake Rosabelle; in both holes frozen ground was encountered beneath the lake at depths of 42 and 111 ft.

Judd, W. R. *See* Krynine, D. P.

Kachadoorian, Reuben, and others, 1959, Geology of the Ogotoruk Creek area, northwestern Alaska: U.S. Geol. Survey open-file report, 43 p. (TEM–976).

Permafrost table is believed to be 10 ft deep in bedrock areas and 15–25 ft deep in modern beach deposits. Permafrost is absent beneath the Chukchi Sea beyond 200 ft from shore; near shore it is of unknown thickness and extent. Thickness of permafrost on shore is estimated at 500 to 800 ft, and locally permafrost may include pockets of unfrozen brine with temperatures below 32°F.

Kachurin, S. P., 1938a, Permafrost and geomorphological observations at the mouth of the Aanadyr River in 1935 [Merzlotnye i geomorfologicheskie nabliudeniia v ust'e reki Anadyr v 1935 g.]: Akad. Nauk SSSR, Kom. vechnoi merzloty Trudy, v. 6, p. 3–61.

Continuous permafrost over 100 m thick beneath an active layer 50 to 60 cm thick was found in the area. Temperature of permafrost was —4° to —5°C at 5 to 6 m. Thermokarst features and hummocks formed by water under hydrostatic pressure are common.—From SIPRE U–1785; condensation and emendation by I. V. Poiré, 1949.

1938b, Frozen ground recede: Akad. Nauk SSSR Comptes rendus (Doklady), new ser., c. 19, no. 8, p. 595–599. [English.]

Borings were made at Old Turukhansk on the Yenisei to reexamine the site of Middendorf's 1843 soil-temperature measurements. In two holes drilled through alluvial clay and sand, ground water appeared at depths of 7 m and 16 m. Soil temperatures were 0.3°–0.4°C higher than 1843, and in one hole frozen ground, reported in 1843, was not present in 1937. Air rushed into one bore hole, making a sound audible at a distance of 25–30 m; melting of ground ice is believed to have left a partial vaccum (due to volume change on melting) that was preserved by underlying permafrost and overlying impermeable clay.

1946, Origin of the most common types of ground ice in the northern regions [O genezise nailolee rasprostranennykh iskopaemykh l'dov severa]: Akad. Nauk SSSR, Inst. Merzlotovedeniia im V. A. Obrucheva, 38 p.

Types of ice in permafrost include small grains and layers, small to large ice lenses and layers, and vein ice, naled' ice, and lake ice. Although, in a few instances, ground ice may be a buried remnant formed in a remote geologic epoch, most of it was formed in place in recent geologic time. Conditions favoring formation of ground ice are (1) a gently sloping or horizontal plain, (2) a cover of peat moss, (3) a thin active layer, and (4) a supersaturated active layer. Under these conditions a wedge of slud (mixture of mud and water) may become lodged between the active layer and permafrost. In the fall during freezing there is rearrangement of soil particles due to migration of water, formation of cracks, and swelling of the ground; thus the active layer is increased in thickness, and the period required for complete freezing of the active layer down to permafrost is longer than before. A lens of supersaturated ground is formed as freezing of the active layer approaches permafrost, and a lens or layer of ice is formed at the base of the highly supersaturated lens between the active layer and permafrost.

Duration of the freezing period is important, for the longer the period, the more ice is formed. After the active layer reaches permafrost, the thickness of the active layer becomes greater because of the 9 percent expansion of water in forming the ice lens, and the following year this increase in thickness will result in an incomplete thawing of the former active layer. Under favorable conditions repetition of this process from year to year may build up a thick continuous ice layer between the active layer and the former top of the permafrost.—From unpublished condensation and emendation by I. V. Poiré, 1949.

Kachurin, S. P. *See also* Efimov, A. I., 1947; Sumgin, M. I., and others, 1940.

Kalabin, A. I., 1958a, Permafrost and ground waters of the Arkagalinskiy district [Vechnaia merzlota i podzemnye vody Arkagalinskogo raiona]: Magadan, Vses. nauchn.-issled. inst. zolota i redkikh metallov Trudy, v. 7, Merzlotovedenie, no, 1, p. 1–16.

Tabulation of data and diagrams on the permafrost regime and hydrogeologic conditions of the coal-bearing region 750 km northwest of Magadan. The average yearly temperature is —13°C, and the ground is continuously frozen. Exploratory borings for coal were used for study of permafrost. The thickness of permafrost, its upper and lower limits, temperature regime within frozen rocks, its variation according to month and depth, and other data are reported. Ground water above and below the permafrost is described.—From Arctic Bibliography 59015.

1958b, Permafrost and hydrogeology of northeastern USSR [Vechnaia merzlota i gidrogeologiia Severo-Vostoka SSSR]: Magadan Vses, nauchu.-issled. inst. zolota i redkikh metallov Trudy, v. 7, Merzlotovedenie, no. 7, p. 1–52.

A summary of a doctoral dissertation describing field work and previously-collected data in the area east of the Lena River, including the Yana-Chukotka mountain region, Koryak-Kamchatka mountain region, East Siberian lowland Kolyma and Anadyr-Penzhinskaya depressions. The origin, development, thickness, and temperature regime of the permafrost, and characteristics of the active layer are outlined. Ground-water occurrence above and below permafrost, water balance, seasonal runoff, and mineral springs are described. Includes a plan of the hydrogeologic regions and a permafrost-hydrogeologic map at 1:5,000,000.—From Arctic Bibliography 59014.

1958c, Ground waters of northeastern USSR [Podzemnye vody Severo-Vostoka SSSR], *in* Magadanskaia oblastnaia tipografiia upravleniia kul'tury: Magadan, Vses. nauchn.-issled. inst. zolota i redkikh metallov Trudy, Merzlotovedenie, no. 9, 86 p.

According to geostructural, geomporphic, and geologic-lithologic conditions the ground water is distinguished as to location above, within, or below permafrost. Occurrence, source, circulation, passageways, and other features of underground waters are discussed.—From Arctic Bibliography 59013.

1958d, Springs and icing mounds of ground water in northeastern USSR [Istochniki i naledi podzemnykh vod na Severo-Vostoke SSSR]: Magadan, Vses. nauchn.-issled. inst. zolota i redkikh metallov, Trudy v. 7, Merzlotovedenie, no. 7, p. 10–32.

Various types of springs developed from ground water above and within the permafrost layer are described, and their discharge, composition, and tem-

perature are noted. Icing mounds are classified according to their source of supply, their form, structure, and size. Examples from the Yana, Indigirka, Kolyma, and Iul'tina (Chukotka) basins are given. Methods are suggested for prevention of icing mounds.—From Arctic Bibliography 59011.

Kalatin, N. N., 1930, The role of actinometry in the solution of permafrost problems: Akad. Nauk SSSR, Materialy Kom. izuch. estestvennykh proizvod itel'nykh sil SSSR, no. 80, Sbornik "Vechnaia Merzlota," p. 201–231. [Russian.]

Kalesnik, S. V., 1937, The Pamirs (Pamir): Vestnik Znaniia, v. 35, no. 6, p. 40–45.

A layer of permafrost 3.5 m thick is reported at the bottom of Lake Kara Kul.—From SIPRE 15354.

Kaliaev, A. V., 1947, Anabiosis under permafrost conditions: Mikrobiologiia, v. 16, no. 2, p. 121–125.

Kamenskii, G. N., 1947, Hydrogeological investigations of the sources of water supply under permafrost conditions [Osobennosti gidrogeologicheskogo issledovaniia istochnikov vodosnabzheniia v usloviiakh vechnoi merzloty], chap. 6, p. 196–201 and p. 281–283, *of* Kamenskii, G. N., Poiski i razvedka podzemnykh vod: Moscow-Leningrad, Gosgeolizdat, 313 p.

Prospect drilling for water in ground having negative temperatures is complicated by freezing of the drilling tools in the hole; this problem can be eliminated by using heated water, steam, and brine solutions during drilling. Systematic measurement of temperatures should be made during drilling, either with slow-recording or electric thermometers, in order to determine the depth of the lower boundary of permafrost and the presence of talik, as shown by positive temperatures. Test-pumping experiments are made to determine the efficiency and reserves of ground-water reservoirs.

Of the various types of suprapermafrost water, that confined in thick alluvial deposits which do not completely freeze in winter is of significance. Yield of suprapermafrost waters is subject to fluctuation throughout the year, and the maximum and minimum yield must be determined by research work. Determination of maximum production is made during the summer when thawing is at its maximum; pumping is done by using the "Tim method" (Thiem?) in conjunction with calculations of the distribution of flow, or by practical exploration methods of interaction of drill holes. In summer, it is important to consider influence of surface water on productivity of aquifers, especially those connected hydraulically with rivers. Determination of minimum flow is made during the maximum freezing period in late winter when the weak suprapermafrost supplies freeze; even the better aquifers are reduced to a minimum. Test pumping in this case must be prolonged 10 to 15 days, or even 1 to 2 months. Under these conditions recharge of the aquifer is stopped and the reserves diminished. The estimate of reserves should not be based solely on the natural distribution of flow, but on the measure of temporary reserves that are recharged during the period of summer thawing. Methods of test pumping of suprapermafrost waters for productivity are the same as for artesian waters and shallow aquifers. Investigations are recommended of icings and hydrolaccoliths originating from subpermafrost and suprapermafrost waters. The flow of water that forms icings can be determined by measurements of the volume of ice. Information on the thickness of permafrost is given, and the increase in temperature is cited as 1°C per 100 m depth in permafrost regions.

Mining operations are commonly facilitated by permafrost which maintains stability. However, in the Amderma region, the mines are infiltrated by salt water which has a temperature of —5°C near the surface. The permafrost layer, about 400 m thick, has a temperature of —4.8°C at a depth of 215 m. Comparison of chemical analyses of sea water and water from mines near the coastline shows that salt water will penetrate permafrost layers and hamper mining operations.—From unpublished partial translation by W. Korol-Perfiliew: SIPRE U–4752, U–4753.

1949, Ground-water zones and soil geography [Zonal'nost gruntovykh vod i pochvenno-geograficheskie zony]: Lab. gidrogeol. problem Trudy. v. 6, p. 5–21.

The effects of physiography on the phsyicochemical properties of ground water are discussed, and investigations of the problem are reviewed. Four zones of ground water are distinguished in the USSR. Ground temperature is the most important influence on the chemistry and distribution of ground water. An interrupted cycle of ground-water influx and run-off is observed in zones of permafrost. Mineralization of ground water in the permafrost zone increases to the south. Seasonal interruption of ground water influx and a lower winter level of run-off without complete stoppage occur in zones of seasonal soil freezing. Soil and ground-water salinity is observed in warm climates, where the processes of ground-water exchange continue throughout the year.—From SIPRE 9031.

Kamenskii, G. N., Klimentov, P. P., and Ovchinnikov, A. M., 1953, Hydrogeology of the sites of mineral resources [Gidrogeologiia mestorozhdenii poleznykh iskopaemykh]: Moscow, Gos. Izd., Geologicheskoi literatury, 355 p.

A monographic study of the hydrogeology of mining districts and oil and gas fields; includes chapters on ground-water conditions in various types of terrain, the composition of the ground waters associated with different types of mineral deposits, and the role of ground waters in mineral exploration.—Geol. Soc. America, Bibliography and Index of Geology Exclusive of North America, v. 20, p. 267.

Kamenskii, G. N., and others, 1938, Regimen of ground waters [Rezhim podzemnykh vod]: Moscow-Leningrad, Glavnaia Pedak. Stroitel'. Lit., 192 p., 111 figs.

A study of the regimen of ground waters, including discussion of theoretical investigations, the influence of meteorological factors, ground waters in coastal regions, and artesian waters.—Geol. Soc. America, Bibliography and Index of Geology Exclusive of North America, v. 13, p. 137.

Kamenskii, G. N., Tolstikhina, M. M., and Tolstikhin, N. I., 1959, Hydrogeology of the USSR [Gidrogeologiia SSSR]: Moscow, Gos. nauchn.-tekhn. Izd., Literatury po geologii i okhrane nedr, 336 p.

Kammerikh, A. O., 1958, Ice conditions in rivers [Ledovyi rezhim rek]: Priroda, v. 47, no. 1, p. 128.

Solid freezing of rivers as well as congelation of ground water cause the appearance of unusually large icings as thick as 5 m in northeastern Siberia.—From SIPRE 16320.

Kapterev, P. N., 1936, Permafrost and its control [Vechnaia merzlota i bor'ba s nei]: Nauka i Zhizn', v. 3, no. 11, p. 30–35.

The formation of ground ice and river icings is analyzed and their effects on structures are discussed.—From SIPRE 10113.

Kapterev, P. N., 1947, Anabiosis in permafrost [Anabiose im ewigen Eise]: Deutsche Gesundheitwesen, v. 2, p. 517.

Bacteria, algae, and larger marine organisms were revived after several thousand years in frozen mud layers in eastern Siberia. The material was obtained from depths to 41 m. The organisms did not differ from existing ones. Possible revival of pathogenic micro-organisms in corpses buried in frozen soil is suggested. Deep-soil thawing may cause ground-water pollution.

Karlstrom, T. N. V. *See* Hopkins, D. M., 1955.

Kats, N. IA., 1937, Swamp types and their distribution over European Russia [Tipy bolot i ikh razmeshchenie na territorii Evropeiskoi chasti SSSR]: Zemlevedenie, v. 39, p. 388–456.

Peat mounds as high as 3–4 m and 15 m or more in diameter contain frozen ground and ice in the *Sphagnum* swamps. The mounds form under hydrostatic pressure over permafrost strata, and the spaces between the mounds thaw completely near the end of the summer.—From SIPRE 12227.

Katz, F. J., 1910, Gold placers of the Mulchatna [Alaska]: U.S. Geol. Survey Bull. 442–E, p. 201–202.

Bedrock on the Mulchatna River upstream from Koktalee has not been prospected because of ground water in the deposits. Gravel deposits are 4 to 16 ft thick. Up to 1909 no permanent frost was reported.

Katz, F. J. *See also* Martin, G. C., 1912; Prindle, L. M., 1909.

Kellogg, C. E., and **Nygard, I. J.**, 1951, Exploratory study of the principal soil groups of Alaska: U.S. Dept. Agriculture, Agr. Mon. 7, 138 p.

Permafrost restricts drainage of water into the soil, and as a result the zone above the permafrost table is generally wet. During the freezing the wet soil above permafrost may be subjected to pressure, and frost mounds and blisters may form at the surface.

Kelsey, S. T., Jr., 1945, Naknek [Alaska] airport construction on Bering Sea: Pacific Builder and Engineer, v. 51, no. 9, p. 60–62.

Predominant soil encountered was washed sand which lies on dense clay and boulder hardpan. The only permanently frozen ground was north of the north end of the north-south runway. Ground-water level was near the clay hardpan, and as much as 7 ft of clay had to be removed below grade where ground water was prevalent.

Keränen, J., 1923, On frozen ground in Finland [Uber den bodenfrost in Finland]: Helsinki, 57 p.; Langnas A., 1950, English abstract of German text: SIPRE files, 8 p.

Data are presented on average temperature and snow conditions from 1891–1920, the depth of frozen ground in 280 districts grouped according to 12 regions, the thawing of frozen ground, and sporadic permafrost. Permafrost phenomena in Lapland and southern Finland, and the effects of frozen soil on agricultural conditions are discussed.—From SIPRE U–3157.

Kerns, W. H. *See* Rutledge, F. A., 1953.

Keso, Lauri, 1941, Freezing of ground water [Maavesien jäätymisestä]: *in* Maavesistä: Maataloustieteellinen Aikakauskirja. v. 13, p. 187–188.

The type of soil fineness of the soil grain, the amount and depth of the ground water, and the rate of freezing of the ground water influence the forma-

tion of various types of ice wedges. Water at a temperature of 0°C freezes under the pressure of 1 kg per cm^2. Increasing pressure decreases the freezing temperature of water until the freezing temperature reaches —22°C under the pressure of 2115 kg per cm^2. Further increase in the pressure increases the freezing temperature until it reaches 0°C at about 1 atmosphere of pressure and at lower temperature and increased pressure. Homogeneous, massive ground ice originates in saturated, sandy soils where the ground water reaches to the surface. Heterogeneous, striped layers of ice, the size of which varies greatly, form in the saturated silt, clay, or silty clay soils.—From SIPRE U-2429.

Khakimov, Kh. R., 1957, Calculating the effects of percolating water on the freezing of sandy soils [Uchet vliianiia fil'tratsionnogo potoka na promerzanie peskov]: Nauchn.-issled. inst. osnovanii i podzemnykh sooruzheni Sbornik, v. 31, p. 33–56.

The effects of percolation speed on the freezing of sand are mathematically analyzed taking into account the thermal characteristics of the sand and their variations associated with ice formation. The accuracy of suggested methods of evaluating the problem are discussed, and experimental data on artificial sand freezing are used to determine the critical speed of water percolation in sandy soils of various compositions.—From SIPRE 16732.

Khomentovskii, A. S., and others, 1935, Contributions to the question of salt contents in springs and lakes of east Siberia: Glavnoe Geol.-Geod. Upra., Materialy geol. polez. iskop. Vostochnoi Sibiri, v. 6, 116 p.

Papers by A. S. Khomentovskii, N. B. Makarov, B. N. Rozhkov, I. N. Gladtsin, E. S. Bobin, and N. I. Tolstikhin.

Khomichevskaia, L. S., 1940, Hydrological conditions of the suprapermafrost horizon in the upper Zei River region [Gidrologicheskie usloviia nadmerzlotnogo gorizonta v raione verkhnego techeniia r. Zei]: Akad. Nauk SSSR, Kom. vechnoi merzlote Trudy, v. 9, p. 135–154.

Permafrost of the Zei region is an impervious zone at an average of 0.95 m below the surface, which increases the amount of ground water in the suprapermafrost layer. The suprapermafrost layer is often supersaturated throughout the year. Marshy vegetation is present in the lowlands and along the slopes of water divides. The water supply of the suprapermafrost layer is inadequate for consumption because it freezes during the winter and frequently evaporates during the short hot summers. Buildings foundations and roads may be damaged or destroyed by the frost action of permafrost areas when the soil is composed of clay, loam, and sand particles smaller than 0.55 mm in diameter. Sandy soils having grain particles 0.5 mm or larger in size are adequate for construction purposes when located along well-drained slopes.—From SIPRE U-1803.

1955. The concept of "active layer" in permanently frozen rock areas [O poniatti "deiatel'nyi sloi" v oblasti rasprostranenia mnogoletnemerzlykh gornykh porod]: Akad. Nauk SSSR, Inst. Merzlotovedeniia, Materialy k osnovam ucheniia o merzlykh zonakh zemnoi kory, v. 2, p. 45–51.

Ambiguities in the use of the term "active layer" are noted. The use of the terms "seasonal freezing" and "thawing" is suggested. The active layer applies to the ground layer affected by winter freezing or summer thawing and also to those layers subject to annual variations in temperature. The term is sometimes

applied to all strata located above the permafrost layer. Separate terms are recommended for all these processes and conditions.—From SIPRE 13731.

Kindle, E. M., 1920, Arrival and departure of winter conditions in the Mackenzie River basin: Geog. Rev., v. 10, no. 6, p. 396.

A well at Fort Simpson at the confluence of the Liard and Mackenzie Rivers encountered frozen ground from a depth of 5 ft to 40 ft.

Klimentov, P. P. *See* Kamenskii, 1953.

Kojinov, V. E., 1935, Russian water supply system in areas where the ground is perpetually frozen: Water Works Eng., v. 88, p. 1234–1237.

Permafrost and cold climate in nearly half of the Soviet Union cause the following difficulties with water systems: (1) ground water is found in smaller amounts than in temperate regions; (2) many rivers freeze to the bottom in winter or are of unsuitable quality as a water supply; (3) water pipes laid in frozen ground are subject to freezing; (4) water works buildings are subject to differential settlement and heaving caused by thaw of permafrost and frost action; (5) preheating is required before distributing the water. Water sources above permafrost are generally undependable in late winter, but are locally developed by stone wells or galleries. Artesian wells through permafrost tend to freeze and often require warming by steam.

Kolesnikov, A. G., 1953, Temperature variations in a water reservoir during winter [Khod temperatury vody v vodokhranilishche v zimnii period]: Akad. Nauk SSSR Doklady, new ser., v. 92, p. 37–40.

The processes of thermal exchange between water and ground during the period of ice cover formation and during winter are analyzed. The temperature distribution in the ground may be calculated from data on water temperatures in the summer and the time interval between maximum water temperature and reservoir freezing.—From SIPRE 7028.

Kolesov, G. G., and **Potapov, S. G.,** 1937, On permafrost [O vechnoi merzlote], *in* Kolesov, G. G., and Potapov, S. G., Sovetskaia IAkutiia: Moscow, Gos. Sotsialist.-Ekon. Izd., p. 36–38.

Yakut ASSR lies within the region of continuous permafrost. The areas along the rivers are dotted with surface icings or naledi. The Nakharansk naled, 3–4 m thick, covers an area of about 100 sq km. A total of 117 maledi developed along a 728-km stretch of the Amur-Iakutsk railroad during the winter of 1927–28; some were serious enough to disrupt traffic.—From SIPRE U–3583.

Koloskov, P. I., 1932, An attempt at classification of the objects of the cryosphere [Opyt klassifikatsii obiektov kriosfery]: Akad. Nauk SSSR, Kom. izuch. vechnoi merzloty Trudy, v. 1, p. 51–54.

The cryosphere is divided into (1) permafrost of the soil, (2) permafrost of the high mountain regions, and (3) permafrost of sea waters. Maintenance of a temperature of 0°C or less for at least 2 yr or more is a common characteristic of all three types. Further scientific classification is given, and the establishment of a uniform nomenclature for permafrost is suggested.

1937, Natural conditions of water vapor condensation in the ground (Priordnye usloviia vnutripochvennoi kondensatsii atmosfernykh parov): Promlemy fiz. geografii, v. p. 169–202.

Vapor condensation in the ground under various temperature and cover conditions, particularly in permafrost zones, was investigated, and theories explain-

ing the development of the process are discussed. Recent data on distribution of temperature and water vapor near the ground, within the vegetation cover, and in the upper soil layers are inadequate, and further investigations are required. Intense condensation of water vapor in the ground was observed in areas of permafrost and deep seasonal freezing where there was low moisture content near the surface in summer due to moisture migration to the frozen strata. Water condensed in the active layer could not penetrate deeply because the frozen layers were impervious to water.—From SIPRE 14171.

Kolosov, D. M., 1938a, Geomorphological sketch of the western part of the Verkhoyansk region [Geomorfologicheskii ocherk zapadnogo Verkhoian'ia]: Vses. inst. mineral'n. Syr'ia Trudy, v. 116, p. 75–99.

Soil structure and relief in the western Verkhoyansk area depend greatly on the severe climate and on permafrost, which occurs everywhere at depths ranging from 0.8 m in foothills to 0.2–0.3 m on the main divide. Permafrost limits vegetation and causes intense water vapor condensation in the cold suprapermafrost ground. Frozen strata impervious to water produce swamping over large areas. Deep-soil freezing and solidly frozen rivers are among the requirements for formation of river and ground naleds, which cover up to 20 percent of several river valleys and cause intense erosion of riverbanks.—From SIPRE 14370.

——— 1938b, Icings (naledi) and geomorphological processes [O nalednykh iavleniiakh kak geomorfologicheskom protsesse]: Problemy fiz. geografii, v. 6, p. 125–134.

The geomorphological factors in naled formation in northeastern Siberia are discussed. Regularities in the occurrence of naleds in the same location are explained by a close relationship between naled formation and the valley structure. Strong erosive forces at the edge of the naleds are due to temperature changes. Canyons and tunnels formed in naleds during the summer melting period gradually deform river beds. The gradual development of icing valley sections is schematically illustrated.—From SIPRE 7532.

Koridalin, E. A., 1934, The possibility of applying seismic investigations to the study of permafrost [O vozmozhnosti primeneniia seismicheskikh issledovanii k izucheniiu vechnoi merzloty]: Akad. Nauk SSSR, Kom. izuch. vechnoi merzloty Trudy, v. 3, p. 13–19.

Seismic methods, analogous to those used in geologic research, were attempted in the study of subterranean relief and the geologic structure of permafrost because these procedures were cheaper and quicker than drilling. It was assumed that permafrost would offer no particular difficulties in seismic investigation. Indications are, however, that more knowledge is needed for studying permafrost soils consisting of many layers. It is possible that the theory of auto vibrations of the layers and that of stationary waves could be applied. A brief theoretical background and description of the apparatus are given.—From SIPRE U-384.

Korol, Nestor, 1955, Agriculture in the zone of perpetual frost: Science, v. 122, no. 3172, p. 680–682.

The presence of impermeable frozen ground at depth tends to oversaturate the soil; uneven freezing of such soils may cause bulgunniakhs (icing mounds) as high as several meters. Shallow rivers and lakes freeze to the bottom. Where large amounts of deep ground water reach the surface immense ice fields, mounds, and hills are formed, covering hundreds of square km.

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Kosmachev, K. P., 1953, Pingos (Bulgunniakhi): Priroda, v. 42, no. 11, p. 111–112. [Privately translated by Terence Armstrong, Scott Polar Research Inst., Cambridge, England.]

The large icing mounds of Yakutia are described and their origin is discussed. A hypothesis of archaeologists that the mounds were ancient tombs stimulated investigations of their structure. "Bulgunniakh" is a name widely used in northeastern Siberia for large icing mounds, which reach 40 m or more in diameter and 20–30 m in height in Yakutia. These mounds occur in clay and sand loam, and are associated with permafrost. Hydraulic pressure induced by ground-water freezing causes frost heaving of the ground, an initial stage of icing-mound formation. Bulgunniakhs in Yakutia are thought to be many centuries old.—From SIPRE 11742.

Kozin, K. P., 1936, Electrical prospecting in regions with permanently frozen ground: Biull. neftianoi geofiziki 3, p. 31–43, Moscow.

The problem of applying the resistivity and natural current measurements in permanently frozen ground is discussed. Laboratory experiments revealed that rocks affected by permanent freezing still possessed electrical conductivity. Explanation of this phenomenon as well as that of generation of electrodynamic forces in the areas on which a degree of freezing is observed are given. The conclusion is drawn that both the above-mentioned methods may be successfully applied to the solution of some problems connected with hydrogeology, engineering, and economic geology.—Author's abstract, *in* U.S. Geol. Survey Bull. 909, Geophys. Abs. 4508, p. 129, 1938.

Koz'min, N. M., 1892, Permafrost in several areas of eastern Siberia [O iavleniiakh vechnoi merzloty v nekotorykh miestmostiakh Vostochnoi Sibiri]: Irkutsk, Vostochno-Sibirskogo Otdel. Russkogo geog. obshch. Izv., v. 23, no. 4–5, p. 46–72.

Continuous, island-type, and layered permafrost distribution observed in the area show that permafrost formation depends largely on annual air temperatures and the intensity of precipitation. An increase in springs and ground-water circulation also are unfavorable for permafrost.—From SIPRE 14492.

Kriuchkov, V. V., 1958, The hydrothermal regime of soils in the Khiiny Mountains [K voprosu o gidrotermicheskom rezhime gruntov Khibinskogo gornogo massiva]: Inf. sbornik o rabotakh geog. fak. Moskovskii Gos. Univ. po mezhdunarod. Geofiz. Godu 1, p. 185–205.

The results of daily measurements of the temperature and moisture content of mountain soils at 370–904 m elevation as related to relief, exposure, and weather conditions are reported, and data are tabulated and graphed. Temperature measurements were made at depths from 20 to 240 cm by means of Hg thermometers, and soil moisture was determined using the method developed by Gromov, which is based on the speed of cooling of water poured into a vessel buried in the soil. The warmest soils were found at the bottom of valleys and south slopes; the coldest on north slopes. The minimum temperature under snow at the bottom of valleys did not fall below −2° to −2.5°C and was recorded in November, remaining nearly constant from December to February or showing a tendency to increase with snow-covered thickness due to the heat reserves in the lower soil layers. Soil moisture depended primarily on relief and wind, precipitation amounts being equal. The least soil moisture was recorded on the top of slopes and plateaus; the most, at the bottom of valleys. The water collecting in the lower portions of slopes sometimes froze to form ice layers 60–80

cm thick. Soils were much dryer in the fall-winter season than in early spring and summer.—From SIPRE 17023.

Kruglikov, N. M., 1959, Hydrogeologic conditions of the Berezovo district [Gidrogeolicheskie usloviia Berezovskogo raiona], Leningrad Vses. neft. nauchn.-issled. geol. inst., Geologiia i neftenosnost' Zap. * * * 1959, p. 296–311.

A study of ground water and gas carried out since 1954 in the search for oil and gas.—From Arctic Bibliography 59438.

Krylova, E. K., 1960, Graphical methods of representing permafrost characteristics [Metody graficheskogo otobrazheniia kharakteristik tolshch merzlykh gornykh porod]: Akad. Nauk SSSR, Inst. Merzlotovedeniia im. V. A. Obrucheva Trudy, v. 16, p. 160–171.

Methods of depicting ground-water conditions in permafrost regions are given.

Krynine, D. P., and **Judd, W. R.,** 1957, Principles of engineering geology and geotechnics: New York-London-Toronto, McGraw-Hill, 730 p.

Ground water above permafrost in summer may be a limited source of supply, but because of its shallowness, it is subject to contamination and commonly disappears in winter. If the active layer is in impervious materials, ground water trapped between the active zone and permafrost may move horizontally to contribute to formation of hydrolaccoliths, or it may form a conduit through the active zone or appear in thawed zones beneath heated buildings or along streams and abandoned stream channels.

Water within permafrost occurs in alluvium near rivers, abandoned river channels, or in thawed gravel beds, and even in thawed areas between masses of permafrost, near standing water, on south-facing hillsides, and where vegetation has been stripped.

Water below permafrost occurs in large quantities and generally satisfies sanitary requirements; it is located in alluvium beneath permafrost and in joints and other space in bedrock. In hilly regions water under permafrost may be under high pressure and flowing wells may result.

Icings formed at points of ground-water emergence upslope from places where deep freezing has taken place can be controlled by construction of frost belts at some distance upslope from the road or other structure. Icings may be controlled also by ice fences and heating.

Kudriavtsev, V. A., 1947, Determination of the lower boundary of permafrost [Ob opredelenii nizhnei granitsy vechnoi merzloty]: Akad. Nauk SSSR, Merzlotovedenie, v. 2, no. 1, p. 44–47.

With increase in deep prospect drilling for minerals in permafrost regions, a method is required for determining the lower boundary of permafrost. Use of drilling fluids causes disturbance in natural thermal regime of drill hole, and a 1-to 2-month or longer waiting period is required before any thermal data can be recorded. In 1943–44, P. A. Solov'ev measured the temperatures in Yakutsk water well 2, and kept up the measurements for a year. From these data it was concluded that the temperature of the entire hole was positive. However, the temperatures were highest in the upper part of the hole and gradually decreased with depth. The thermal minimum in the hole corresponds to the base of permafrost. Similar information was obtained from water wells at Vorkuta and Yakutsk well 1.

After drilling, the temperature of the hole is approximately the same as the drilling solution and a thawed area in the shape of an inverted cone is formed around the hole because the drilling solution circulated longer at the upper part of the hole than in the lower part. According to the theory of thermal conductivity, the quantity of heat circulation through a known cross-sectional area is directly proportional to the thermal gradient. In this case, the thermal gradient, exists along the walls of the drill hole; the natural thermal gradient must be restored after drilling. Initial temperature immediately after drilling is the same throughout the hole, but as the natural thermal gradient is restored, the thawed area around the hole will shrink gradually, starting at the lower limit of permafrost. A short time after completion of the drilling, temperatures in permafrost will correspond to the thermal gradient of the depth of the hole, expressed as the slope of a straight line showing decrease in temperature from upper to lower limit of permafrost. In the thawed layer under permafrost, the thermal gradient will be equal to the difference of the temperature of the drilling solution and the natural temperature of the thawed layer divided by the radius of increase of warming temperature from the lower limit of permafrost downward. Therefore, the thermal gradient of the wall of the drill hole toward the center of the drill hole will be a maximum at the lower limit of permafrost, then begin to decrease. Thus, the rate at which the natural thermal regime is established will be a maximum at the lower limit of permafrost and will decrease in the depth of the hole.

The temperature profiles made on January 26, April 12, May 19, and July 7 are plotted for Yakutsk water well 2, and the lower limit of permafrost near 215 m is reflected by a change in slope of the thermal gradient curves for each date. Thus, use of this method may eliminate the need to wait for reestablishment of the natural thermal gradient of the hole before determining the lower limit of permafrost.

Kuenen, P. H., 1955, Realms of water: New York, John Wiley & Sons, 327 p.

Freezing of ground water takes place in any climate subject to frost, but where the mean temperature is below 0°C, the winter frost penetrates to a depth beyond reach of summer thaw, and the cumulative effect of this process is permafrost. Heat flow of the earth tends to offset the downward penetration of frost. Permafrost forms an impermeable layer which commonly results in artesian conditions that sometimes form ice mounds in winter where springs occurred in summer. Impermeability of permafrost to melt water and precipitation saturates the ground surface and leads to such processes as solifluction, etc. Ice wedges are formed near the surface by cracking of the ground as it contracts during cold weather; the cracks fill with snow which turns to ice, and the cracks widen still more each year and become filled with ice until ice wedges are formed.

Lachenbruch, A. H., 1956, Effect of the ocean on permafrost temperatures Geol. Soc. America Bull., v. 67, no. 12, pt. 2, p. 1714.

In high latitude regions the large difference between the mean annual temperature of the surface of the ground and that in the unfrozen bottom sediments beneath bodies of water has a marked effect on ground temperatures to depth of several hundred feet. The effect is of particular interest near the edge of the ocean where it depends upon the magnitude of the temperature differences between the land surface and ocean bottom, the thermal properties and moisture content of the sediments, and past changes in climate and shoreline configuration. Theoretical considerations suggest that, except where there are transgressing shorelines, permafrost at depths greater than about 100 ft beneath the ocean bottom is not to be expected more than a mile offshore. Similar considerations indicate that coastal geothermal installations in the Arctic and Antarctic can give information regarding post-Pleistocene shoreline changes.

The geothermal effects of bodies of water offer a possible explanation for the anomalously large outward earth-heat flow recently reported by Misener for Resolute Bay, Cornwallis Island, Northwest Territory, Canada.—Author's abstract.

1957a, Thermal effects of the ocean on permafrost: Geol. Soc. America Bull., v. 68, p. 1515–1530.

The large difference between mean annual temperature at the ground surface and that in unfrozen sediments beneath bodies of water can affect ground temperatures to depths of several hundred feet. Near the edge of the ocean the effect depends on the magnitude of the temperature difference between the land surface and the ocean bottom, the thermal properties of the ground materials, and past changes in climate and shoreline configuration. Theoretically, permafrost to depths greater than about 100 ft beneath the ocean bottom is not expected at points farther than a few thousand feet offshore, except in cases where there are transgressing shorelines.

The only heat-flow value is that given for Resolute Bay, Northwest Territories, Canada, by Misener (1955), which was anomalously high. Corrections for lake and ocean influence on the ground temperature and for the rapid regression of sea level from the site some 7,500 yr ago suggest a value for heat flow that is nearly normal. If the heat flow is normal, the calculations suggest that emergence of this part of Cornwallis Island has taken place at a mean rate of 1 to 2 ft per century. Data from Barrow indicate that the thermal effect of the ocean is so great that the shoreline there has been relatively stable for the past few thousand years; it is unlikely that oceanic permafrost (Black, 1950) occurs there. At Cape Simpson, 60 miles east of Barrow, data suggest that an active transgression might be taking place. These conclusions are consistent with geomorphic evidence.

1957b, Three-dimensional heat conduction in permafrost beneath heated buildings: U.S. Geol. Survey Bull. 1052–B, p. 51–69 [1958].

The general Green's function solution has been integrated for the case of heat conduction in a homogeneous semi-infinite medium in which the temperature at the surface varies sinusoidally with time but the mean temperature and amplitude of the variation are different within and outside an arbitrarily shaped region at the surface. The amplitude and mean temperature can be treated as functions of positions within the arbitrary surface region. For certain simple surface regions the results can be expressed in terms of tabulated functions. Numerical results can be expressed in terms of tabulated functions. Numerical results for the general case can be obtained by simple graphical procedures.

Although the discussion is devoted primarily to the disturbance caused by a heated building, the methods apply directly to several other important thermal problems in permafrost. Geothermal disturbance caused by bodies of water in high latitudes is similar to that caused by a heated building in that the mean annual temperature beneath the water is anomalously high and the amplitude of seasonal temperature variation is low.—From author's abstract and summary.

1960a, Preliminary interpretation of geothermal data from Ogotoruk Creek, Alaska, *in* Kachadoorian, Reuben, and others, 1960, Supplementary report on geologic investigations in support of phase II, Project Chariot in the vicinity of Cape Thompson, Northwestern Alaska, p. 7–23: U.S. Geol. Survey open-file report (TEI-764), 30 p.

Even though some difficulties were encountered with drilling and setting thermal cables in holes Able and Baker, it is possible to discuss geothermal results by allowing in advance for disturbance due to drilling. The equilibrium temperature of −5.65°C at a depth of 114 ft can be used as an approximation of the mean annual temperature of the ground surface in tundra-covered portions of the interior of the Ogotoruk Creek Valley. Projecting the temperature curve downward, the bottom of permafrost in hole Baker is about 1,200 ft and in hole Able 1,000 ft.

Apparently the ground temperatures are not in equilibrium with the configuration of the present shoreline and lagoon. It is probable that the shoreline is transgressing; but the lagoon has been filling, and calculation of rates of the processes cannot be made on the basis of present data. From studies of temperatures at depth in hole Baker, it appears that the mean annual temperature at the ground surface is warming, a change of 1°C taking place in the last century, probably in the last 50 yr. Mean annual temperatures at the surface of the ground is not the same as mean annual air temperature.

Lachenbruch, A. H., 1960b, Thermal contraction cracks and ice wedges in permafrost: U.S. Geol. Survey Prof. Paper 400–B, p. B404.

Lachenbruch, A. H., Greene, G. W., and Marshall, B. V., 1960, Preliminary results of geothermal studies at Ogotoruk Creek, AEC Project Chariot test site, Northwestern Alaska [abs.]: Alaskan Sci. Conf., 11th, Anchorage 1960, Proc., p. 167.

Temperature measurements to depths of about 500 ft have been made in boreholes at the Project Chariot Test Site at Ogotoruk Creek on the northwestern coast of Alaska. Theoretical analysis of these data suggest a post-Pleistocene marine transgression, recent lagoon filling, and an increase in mean ground-surface temperature of about 1°C in the past half century. Extrapolation of temperature profiles yields a local inland permafrost depth of about 1,200 feet and a mean annual ground-surface temperature between −5.5° and −6.0°C. Because the temperature disturbance caused by drilling is still appreciable (about 0.15°C in April 1960) and because measurements have not yet been made in the critical 500- to 1,000-ft-depth interval, these conclusions should be considered as tentative.—Author's abstract.

Lachenbruch, A. H. *See also* Greene, G. W., 1960; Péwé, T. L., 1958.

Langbein, W. B., and Iseri, K. T., 1960, General introduction and hydrologic definitions: Manual of hydrology, Part I, General surface-water techniques: U.S. Geol. Survey Water-Supply Paper 1541–A, p. 1–29.

Lange, O. K., Data for the classification of ground water [Materialy dlia klassifikatsii podzemnykh vod]: Leningrad, Gidrogeol. Siuezda Trudy, v. 8. Incomplete reference cited in Tolstikhin, 1941.

Lange, O. K., and Filatov, K. V., 1947, Essays on the regional hydrogeology of the USSR [Ocherki po regionalnoi gidrogeologii SSSR]: Materialy poznaniiu geol. stroeniia SSSR, new ser., no. 8 (12), 100 p.

Reports on the zonal distribution of ground water in the USSR by Lange and their mineralization by Filatov.—Geol. Soc. America, Bibliography and Index of Geology Exclusive of North America, v. 23, 1958, p. 324, 1960.

Lapina, N. N., 1956, Variations in the porosity and gas permeability of rocks at temperatures below 0°C [Izmeneniia poristosti i gazopronitsaemosti porod pri otritsatel'nykh temperaturakh]: Nauchno-issled. inst. geologii Arktiki Trudy, v. 89, p. 189–200.

The effects of temperatures below 0°C on changes in the physical properties of gases and rocks are examined on the basis of experiments with freezing sand samples of various granulometric composition and moisture. Temperature decrease increased the gas permeability of dry sand, with max. increase observed in the temperature range from —2° to —5°C. Increased permeability in moist samples occurred only at temperatures sufficiently low to freeze the pore water. Samples at maximum moisture capacity were practically impervious to gas after freezing of the water. Gravity water froze at —3°C, capillary water at —6° to —70°C, and bound water near —70°C.—From SIPRE 15622.

Laverdière, Camille, 1955, The origin of pingos [L'origine des pingos]: Rev. canadienne géographie, v. 9, no. 4, p. 226.

Fritz Muller, a Swiss geoligist, in 1955 worked under a research grant from the Arctic Institute on the pingos at the mouth of the Mackenzie and on the northeast and north coasts of Greenland. He believes that pingos are related to permafrost phenomena and that they are formed by the action of flowing water under the permanently frozen soil. Like the lava of a volcano, this water bores a passage up to the surface of the soil, pushing up in the form of a dome the overlying loose material, but this peaked form is due especially to the accumulation of the trapped particles in free air; in the Mackenzie, other geomorphic factors seem to enter into the formation of the pingos. This water, called juvenile, would then come from the interior of the earth in the example of that feeding warm springs and geysers.

Lebedev, A. F., 1936, Soil and ground waters [Pochvennye i gruntovye vody]: Akad. Nauk SSSR Izd., 314 p. Moscow.

Old and new theories of ground-water formation are summarized and discussed. The laws of free, oriented and bound water migration in the soil both up and down are discussed. Problems of soil moisture accumulation and the role of evaporation and condensation of water in the formation of ground ice in permafrost are explained. The soil composed of solid or loose rock strata, frozen or unfrozen, is always porous to water vapor to a certain degree. Water condensing in permafrost in the form of ice layers comes from lower strata where vapor pressure is greater.—From SIPRE U-5900.

Leffingwell, E. deK., 1915, Ground-ice wedges, the dominant form of ground-ice on the north coast of Alaska: Jour. Geology, v. 23, p. 635–654.

1919, The Canning River region, northern Alaska: U.S. Geol. Survey Prof. Paper 109, 251 p.

The report outlines the explorations made in northern Alaska from 1906 to 1914 and describes the geography, living conditions, geology, topography, geomorphology, and, in particular, the ground ice that is so prevalent in the coastal-plain sediments. Existing literature on ground ice is thoroughly reviewed. (See p. 179–241.)

Two springs occur in the area; one at the contact between the Lisburne limestone and Sadlerochit sandstone occurs at the west end of the Shublik Mountains (Shublik spring). Several large springs gush out of the lower slope 400 ft above river level and gather together into a stream that cannot be forded. The Shublik springs flow all winter, and locally keep the river open; temperature of one of the springs was measured as 43°F. Other springs occur at the northeastern end of the Sadlerochit Mountains and were measured at 50°F some distance from the outlet.—From p. 58–59.

Lefroy, J. H., 1886, Report upon the depth of permanently frozen ground in the Polar regions, its geographical limits, and relations to the present poles of greatest cold: Royal Geog. Soc. Proc., v. 8, p. 740–746.

A summary of the thickness and horizontal extent of permafrost in Alaska, Russia, and Canada. Data from Russia is taken from the works of Voiekov and that in Canada from results of a questionnaire sent to the settlements.

Legget, R. F., and **Dickens, H. B.**, 1959, Building in northern Canada: Canada, Natl. Research Council, Div. Bldg. Research Tech. Paper 62 (NRC 5108), 41 p.

Among the major problems of building in northern Canada are water supply and sewage disposal; see treatment by Dickens, H. B., 1959.

Leiboshits, N. A. *See* Tolstikhin, N. I., and Leiboshits, N. A., 1955.

Leningrad, Vsesoiuznyi Geologicheskii Institut, 1958, Explanatory notes on a hydrochemical map of the USSR at 1: 5,000,000 scale, I. K. Zaitsev, ed. [Ob"iasnitel'naia zapiska k gidrokhimicheskoi karte SSSR v masshtabe 1: 5,000,000 red. I. K. Zaitsev]: Moscow, Gosgeoltekhizdat, 144 p.

Describes content and arrangement of the map, the joint work of several scientists. Regions for which ground water characteristics are given include the West Siberian lowland, Siberian platform, and northeastern USSR. The map itself, a colored hydrochemical map of the ground waters of the USSR, in eight parts, was published by the Geological Institute in 1956.—From Arctic Bibliography 59704.

Leont'ev, A. V., 1946, A possible principle for designing a deep frost-profile gage [Odin iz vozmozhnykh printsipov ustroistva glubinnogo merzlotomera]: Merzlotovedenie, v. 1, p. 81–82.

The principle is based on the detection of frozen layers in slurry-filled boreholes 200–600 m deep. A metal cylinder suspended on a cable is dropped into the borehole before the hole is filled with water or a slurry that is easily penetrable by the cylinder. Frozen soil strata should cause the water or mud to freeze in the vicinity and stop the cylinder as it is being raised. The lower boundary of each frozen layer is logged; the frozen area is thawed electrically, and the cylinder is raised to the next frozen sector.—From SIPRE 15894.

Levin, A. G., 1959, Certain characteristics of the water balance of the northeastern USSR [Nekotorye cherty vodnogo balansa severo-vostoka SSSR], *in* Materialy po obshchemu merzlotovedeniiu: Akad. Nauk SSSR, Inst. Merzlotovedeniia, p. 238–243.

The components of the long-term water balance in permafrost regions are examined with special emphasis on runoff, precipitation, and total evaporation, which contribute 95 percent to the water balance as compared with 2–5 percent from subpermafrost water and surface contributions to ground-water recharge. Methods of determining each of the primary factors are described, and an equation describing the water balance is presented.—From SIPRE 17946.

Lewin, J. D., 1948, Essentials of foundation design in permafrost: Public Works, v. 79, no. 2, p. 28–30.

The depth to which the active zone freezes, called the frost zone, depends on the thermal regime of the soil, severity of the winter, thickness of snow cover and vegetation, and soil characteristics. In an unfrozen stratum between permafrost and the active zone, ground water may become confined and be sub-

jected to artesian pressure. If the pressure is great enough, water may break through the frozen active layer and discharge at the surface to form a "nalyed" (icing), or it may merely lift the upper frozen layer to form a mound. Under heated buildings erected on the frozen active zone, the heat may thaw the seasonal frost until it is weak enough to permit water to break through. The water may wash out the foundations or freeze on contact with the air and lift the structure.

Permafrost is classified into (1) dry ground containing either no ice or crystalline ice in the voids; (2) moist ground containing a limited amount of ice; and (3) saturated ground consisting usually of fine-grained clayey or silty soil, containing ice as crystals, lenses, veins, or layers. Dry ground is not subject to heaving or settling. Moist ground has slight subsidence; saturated ground has properties of soft rock when frozen, but when thawed is subject to settlement and is very soft, the degree depending on ice content. Areas of permafrost are (1) region of solid stationary permafrost, (2) region of stratified permafrost consisting of layers of frozen and thawed ground, (3) region of permafrost with talik islands or inclusions, and (4) region of thawed ground with permafrost islands or inclusions.

Lichkov, B. L., 1954, V. V. Dokuchaev's law of horizontal zonality in application to ground waters and the degree of subordination of other subterranean waters to the horizontal zonality [O zakone gorizontal'noi zonal'nosti V. V. Dokuchaeva v primenenii k gruntovym vodam i o stepeni podchineniia gorizontal'noi zonal'nosti ostal'nykh podzemnykh vod]: Geog. sbornik, 1954, no. 6, Voprosy izuch. vodn. resursov, p. 81–119 (83 references).

Attempts at zoning of the earth's surface have been based chiefly on study of climate, flora, and fauna. V. V. Dokuchaev stressed the significance of soils as the indicator best reflecting all the conditions of any one zone. The followers of Dokuchaev, V. S. Il'in, V. V. Alabyshev, and others have tried to extend this concept of a natural zone to the underground layers of ground water. Their studies are summarized and completed by the author. Various types of ground and other subterranean waters in arctic and subarctic areas are included; and the division of these areas into zones is shown on maps of the USSR and of the world.—Arctic Bibliography 46347.

Liubimov, L. N., 1935, Construction of railroads in permafrost [Stroitel'stvo zheleznykh dorog v oblasti vechnoi merzloty]: Sotsialist. transport, no. 1, p. 34–46.

Railroad construction in permafrost regions is discussed. Some of the items included are heaving and settling of structures, seepage of underground waters into poorly insulated warm structures, freezing and destruction of water conduits, solifluction of scarps, and surface ice along the railroad line.—From SIPRE U–3932.

Liverovskii, A. D., and **Morozov, K. D.,** 1941, Construction on permafrost [Stroitel'stvo v usloviiakh vechnoi merzloty]: Moscow, Stroizdat Narkomstroia. [Translation by Meir Pilch, St. Anthony Falls Hydraulic Lab., Minnesota Univ., for St. Paul Dist., Corps of Engineers, U.S. Army, 306 p., 1952.]

The active layer may be saturated or supersaturated because of the impervious character of the underlying permafrost; the water table in summer in such cases is generally high. As winter freezing sets in, ground water becomes pressed between permafrost below and the descending seasonal frost. Ground water under hydrostatic head seeks an outlet to the surface and flows toward unfrozen areas, such as those under structures, or wherever the frozen layer is thin; it bursts through the upper ground layer and flows out at the surface to form ground icings.

Water in contact with permafrost transfers its thermal energy to the permafrost and tends to thaw it; conversely, the permafrost tends to freeze the water. There occurs, therefore, an active equilibrium between the volume of surface and ground water in the liquid phase and the geographic and geologic continuity, thickness, and temperature of permafrost.

Ground water is classified, according to Tolstikhin, into suprapermafrost, in the active layer, intrapermafrost water, and subpermafrost water. The intrapermafrost water is stable with respect to season. The subpermafrost water, under certain conditions, frequently bursts through the permafrost layer and emerges as permanent springs, which form icings in winter.

Ground water within permafrost occurs also as ice, which includes buried glacial ice, buried snowbanks, preserved as ice, icings, lake ice, river ice, sea ice, ice formed within icing mounds, ice formed by freezing of suprapermafrost water and intrapermafrost water, and ice crystals and veins formed by freezing of water in former taliks. The role of various types of ground water in formation of river and ground icings is summarized, and the role of permafrost in formation of asymmetrical valleys, tundra polygons, mari, mounds, and other frost features is discussed.

The presence of permafrost and complete freezing of the suprapermafrost water in the active zone causes a drastic reduction in supply of ground water to rivers. During winter low flow, many rivers freeze to the bottom, and in many places the underflow through the riverbed alluvium may be halted by deep frost penetration.

Lliboutry, Louis, 1957, Cryopedological studies in the Andes of central Chile [Studia kropedologiczne w Andach srodkowo-chilijskich]: Poland, Biul. Peryglacjalny 5, p. 5–10.

Studies in the Andes of Santiago in 1952–56 suggest that permafrost may occur at elevations above 4,500 m.—From SIPRE 17055.

Lohr, E. W., 1957, Chemical character of public water supplies of the larger cities in Alaska, Hawaii, and Puerto Rico, 1954: U.S. Geol. Survey Water-supply Paper 1460–A, p. 1–39.

Analytical data are presented on the quality of ground water at Fairbanks and Nome within the permafrost region of Alaska. In these public supplies dissolved solids are, respectively, 200 and 450 ppm. Water at Fairbanks is obtained from two 24-in 200-ft wells along the Chena River; their yield is 1,900 and 1,200 gpm. Emergency supplies are available from a 53.5-ft dug well owned by Northern Commercial Co. and rated at a yield of 1,340 gpm. The water is treated, and the Fe reduced from 2.9 to 0.8 ppm, the Mn from 0.31 to 0.00 ppm, the HCO_3 from 176 to 57 ppm, and total dissolved solids from 197 to 126 ppm.

At Nome water is provided from the 68-ft well of Pioneer Water Co., the 25-ft well of Bronson Water Co., and the 20-ft, 36-in diameter well of Moonlight Water Co. The first 2 wells have more than 430 ppm dissolved solids, that of Moonlight Water Co., 129 ppm.

Lokerman, A. A., 1957, The planned changes in permafrost terminology [O proekte izmeneniia terminov merzlotovedeniia]: Geol. Sbornik (Lvov) 4, p. 367–371.—*See* annotation, Akad. Nauk SSSR, Inst. Merzlotovedeniia, 1956.

Loparev, N. G., and Tolstikhin, N. I., 1939, The hydrolaccoliths in Khada-Bulak [Gidrolakkolity Khada-bulak]: Vses. geog. obshch. Izv., v. 71, p. 1295–1311.

The structure of hydrolaccoliths and the role of permafrost and geomorphological factors in their formation is discussed. The formation of hydrolaccoliths is connected with the freezing of ground water in the permafrost zone, and they are a particular form of ground icing. Experimental drilling in hydrolaccoliths yielded ice and frozen soil. The frozen layer in the region is from 7.9 to 13.6 m thick, and the active layer is from 3 to 4.7 m deep.—From SIPRE 9008.

Lovell, C. W., Jr., and Herrin, Moreland, 1953, Review of certain properties and problems of frozen ground, including permafrost: U.S. Army, Corps of Engineers, Snow Ice and Permafrost Research Establishment Rept. 9, 124 p.

Lukashev, K. I., 1938a, The permafrost region as a special physicogeographical and construction area [Oblast' vechnoi merzloty kak osobaia fiziko-geograficheskaia i stroitel'naia oblast']: Izd. Leningradskogo gos. univ., 186 p.

Chapter 3 of this book describes hydrologic conditions in the permafrost regions. Information is given on ground water and its movement under permafrost conditions and on rivers and lakes. Chapter 11 describes icings and includes data on their causes, types, examples, deformation of structures, and preventive measures used against them.—From Arctic Bibliography 10427.

1938b, Frost heaving by permafrost [Puchenie gruntov v usloviiakh vechnoi merzloty]: Stroitel'stvo Dorog, v. 1, no. 10, p. 20–21.

The formation of frost heaves is determined by soil composition, hydrological conditions, and soil freezing. Laboratory investigations indicated that the intensity of frost heaving is dependent on the depth of permafrost and depth of the active layer. Extensive frost heaving does not occur in the coastal areas of the Arctic Ocean where the active layer is thin and permafrost is deep. The active layer increases in depth toward the south, resulting in increased frost heaving. Hydrostatic pressure generated by retained capillary and ground waters during the freezing processes affect the intensity of frost action in soils.—From SIPRE U-5225.

Lutskii, S. L., 1946, Permafrost in Sakhalin [Vechnaia merzlota na Sakhaline], *in* Ostrov Sakhalin: Moscow-Leningrad, Izd. Glavsevmorputi, p. 27–28.

Permafrost in the Sakhalin Peninsula has an irregular distribution. The depth of the active layer varies from 0.5+ to 1.5 m according to local conditions. The thinnest permafrost was found in the northern tundra region under the moss. Permafrost was not observed along the southern coastline and valleys of large rivers. Permafrost caused a high moisture content in the upper layers of the soil and intensive spring flooding of rivers. The freezing processes in soil also cause the formation of icing mounds, and surface ice (naleds), when subterranean waters, under pressure by frost action, break the surface, spread and freeze.—From SIPRE U-5591.

L'vov, A. V., 1916, Prospecting for and testing sources of water supply along the western part of the Amur Railroad [Poiski i ispytaniia vodoistochnikov vodosnabzheniia na zapadnoi chasti Amurskoi Zheleznoi dorogi v usloviiakh "vechnoi" merzloty pochvy]: Irkutsk, 881 p.

McCarthy, E. E., 1914, Stripping frozen gravel: Mining Mag., v. 10, p. 289–295.

In the Klondike region, Yukon Territory, Canada, information from thousands of bar and drill holes have been used to plot data on colored maps showing the

outline of frozen ground, unfrozen zones, and partly frozen ground. In almost all places where there is an overburden of muck, the underlying gravel is frozen. Where areas of unfrozen ground have been found, there is little or no overburden of muck; however, many areas free of muck are frozen to bedrock. The transition from the frozen to unfrozen condition is gradual and in the form of a curve. The curves always shape toward a drainage channel; unfrozen areas are almost invariably connected to a thawed bedrock channel. An area being dredged on Hunker Creek has practicaly no muck, and the upper 25 ft of gravel is unfrozen; however, the lower 5 ft of gravel and bedrock are frozen. The Klondike River, a large stream with a bed of coarse gravel, has in its valley naturally thawed areas connected by unfrozen river channels which have established drainage throughout the year. The underground flow and seepage appears to be responsible for the thawed areas; their difference in character and permeability of the gravel and difference in degrees of cold in the frozen gravel cause irregular distribution of the areas of unfrozen ground. It is unsafe to apply the conclusions drawn from the Klondike Valley to the frozen deposits of the smaller creeks in the district.

MacCarthy, G. R., 1952, Geothermal investigations on the Arctic slope of Alaska: Am. Geophys. Union Trans, v. 33, no. 4, p. 589–593.

Limited data suggest that part of the tundra that are higher and better drained have (at depths of about 100 ft) lower electrical resistivities and higher ground temperatures than the lower wetter areas. The differences in ground temperatures may be as great as 1.5°C and are probably caused by difference in heat diffusivity between dry and wet tundras. The variations in resistivity noted are largely controlled by the number of mobile ions; this, in turn, is a matter of temperature and percentage of ground ice present, except where differences in salinity of the soil moisture introduce complications. Extremely saline formations are present in some 100- to 120-ft wells, and in a traverse across alternating dry and wet tundra, with electrode separation adjusted to penetrate about 50 ft, the resistivities ranged from less than 2,000 ohm-cm in the dry areas to about 320,000 ohm-cm in the wettest areas. Application of these data to other parts of the tundra is not clear, because the area tested was one of old beach ridges and lagoons and because of proximity to the sea and the possibility of infiltration of salt water into the deposits.

1955, Natural earth potential anomalies near Point Barrow, Alaska [abs.]: Am. Geophys. Union Trans., v. 36, no. 3, p. 519.

Certain abandoned gravelly beach ridges were found to be markedly negative in natural potential in respect to the surrounding silty tundra during the season of thaw, but became markedly positive during the freezeup. The magnitude of these potential anomalies can be correlated roughly with the thickness of the active layer and with the rate at which thawing or freezing takes place. These potentials are believed to be caused by the forced circulation of water through the more permeable materials (electrofiltration potential) and perhaps also by the buildup of electrical charges along ice-water interfaces during the freezing process.—From author's abstract.

MacCarthy, G. R. *See also* Barnes, D. F., 1956.

McConnell, R. G., 1905, Report on the Klondike gold fields: Canada Geol. Survey Ann. Rept., pt. B, v. 14, p. 1B–7B.

The thickness of the frozen deposits varies considerably; it is less on the ridges than in the valleys and less on southern than on northern exposures. A shaft in the valley of Eldorado Creek was stopped by running water at a depth of a little more than 200 ft. On most creeks both frozen muck and frozen gravel are present; these deposits are thawed by steam or by water underground.

MacFarlane, I. C., 1957, Guide to a field description of muskeg (based on the Radforth classification system): Canada, Natl. Research Council, Assoc. Comm. on Soil and Snow Mechanics Tech. Mem. 44, 36 p.

MacKay, B. R., 1945, Canada's ground water resources from a geological aspect: Am. Water Works Assoc. Jour., v. 37, p. 84–100.

This introduction to the report is a statement of the past studies of the Water Supply and Borings Section, Geological Survey of Canada, the materials available for study, and a sketch of the physiography and geology of Canada. Most of the ground water utilized comes from unconsolidated deposits.

Canada is divided into three major structural units, the Laurentia, Cordillera, and Appalachia units, which are subdivided into stratigraphic units, and further subdivided into ground-water provinces. Permafrost is mentioned in discussion of certain units and provinces, as follows.

In the Arctic Islands Paleozoic ground-water province, the glacial drift is frozen, and water supplies are developed from either streams or wells that penetrate the frost zone into underlying bedrock. In the Arctic Islands Mesozoic province, water could be obtained from porous sandstone aquifers below the frostline. The Appalachia structural unit lies south of the permafrost zone, and the Cordillera unit is not subdivided.

MacKay, J. R., 1955, The Anderson River map-area, N.W.T.: Canada Dept. Mines and Tech. Surveys, Geog. Br. Mem. 5, 137 p.

Even though the area lies within the permafrost zone, underground drainage occurs. In 1951 underground drainage was observed passing through a sand and gravel terrace near Rummy Lake, and the flow, in the form of perennial springs, fed a creek that built an ice fan each winter. The source of the flow was probably a lake a few hundred yards away. Another example of drainage through sand and gravel was seen on July 4, 1951, on the east side of Stopover Lake near the source of Horton River. The entire flow of a stream 10 ft. wide and several inches deep discharged into a lake 100 ft. across. The lake had no outlet, but conical pits in the bottom were seen to be the places through which water drained into the ground.

Ground ice in the region forms tundra polygons like those described by Leffingwell (1919) and Black (1953); the broad ice wedges are 5–10 ft across and probably go down 20–30 ft or more. Some ice wedges in permafrost extend below sea level. Polygons in the tundra flats bordering the old channel leading from Horton River to Harrowby Bay are hardly more than 150 yr old, and some are younger because they have kept pace with continuous infilling of the channel. Pingos occur at the foot of Parry Peninsula, 4 miles south of Langton Bay, at 68°13′ N. 122°35′ W. and at 69°3′ N. 120°15′ W.; they are as much as 150 ft high. In 1955, storm waves intersecting a pingo on the east side of McKinley Bay exposed the core of clear white bubbly large-crystalled ice which was overlain by 4–5 ft of brown sand, locally containing small clam shells.

1956, Mackenzie delta—a progress report: Canadian Geographer, v. 7, p. 1–12.

The pingos on the Mackenzie delta are generally restricted to the older delta deposits. However, they are present in small numbers in other regions, such as Victoria Island. On the west side of Richards Island pingos are apparently built on a veneer of modern delta deposits that covers the eroded deposits of the older delta. Any acceptable theory of origin of pingos must account for their close association with the old deltaic deposits.

McLaughlin, D. H. *See* Bateman, A. M., 1920.

Maddren, A. G., 1907, Smithsonian exploration in Alaska in 1904 in search of of mammoth and other fossil remains: Smithsonian Misc. Colln., v. 49, no. 1584, p. 5–117.

A discussion based on field work 1899–1904 and on the literature on Alaskan Pleistocene and Recent deposits, their ground ice, and the relation of the mammoth to both ice and the deposits. An appendix of about 50 pages consists of a description of reported occurrences of ice at Eschscholtz Bay, in the Kotzebue Sound area, and those on Kobuk River.

1909a, Gold placers of the Innoko district [Alaska]: U.S. Geol. Survey Bull. 379–E, p. 238–266.

Locally, in the narrow valleys and gulches where the drainage is feeble, much of the alluvial material remains permanently frozen, but in the wider bottoms of the larger streams and the main river the alluvial deposits probably carry live water in some quantity throughout the year.

* * * * * * *

The alluvial covering of the bed-rock floor is in general permanently frozen over most of that part of Alaska lying north of the area that drains into the Pacific Ocean, though there are local variations of this condition. The extent and development of the ground frost depend on the extent, position, thickness, and proportions of the gravel, sand, clay, and humus members that compose the alluvium and the amount of underground and surface water present. Generally the alluvial deposits are permanently frozen where they are not well drained by an abundant supply of surface water and where the circulation of underground water is feeble. There is, however, no uniformity of condition even within small areas, either vertically or horizontally, for often while shafts are being sunk in ground that appears to be solidly frozen, layers charged with live water are encountered and flood the workings in such quantity that the workers are "drowned out."—Author's report, p. 240, 241.

A shaft dug 30 feet in rock at the head of Carter Gulch near the divide on the Ganes Creek-Takotna River trail had 10 ft of ice when visited in 1908.

1909b, Placers of the Gold Hill district [Alaska]: U.S. Geol. Survey Bull. 379–E, p. 234–237.

About 20 prospect holes were dug in alluvial deposits of the creeks of the district, 25 miles west of Tanana, during the winter of 1907–08. Frozen ground was encountered in many of the shafts; those that reached bedrock were probably entirely in frozen ground, and those that did not reach bedrock were prevented from doing so by the presence of live water in thawed ground.

1910a, The Innoko gold-placer district, Alaska, with accounts of the central Kuskokwim Valley and the Ruby Creek and Gold Hill placers: U.S. Geol. Survey Bull. 410, 87 p.

In the Gold Hill area 20 holes were dug in frozen ground; some reached bedrock and others encountered live water beneath the frozen ground and were abandoned before reaching bedrock.

1910b, The Koyukuk-Chandalar gold region [Alaska]: U.S. Geol. Survey Bull. 442–G, p. 284–315.

A shaft on Wiseman Creek, 1 mile below the mouth of Nolan Creek, penetrated 40 ft of muck, 180 ft of clay, 30 ft of gravel, and 10 ft of ground-up rock and gravel before reaching bedrock; the shaft was dry. The deep-frozen pay gravel deposits in the Nolan Creek placer mines lie on bedrock at a depth of 20 to 25 ft on Discovery claim, at the mouth of Fay Gulch, to a depth of 180 ft on claim 8 below Discovery, at the mouth of Nolan Creek. Vermont Creek in its lower course flows across deep frozen deposits that constitute bench deposits of the Hammond Valley; a shaft sunk 90 ft in these deposits was in frozen ground.

1911, Gold placer mining developments in the Innoko-Iditarod region [Alaska]: U.S. Geol. Survey Bull. 480–I, p. 236–270.

Little Creek, in the Innoko drainage, has unconsolidated deposits 10–25 ft deep that are partly frozen and partly unfrozen. Shaft sinking and drifting have been done in the valley bottom where the deposits are deepest and contain more or less perpetual frost; shafts and drifts are not economical in unfrozen ground. On Spruce Creek the valley floor at one mined area consists of deposits of muck, clay, and slit, most of which are frozen. Ophir Creek has a fill of 25 or 30 ft of gravel, slit, clay, and muck, which are for the most part frozen. On Yankee Creek, coarse gravel 5–7 ft thick is mantled with 1–3 ft of muck; the gravel deposits are largely unfrozen, perhaps because the unconsolidated deposits and muck cover are thin, or possibly because of good circulation of water through the thawed gravel.

Placers of Otter Creek, in the Iditarod drainage, are generally frozen and consist of 1–6 ft of auriferous gravel overlain by 4–12 ft of sediment and muck. Where mining has been done, unfrozen ground encountered in some places commonly contained flowing ground water. In Flat Creek precipitation falls into closely spaced granite boulders and flows down by many underground channels to emerge at the foot of the slopes and form the creek. The cover of frozen sediment and muck is thin on upper Flat Creek but thicker downstream. On Willow Creek a few feet of mucky vegetable humus and moss overlie 10–25 ft of frozen silt and clay with thin beds and lenses of shaly gravel. Many prospect pits have been filled with seepage water, and shafts have been stopped by flooding.

1913, The Koyukuk-Chandalar region, Alaska: U.S. Geol. Survey Bull. 532, 119 p.

Placer deposits are divided into several categories. Present stream placers in the valley bottom along present stream courses are generally in an unfrozen condition during the summer when streams are flowing. Other stream placers are buried beneath thick accumulations of alluvium and are generally frozen throughout the year, except during summer in places where streams flow over their surfaces and in the more porous gravel beds where ground water is plentiful enough to circulate freely. Bench placers may have an overburden that is thick or thin, frozen or unfrozen.

"Over all northern Alaska the unconsolidated deposits, whether gold-bearing or not, are as a rule firmly bound together by a widespread and almost constant frost or ice throughout their thickness and extent. This condition also extends to some depth into the hard country rocks wherever percolating water penetrates them. The amount of unfrozen ground in northern Alaska is a very small percentage of the whole, and even this is in an unfrozen condition only for about one-third of the year, during the season of flowing surface water or the few months of summer. Occasionally the larger streams carry enough circulating water through the more porous beds of gravels in their valleys to maintain an unfrozen condition throughout the whole year".—Author's report, p. 80.

Frozen ground occurs on Marion Creek, a tributary of Middle Fork Koyukuk River, 4 miles upstream from Coldfoot; in some places, however, live water has hindered prospecting on this creek. Near Wiseman Creek, a mile below the mouth of Nolan Creek, a dry shaft 260 ft deep encountered 40 ft of muck, 180 ft of clay, 30 ft of gravel, and 10 ft of mixed rubble and gravel before entering bedrock. Another shaft was dug 335 ft on Wiseman Creek, and a pipe was driven to 365 ft without reaching bedrock. On Nolan Creek the pay gravel was found to underlie thick frozen muck and clay, and the bedrock is 20–25 ft deep under the upper part of the creek and 180 ft deep near its mouth.

Minnie Creek has been little prospected because of the occurrence of thawed ground and live water. Some frozen ground is reported along Gold Creek. Deep frozen overburden masks bedrock in Jim Gulch, a tributary of Glacier Creek at the head of South Fork Koyukuk River.

Maddren, A. G., 1918, Gold placers near the Nenana coal field [Alaska]: U.S. Geol. Survey Bull. 662–G, p. 363–402.

On Daniel Creek, a tributary of Totatlanika River, the greater part of the alluvium in the valley floor does not contain permanent frost. There are small areas in which seasonal frost persists well into summer, and therefore there may be some permanently frozen zones in the deeper alluvium. Practically no permanent frost occurs in the alluvium of the middle basin of Totatlanika River.

Maddren, A. G. *See also* Moffit, F. H., 1908.

Makarenko, F. A., 1958, Ground-water source of thermal energy [Podzemnye vody—Istochnik teplovoi energii]: Priroda, no. 9, p. 89–91.

Use of geothermal energy is now being explored in many parts of the world and for a variety of purposes. In the USSR its use is now largely confined to health resorts. Hot waters have recently been discovered beneath the permafrost in northern and northeastern USSR. These waters reach the surface with temperatures up to 90°C or 100°C. Many geosynclinal and platform basins contain large amounts of hot water. The West Siberian artesian basin is probably the largest of these. The Caucusus region is particularly noteworthy for basins that contain large amounts of very hot water under high pressure; temperatures range up to 150°C and 270°C. Volcanic areas of Kamchatka and the Kurile Islands are suitable for generation of electric power and for hothouse agriculture.

Extensive development of hot ground water is planned in the Soviet Union. These waters are also expected to yield large quantities of sulfur, boric acid, bromine, iodine, carbon dioxide, helium, lithium and others as byproducts—Geophys. Abs. 177-266, U.S. Geol. Survey Bull. 1106–B, p. 198–199, 1959.

1959, Underground waters are source of heat energy: Current Sci., v. 28, no. 3, p. 104–105, 1959.

The hydrothermal resources of the USSR are practically unlimited. The first general summary published on possible sources of underground hot water and steam for heating and power production recommends that more than 60 towns can be centrally heated and suggests more than 100 districts where hot underground waters should be used regionally for agriculture, residential, communal, technical, and sanitary-hygienic purposes. Use of geothermal resources could save the national economy millions of tons of fuels and relieve pressure on transport.—Geophys. Abs. 177-227, U.S. Geol. Survey Bull. 1106–B, p. 199, 1959.

Makerov, IA. A., 1926, Darasun mineral springs [Darasunskie mineral'nye istochniki], *in* Materialy po geologii i poleznym iskopaemym: Dal'nego Vostoka Krai 44, Geol. Kom. Dal'nego Vostoka Krai.

1938, Mineral springs of the Far Eastern region (in Russian): Acad. Sci. U.S.S.R., Far Eastern Br., Bull. 28 (1), p. 3–36.

Makkaveev, A. A., 1936a, Hydrogeological observations in the Byshintu basin in the Gobi Altai (Mongolia): Russia, All-Union Sci. Research Inst. Econ. Minerology, Ground Water Hydrology and Eng. Geology, Symposium 2, p. 53–66. [Russian.]; Geol. Soc. America, Bibliography and Index of Geology Exclusive of North America, v. 6, 1938, p. 180, 1939.

1936b, Hydrogeology of Indiga Bay [Kratkie svedeniia po gidrogeologii raiona Indigskoi bukhty]: Gidrogeologiia i inzh, geologiia, v. 3, p. 20–30.

The physiography of the area located between 67° and 68° N. Lat and 47° to 48° E. long is described and the problem of water supply is discussed. Continuous permafrost occurs in the area, except under the sand beaches along the shore, at a depth from 0.5–0.7 m. The snow cover averages about 50 cm deep and the Indiga River does not freeze solidly. Spring water flowing through and above the frozen strata into the river has a summer temperature of about 3°C.—From SIPRE 12958.

Makkaveev, N. I., 1955, The river channel and erosion of its basin [Ruslo reki i eroziia v ee basseine]: Moscow, Izd. Akad. Nauk SSSR, 346 p.

General review of river erosion and hydrology. Effect of permafrost and icings noted on p. 168–169.—Arctic Bibliography 41220.

Maksimov, V. M., 1958, The chemistry of subterranean waters of the Yakut artesian basin [O khimizme podzemnykh vod IAkutskogo artezianskogo basseina]: Leningrad, Gornyi inst. Zap., v. 34, no. 2, Geologiia i inzh. geologiia, p. 40–54.

Characteristics of the artesian basin are presented on a map and in cross sections, based on a study in 1951–53. The subterranean waters of pre-Paleozoic, Paleozoic, and Mesozoic deposits are described, and two provinces and 10–12 ground-water horizons are delimited. The chemical composition, based on 160 analyses, is evaluated.—From Arctic Bibliography 60017.

Maksimov, V. M., and Baskov, E. A., 1958, Ground waters of the Jurassic deposits in the Yakutsk district [Podzemnye vody iurskikh otlozhenii raiona IAkutska]: Leningrad, Gornyi inst. Zap., v. 34, no. 2, Geologiia i inzh. geologiia, p. 55–60.

The ground waters and their suitability for water supply are described on the basis of three drill holes, including their yield, chemical composition and mineralization, and other properties. Expansion of the use of water from Jurassic rocks, already used to supply Yakutsk, is discussed. Attention is called to the possibilities for further exploitation of ground water in unfrozen ground in the first flood-plain terrace of the Lena River near Yakutsk.—From Arctic Bibliography 60018.

Maksimov, V. M., and Tolstikhin, N. I., 1940, On hydrogeological conditions in the vicinity of the town of Yakutsk: Acad. sci. URSS Comptes rendus (Doklady), v. 28, no. 1, p. 93–96. [English.]

The first investigations intended to study ground water at Yakutsk were by Shergin, a merchant who dug a shaft 116 m deep during the 19th century. In 1932–34 Svetozarov and in 1933–39 Kargin made engineering-geology investiga-

tions of the town which included study of water beneath permafrost and certain springs. In 1939 the hydrogeologic party of the Yakutsk Expedition made an investigation to define more precisely the structure of the Yakutsk region, to ascertain the possibilities for obtaining water under permafrost, and to organize drilling for water. The investigations were carried on along both banks of the Lena from Pokrovskoye and Kachikatsy villages to the Kangalassk collieries.

The bedrock is chiefly sedimentary rocks of Cambrian, Jurassic, and younger age. The Cambrian carbonate rocks are 1,370 m thick and are of the "Botomsk" series. The limestones include a seam of chalky clay and bituminous limestone. The bituminous limestone indicates the possibility of relatively high mineralization and salinity. On the right bank of the Lena near Kachikatsy, the "Bulus" spring emerges with a discharge of 60 liters per sec at a temperature of 0.2°C along the contact of sandy-pebble alluvial terrace deposits and the upper eroded surface of the Cambrian carbonate rocks. Fresh ground water near the surface and salt water at great depth were also found in the Cambrian rocks in bore holes on the Amga and Tolba Rivers. Thus, the Cambrian rocks are water-bearing, the fresh-water horizon on top and the salt water at depth. The contact between the Cambrian and overlying Jurassic rocks dips at low angle toward Yakutsk, where it is 330–350 m deep.

The Jurassic rock consist of 550–600 m of sediments. The basal Amginsk series consists of 65 m of medium-grained sands and sandstones with subordinate beds and lenses of coarse sandstone and conglomerate, fine sandstone, schist, and minor lenses of coal. Next is the Upper Kangalassk series, 110 m thick, which is dominantly chalky clay and fine to medium sands and sandstone, with local conglomeratic sandstone horizons; the rocks are locally fossiliferous and contain coal fragments and vegetation imprints. Above the Upper Kangalassk series is the Yakutsk series, 240–245 m of monotonous fine clayey sands and sandstones, clays, limestone, and remains of vegetation and seams of brown coal. The Lower Kangalassk series, more than 65 m thick, consists of sand, sandstones, dense clays, and beds of brown coal.

The Lower Kangalassk series is covered with gray to dark-gray sands passing into loose sandstones with gravel and well preserved remains of almost uncharred wood. At the base is a bed of conglomerate lacking fragments of brown coal. At the top of this series is black clay. On the washed or eroded surface of the "Grey" series are Ancient-Quaternary pebble beds and sands. The position of the "Grey" series between the Malm and the Ancient Quaternary beds, suggests a Cretaceous or, most likely, Tertiary age for the Grey series.

The Jurassic rocks dip from Pokrovskoye along the Lena toward Yakutsk. At Yakutsk occur Cambrian limestones, the Amginsk, the Upper Kangalassk and part of the Yakutsk series. The stratum of sandy limestone is at a depth of 70–71 m below the surface near the Shergin shaft. If permafrost in the Yakutsk region is assumed to be 186–200 m thick, theree water-bearing strata may be found below permafrost: the first, 20 m thick; the second, 30 m thick; and the third, more than 70 m thick, all between depths of 220–350 m beneath Yakutsk. Of these, the first two are fine-grained sands of poor texture and have too low a temperature, but the lowermost horizon consisting of coarse- and medium-grained sands, gravel and pebbles is of interest; its thickness is about 70 m, and coarse sand and conglomerate on the weathered surface of the Cambrian rocks form still additional thickness of water-bearing rocks. The water temperature expected will be approximately 3° to 5°C and the quality is satisfactory, an assumption based on the presence of fresh water springs originating under the lower limit of permafrost; in addition, Siberian Jurassic coal measures are elsewhere characterized by fresh water, and those at Yakutsk are part littoral and part continental, having formed under conditions of damp climate. At great depths in the Cambrian rocks, however, salt water may be found, with mineralization increasing with depth.

Should the thickness of permafrost be less than anticipated, another thick water-bearing stratum will be found beneath permafrost. Important springs ("Ulakan-Taryn") 48–50 km upstream from Yakutsk on the east bank of the Lena emerge from the third water bearing stratum at approximately 300 liters per sec at 0.2°C (Sept. 1939); the water is good. On the east bank of the Lena, 40 km lower Yakutsk (sic) near the "Doidinsk Nasleg" is "Sular" spring with a discharge greater than 50 liters per sec. In winter all these springs from the lower limit of permafrost form huge "glaciers" (icings). In addition to deep spring waters rising through permafrost are other ground waters circulating in the annually thawed superlayer, but these are of small practical value.

Maksimovich, G. A., 1947, Hydrochemical facies of ground water and its zonation [Gidrokhimicheskie fatsii gruntovykh vod i ikh zonalnost]: Akad. Nauk SSSR (Doklady) v. 56, no. 6, p. 625–628.

1948, The classification of underground waters [Klassifikatsii podzemnykh vod]: Lab. Gidrogeol. Problem Trudy, v. 3, p. 57–68.

The principles of underground-water classification used by many investigators are briefly discussed. The dynamics of ground water in strata and fissures are analyzed. Tables of classification are given. Severe climate often causes suprapermafrost-waters to freeze for 6–10 months. Naleds are caused by the freezing of ground water. Partial freezing of suprapermafrost-water is observed in areas of deep permafrost.—From SIPRE 9044.

1950, Principles in the study of hydrochemical facies [Osnovy ucheniia o gidrochimicheskikh fatsiiakh]: Gidrochimi. Materialy, v. 18, p. 75–85.

The basic laws governing the distribution of natural waters of varying composition are discussed. The distribution is associated with the five principal types of geodynamic zonality: planetary, geotectonic, structural, climatic, and geomorphologic. Graphic data are presented on the prevalence and composition of rivers, lakes, ground waters, and different types of ice in relation to the soil solution of different zonal types. Three modes of ice formation are distinguished: the atmogenic ice of snow, hail, glaciers, and cave ice which forms by sublimation processes; anchor ice and ground ice formed by the direct transformation of water into a solid; and lake and river ice where the surface is formed from atmogenic snow and the lower part from frozen water.

Malchenko, E. V., 1928, Soil freezing in eastern Siberia and Yakutia [Merzlota pochvy v Vostochnoi Sibiri i v IAkutii]: Materialy Kom. izuch. IAkutskoi ASSR, v. 11, p. 150–176.

Permafrost causes increased soil moisture in the upper layers, ice mounds, naledi, frost heavings, and other formations associated with water freezing in soils.—From SIPRE 7049.

Marinov, N. A., 1939, Orshanda mineral springs in southeastern Transbaikal [Mineral'nyi istochnik Orshchandy v iugo-vostochnom Zabaikal'e]: Razvedka Nedr, no. 9, p. 21–23.

1948a, Vertical zonation of ground water in the northeastern part of central Asia [Vertikalnaia zonalnost podzemnykh vod severovostochnoi chasti TSentrainoi Azii]: Akad. Nauk SSSR (Doklady), v. 60, no. 8, p. 1385–1388.

A study of the variations in the mineral composition of ground waters from different lithologic zones, with special reference to vertical zoning.—From Geol.

Soc. America, Bibliography and Index of Geology Exclusive of North America, v. 15, 1950, p. 183, 1951.

Marinov, N. A., 1948b, On the conditions for formation of calcium and magnesium-chloride artesian waters in continental Mesozoic and Tertiary formations of central Asia [O vozmozhnosti formirovaniia khlor-kaltsievykh i khlor-magnievykh tipov artezianskikh vod v kontinentalnykh otlozheniiakh TSentral'noi Azii]: Akad. Nauk SSSR Doklady, v. 60, no. 9, p. 1557–1559; 1951, Geol. Soc. America, Bibliography and Index of Geology Exclusive of North America, v. 15, 1950, p. 183.

1949, On the vertical zonation of ground water in the southeastern Transbaikal region [O vertikalnoi zonalnosti podzemnykh vod iugo-vostochnogo Zabaikalia]: Vses. geog. obshch. Izv., v. 81, no. 3, p. 333–337.

Markov, K. K. *See* Avsiuk, G. A., 1956.

Marshall, B. V. *See* Lachenbruch, A. H., 1960.

Martin, G. C., 1919, The Alaskan mining industry in 1917: U.S. Geol. Bull. 692–A, p. 11–42.

In the Chisana district prospecting of deep placer ground on Notch Creek shows that unfrozen ground containing circulating ground water occurs at depth and that pumping is required. In the Gold Mountain district near Tanana, cuts were made on Lancaster Creek, American Gulch, and Grant Creek, where the ground is 12–20 ft deep; gravel deposits on the benches were not frozen.

Martin, G. C., and Katz, F. J., 1912, A geologic reconnaissance of the Iliamna region, Alaska: U.S. Geol. Survey Bull. 485, 138 p.

On the Mulchatna River above the mouth of Koktalee River and on the Koktalee River itself, no permanent frost has been encountered by prospectors.

Maslennikov, M. V., 1951, Underground waters in the permafrost zone [Podzemnye vody v zone vechnoi merzloty]: Moscow-Kharkov, Ugletekhizdat in Inzhenernaia geologiia, gidrogeologiia i osushenie mestorozhdenii, p. 46–64.

Distribution, types, thickness, climatic peculiarities, structure, thermal regime, and origin of permafrost are discussed. Diurnal air temperature variations are reflected in the ground to a depth of 5–10 cm. Snow cover affects ground temperature to a greater extent than vegetation. The lower part of the active layer usually has a temperature below freezing. Underground water is classified into water below permafrost which never freezes, water permanently frozen, and water which undergoes cyclic freezing and thawing. The influence of permafrost on structures is briefly outlined.—From SIPRE U–4990.

Matveev, A. K., 1936, Geological field work during 1935 in the Bureya River basin [Geologicheskie raboty v Bureiskom basseine v 1935 g.]: Razvedka Nedr, v. 6, no. 3, p. 27–32.

The work showed that permafrost is uniformly distributed throughout the area except near the Tyrma River, where islands of permafrost only were found. The heavy surface runoff and swamps of the region are associated with the presence of permafrost. Ground water occurs in the upper layers to a depth of 10–16 m. Construction in the region is seriously hampered by the prevalent swamps and the degradation of permafrost under buildings.—From SIPRE 10059.

Mavritskii, B. F., 1958, History of development of the West Siberian artesian basin and its oil-gas prospects [Ob istorii razvitiia Zapadno-Sibirskogo artezianskogo basseina i perspektivy ego neftegrazonosnosti]: Geologiia nefti, no. 4, p. 38–44.

Determination of the ground-water regimen in the West Siberian Lowland is best accomplished on a basis of age determinations of the water. The formula $T = He/A \cdot 77.1 \times 10^6$ yr is used. The ages thus obtained yield a consistent picture for the movement of younger waters through aquifers and the displacement of older waters.—Geophys. Abs. 180–21, U.S. Geol. Survey Bull. 1116–A, p. 10, 1960.

1960, Geothermal zoning of the West Siberian artesian basin [Geotermicheskaia zonal'nost' Zapadno-Sibirskogo artezianskogo basseina]: Akad. Nauk SSSR Izv., Ser. geol., no. 3, p. 72–83.

The term "geothermal zone" is defined as a group of strata within which the rocks and their enclosed waters are characterized by a definite temperature interval. The West Siberian artesian basin is divided into six geothermal zones ($<0°C$; 0°C–25°C; 25°C–50°C; 50°C–75°C; 75°C–100°C; and $>100°C$) on the basis of analysis of temperature measurements in wells. The minimum is in the Ust' Porta region, where the temperature at 20–25 m depth is 5.2°C (probably —5.2°C, compiler). The maximum was encountered in Koplashevsk borehole 2–P, where the temperature at 2,900 m depth is 125°C.

The distribution of temperature is shown in three profiles [Berezovo-Bol'sherech'ye-Semipalatinsk, Kushmurun-Pokrovskoye-Khanty-Mansiysk, and Turinsk-Tar-Maksimkin Yar] and three maps (at the absolute —1,000 m and 2,500 m levels in Mesozoic formations, and on the pre-Mesozoic basement surface).—Geophys. Abs. 181–299, U.S. Geol. Survey Bull. 1116–B, p. 214–215.

Meinzer, O. E., 1923, Outline of ground-water hydrology with definitions: U.S. Geol. Survey Water-Supply Paper 494, 71 p.

1949, Hydrology, v. 9 *of* Physics of the earth: New York, Dover Publishers, 712 p.

Meister, L. A., 1946, Permafrost thickness in the Igarka region [O moshchnosti vechnoi merzloty v Igarke]: Merzlotovedenie, v. 1 p. 29–30.

Large variations occur in the depth and thickness of permafrost associated with hydrogeological features, distance from the Yenisei, and several other factors. A maximum thickness of about 32.5 m was discovered in a hole sunk to a total depth of 61 m.—From SIPRE 15884.

1955, Shortcomings in the classification of ground water in permafrost [O nedostatkakh klassifikatsii podzemnykh mnogoletnemerzlykh gornykh porod]: Akad. Nauk SSSR, Inst. Merzlotovedeniia, Materialy k osnovam ucheniia o merzlykh zonakh zemnoi kory, no. 2, p. 59–64.

Principles of classification applied by Tolstikhin and others to ground water in permafrost are considered inadequate. They ignore the part played by geological conditions in the formation and circulation of ground water, and consider ground ice as a modified form of liquid only. Subpermafrost, intrapermafrost and suprapermafrost waters are also deficient as terms, because the effects of permafrost vary in moist soil and rocks as well as in strata containing bound water only. A revised classification should be based on geocryological concepts of the formation, circulation, and chemical interaction of ground water, and should consider ground ice as a solid, not as a modified liquid form.—From SIPRE 13734.

Meister, L. A., 1956, Interrelation between theory and practice in the development of permafrostology [O vzaimosviazi teorii i praktiki v razvitii geokriologii]: Akad. Nauk SSSR, Inst. Merzlotovedeniia, Materialy k osnovam ucheniia o merzlykh zonakh zemnoi kory, no. 3, p. 5–17.

The development of permafrostology in the USSR since the middle of the 19th century is briefly described, and theoretical and practical problems influencing progress of the science are discussed. Construction of the Trans-Siberian Railroad and the large economic expansion in the early part of this century resulted in intense study of permafrost, especially after the establishment of the Commission on Permafrostology. Considerable data on the distribution of permafrost and its physical and mechanical properties were collected during 1927–41. The important deductions leading to the general theory of permafrostology and engineering practice were made after the war, particularly during 1952–55.—From SIPRE 14074.

1957, The development of geocryological investigations at the V. A. Obruchev Institute of Permafrostology [Ocherk razitiia geokriologicheskikh issledovanii v Institute Merzlotovedenie im. V. A. Obrucheva]: Akad. Nauk SSSR Izv., Ser. geog. no. 5, p. 124–128.

Soviet permafrostology research from 1929 to 1957 is outlined, and the study of problems which fostered the development of new methods of construction and water supply in permafrost regions is reviewed. Modern advances began with the appearance in 1927 of Sumgin's monograph, "Permafrost in the USSR," and the establishment (by the Academy of Sciences) of the Permafrost Commission (1929), which was reorganized into the Permafrost Committee in 1936, and finally into the Institute of Permafrostology in 1939. The extent of progress can be seen from the 24 volumes of the Trudy, the numerous monographs and symposia, the maps of permafrost, and the several hundred scientists in the Institute and its branches and stations. The new monograph, "Basic Cryology (Permafrostology)," in 2 volumes, completed by the Institute and sent to the printer in 1957 is regarded as a complete summary of this permafrost research. A program of theoretical, laboratory, and field investigations is currently in progress at the Institute itself, its Northeastern Branch (Yakutsk) and at research stations at Igraka, Anadyr', Vorkuta, and Chul'man (the last is known as Aldan Station).—From SIPRE 16263.

Meister, L. A., and Saltykov, N. I., 1958, History of geocryological investigations in the USSR [K istorii geokriologicheskikh issledovanii v SSSR]: Syktyvkar, Komi Knizhnoe Izd., Akad. Nauk SSSR, Inst. Merzlotovedeniia im. V. A. Obrucheva, 82 p.

The historical development of cryological studies in academic institutions and related organizations of the USSR is discussed in detail. The developments in each field of study are considered individually, including permafrost distribution, its thermal regime and influencing factors, and its origin; permafrost terminology; engineering geocryology and the physical and mechanical properties of frozen ground; construction in permafrost areas; the geographical aspects of permafrost, variations in its regional characteristics and their causes; the formation and development of permafrost; ground water in permafrost areas; and vegetation.—From SIPRE 17275.

1959, Outline of the development of geocryological investigations in the USSR [Ocherk razvitiia geokriologicheskikh issledovanii v SSSR], pt. 1, chap. 3, *in* Osnvovy geokriologii (merzlotovedeniia): Akad. Nauk SSSR, Inst. Merzlotovedeniia.

The progress made after the revolution is described, and the contributions of individual scientists are discussed. The resolutions at the 14th and 15th meetings of the Communist Party of the Soviet Union on the Industrialization of the East gave great impetus to permafrost studies. In 1930 a special Commission for the Study of Permafrost was created in the Academy of Sciences. In 1936 this Commission was reorganized to form the Committee on Permafrost, and in 1939 the Institute of Permafrostology. Systematic investigations were conducted by the Institute and scientific organizations of other Government departments. The first major general work on permafrost was published by M. I. Sumgin in 1927. From 1931 to 1940 the Commission and Committee on Permafrost published 10 volumes of papers on the general problems of engineering geocryology. In the following years the Institute of Permafrostology published 15 volumes of studies and 4 issues of the journal "Merzlotovedenie" (Permafrostology). Seven meetings and conferences on this subject were held between 1930 and 1956.—From SIPRE 17913.

Meister, L. A., and Shvetsov, P. F., 1955, Some terms concerning the science of frozen ground and rocks and its place among other sciences [O nekotorykh terminakh v uchenii om zonakh merzlykh pochv i gornykh porod i ego meste sredi drugikh nauk]: Akad. Nauk SSSR Izv., Ser. geog., no. 1, p. 69–73.

The usefulness of the terms "permafrost" and permafrostology" is discussed. The published works of M. I. Sumgin, B. B. Polynov, V. B. Shostakovich, and others frequently confuse the two concepts of frozen ground and permafrost. Replacement of the term "permafrostology" with "geocryology" is suggested, since the frozen soil and rock, in which processes occur below the freezing point, and ice is formed, are component parts of the cryosphere. Geocryology may be defined as the science treating of the conditions of formation, development and distribution of frozen ground or rock, their physical and mechanical properties and modifications of the latter caused by human activity.—From SIPRE 10757.

Mellish, M. H. *See* Hyland, W. L., 1949.

Mel'nikov, P. I., 1942, Study of permafrost in the Yakut ASSR [Izuchenie vechnoi merzloty v IAkutskoi ASSR]: Inf. biull. noveishei literatury geol. nauk., no. 1–6, p. 138.

Permafrost studies of Yakut ASSR initiated in 1927 and continued to date are reviewed. These studies led to the location of subpermafrost waters in Yaktusk and the subsequent solution of the water supply problem. The research explained the extensive icings in the lower reaches of the Kyra River. The thermal regime of the ground and the effects on the stability of structures are discussed.—From SIPRE U-3518.

1959, Principles of the distribution and development of permafrost in the Lena River basin [O zakonomernostiakh rasprostraneniia i razvitiia merzlykh pochv u gornykh porod v basseine r Leny], *in* Materialy po obshchemu merzlotovedeniiu: Akad. Nauk SSSR, Inst. Merzlotovedeniia, p. 91–102.

The principles are examined on the basis of the data obtained by the local permafrost station. The distribution and development of permafrost varies in the region with geological and hydrogeological conditions. Permafrost reaches the surface in most of the territory and is continuous, except in small areas with perforating taliks near water bodies.—From SIPRE 17934.

Mel'nikov, P. I., and Solov'ev, P. A., 1947, Permafrost soil conditions and principles of the Zhatai backwater construction [abs.] [Merzlotonogruntovye usloviia i printsipy stroitelstva Zhataiskogo zatona, IAASSR]: Akad. Nauk SSSR, Otdel. geol.-geog. nauk, p. 166.

A detailed picture of the permafrost conditions of the youngest river terraces, where interaction occurs between permafrost and river water, has been obtained from investigations made in the region of central Yakutia. The development of frozen ground is closely related to the age of the terraces. The proximity of water reservoirs produces mainly local effects. The frozen ground is currently still developing, extending to the terraces as they are formed. The present occurrence of frozen ground and the progress of the process given above are complicated by the counteracting influence of the river and lake water, which occasionally causes local degradation of the permafrost.—Minnesota Univ., 1950.

Mel'nikov, P. I. *See also* Efimov, A. I., 1945.

Mendenhall, W. C., 1905, Geology of the central Copper River region, Alaska. U.S. Geol. Survey Prof. Paper 41, 133 p.

Beneath Chisna River, one-half mile above the mouth of Powell Creek, a shaft was sunk from creek level through 21 ft of compact till into an underlying bed of sand that admitted water and forced cessation of excavation.

Mertie, J. B., Jr., 1918, Gold placers of the Tolovana district [Alaska]: U.S. Geol. Survey Bull. 662–D, p. 221–277.

Bench placer ground on Livengood Creek is solidly frozen from top to bottom. No water and no unfrozen ground have been encountered in the underground workings. Much of the present stream gravel of Livengood Creek is frozen.

1925, Geology and gold placers of the Chandalar district [Alaska]: U.S. Geol. Survey Bull 773–E, p. 215–263.

On Little Squaw Creek, 1½–2 miles above the mouth of the stream, the ground is solidly frozen from the surface to bedrock, but is probably unfrozen near the creek. On claim No. 3 above Discovery the 100-ft main shaft is in frozen ground, but drifts lead from the shaft into unfrozen ground. Therefore, the bottom of the shaft fills with water to a depth of 20 ft in summer, but all the water drains out in winter for some unknown reason. Placer ground on claim No. 3 below on Big Creek is frozen.

1929, Preliminary report on the Sheenjek River district [Alaska]: U.S. Geol. Survey Bull. 797–C, p. 99–123.

The Porcupine Flats, upstream from Fort Yukon, have banks that expose silt, peat, ground ice, sand, and gravel. The upper reaches of the Sheenjek drainage are the sites of aufeis or winter icings caused by freezing of successive stream overflows in winter; these icings persist most of the summer. Eluvial deposits on gentle hill slopes in the piedmont province and much of the ground back from the main waterways are perpetually frozen.

1930a, The Chandalar-Sheenjek district, Alaska: U.S. Geol. Survey Bull. 810–B, p. 87–139.

The banks along outer sides of the meanders of the Porcupine River in the Yukon Flats are composed of silt, peat, and scattered bodies of ground ice.

Bodies of aufeis in the upper reaches of the East Fork Chandalar River persist into summer, and in some cool summers may persist in part throughout the summer. They occur in braided reaches, but it is not clear whether the stream is braided because of the aufeis, or whether the character of the braided channel determines the occurrence of aufeis.

1930b, Mining in the Fortymile district [Alaska]: U.S. Geol. Survey Bull. 813-C, p. 125-142.

In the main valley of Chicken Creek, bedrock is 40-50 ft deep, but only a little of the overlying gravel has been mined because it is too wet for drifting. One-quarter mile west of Chicken a shaft has been sunk 35 ft to a coal bed, and a tunnel and room have been excavated at that level, presumably in frozen ground.

1930c, Geology of the Eagle-Circle district, Alaska: U.S. Geol. Survey Bull. 816, 168 p.

The alluvial deposits are commonly permanently frozen to great depths, except along the banks of the larger streams where circulating ground water has thawed the ground for several hundred feet back from the riverbanks. The frozen ground is thought to be evidence of a previous epoch, in part the Pleistocene, in which the climate was colder than at present; the deep frozen ground, therefore, is regarded as an inorganic fossil record of preexisting climate. Circulation of deeper ground water is restricted by the presence of frozen ground.

1931, A geologic reconnaissance of the Dennison Fork district, Alaska: U.S. Geol. Survey Bull. 827, 44 p. [1932]. *See* annotation, Mertie, 1930c.

1932, Mining in the Circle district [Alaska]: U.S. Geol. Survey Bull. 824-D, p. 155-172.

The older gravel deposits, usually found in bench channels, are largely covered with muck and are commonly frozen. Younger deposits, especially those close to flowing streams, are usually thawed. Drill holes and shafts indicate that claims 22-59 below Discovery on lower Deadwood Creek are on ground that is largely unfrozen.

1933, The Tatonduk-Nation district, Alaska: U.S. Geol. Survey Bull. 836-E, p. 347-443.

Much of the alluvium and upper part of the bedrock has a temperature below the freezing point of water. At many localities, therefore, a water table is not present. Moss and other vegetation not only insulate the ground from summer heat, but they tend to retain precipitation at the surface and diminish the supply of water available to the zone of weathering above the water table. The effects of chemical weathering are thereby reduced.

1934, Mineral deposits of the Rampart and Hot Springs districts [Alaska]: U.S. Geol. Survey Bull. 844-D, p. 163-226.

The alluvium is generally permanently frozen to a considerable depth. Near large streams which do not freeze to the bottom in winter, the alluvial deposits are thawed some distance back from their banks. Where water from hot springs comes to the surface, the heat is sufficient to keep the ground unfrozen.

Aufeis deposits on Minook Creek below Slate Creek remain until late summer at a wide place in the valley. The aufeis may be self-perpetuating because at spring breakup its presence in the river flood plain tends to cause the stream to erode its banks, thus widening the flood plain.

On Hunter Creek, Rampart district on claim 17 above Discovery claim (Discovery is 8,000 ft above mouth of creek) the section consisted of 1–40 ft of frozen muck overlying 2–12 ft of frozen gravel. The gravel contained many lenses and dikes of ground ice. The muck and gravel on claims 14–28 above Discovery, but especially opposite the mouth of Dawson Creek, are frozen. Ground on Lawson Creek is frozen. Placer ground as deep as 30–40 ft on claim 8 above Discovery on Little Minook Creek is frozen, but is worked by open-cut methods.

Discovery claim on Little Minook Junior Creek is at the mouth, and the forks are at claim 25 above Discovery; frozen gravel 4–5 ft thick on claim 18 above Discovery is overlain by 18–25 ft of frozen muck and "slide rock." Winter drift mining on this creek was hampered by presence of water in the locally thawed ground.

Much of the relatively shallow ground on Hoosier Creek is mined by drifting in the frozen alluvium and muck. Frozen ground was encountered in placer mining along the bed of Slate Creek about 2 miles above its mouth.

In the Eureka district, Pioneer Creek flows on a bed of gravel that is 40 ft deep and frozen opposite Jordan Bar and Last Bench. Stream gravel of upper Eureka Creek also is deep and frozen. McCaskey Bar, on the end of the spur between Pioneer and Kentucky Creeks, consists of frozen gravel covered by 15–18 ft of frozen overburden. The section on Seattle Creek consists of 8–30 ft of frozen gravel overlain by 1–3 ft of frozen muck. Gold Run, tributary to Rhode Island Creek, has a pay streak covered by a partly frozen overburden consisting of 15–18 ft of gravel and 2 ft of muck; water present in the underground workings made timbering necessary. Headwater reaches of Hutlinana Creek have deposits of deep unfrozen gravel that cannot be mined on a small scale.

In the Tofty area, in the east bench of Sullivan Creek just above the town, a cut exposed 3–12 ft of gravel overlain by 43–52 ft of muck, all of which is frozen. On the west side of Innesvale Gulch a drift mine is working in a section of frozen deposits consisting of an upper 30 ft of black muck, 60 ft of muck containing fine gravel, and 5–6 ft of gravel on bedrock. On American Creek near the mouth of Colorado Gulch 7–8 ft of frozen gravel is overlain by 5–7 ft of frozen muck.

Mertie, J. B., Jr., 1936, Mineral deposits of the Ruby-Kuskokwim region, Alaska: U.S. Geol. Survey Bull. 864–C, p. 115–245.

Placer ground on Long Creek and Bear Gulch is generally frozen. Deposits on upper bench claims, such as Mascot, Windy, Deacon, and Emil, are generally frozen, but some water was encountered in patches of thawed ground, and pumping is necessary at some mines. From the Novikaket Association claim downstream on Long Creek, considerable thawed ground was found, and both timbering and pumping are increasingly necessary. A block of frozen ground on Novikaket Association claim was being mined by drifts from a shaft that penetrated 40 ft of muck before encountering 5 ft of gravel on bedrock. Placer deposits with a thin overburden of muck on Greenstone Creek are reported frozen. Frozen ground is reported on Monument Creek near the confluence of Rabbit Creek where bedrock lies beneath 15 ft of gravel and 25 ft of surficial muck. The upper part of Swift Creek has unfrozen gravel overburden, but downstream from Discovery claim the 16–20 ft of overburden requires prospecting by drifting at the base of shafts. Placer gold on bedrock beneath 10–20 ft of gravel and 60–70 ft of muck occurs on Meketchum Creek; the ground is frozen to bedrock. Placer deposits on upper Trail Creek consist of both frozen and unfrozen gravel beneath 30–35 ft of muck; no apparent relationship was noted between distribution of frozen ground and proximity to the creek. Placer ground in the lower course of Glen Gulch was frozen; bedrock was at a depth of 35 ft.

Ground in the benches bordering Poorman Creek is generally frozen, but thawed ground containing water occurs along the north side. On Solomon Creek 60-ft shafts encountered frozen ground to bedrock. On Poorman just below Solomon Creek the ground is frozen solidly to bedrock at a depth of 70 ft.

On Flat Creek, Poorman district, a shaft at claim 2 above Discovery indicates 37 ft of frozen muck overlying 18 ft of frozen gravel on bedrock. Nearly 55 ft of frozen muck, locally containing ice, occurs on bedrock at claim 2 above Discovery on Moose Creek near Placerville. Ground being worked on Cripple Creek in 1933 consisted of unfrozen muck 2–12 ft thick overlying 5–6 ft of gravel. On Colorado Creek, east of the workings on Cripple Creek, the overburden ranges from 3 to 20 ft thick and is frozen.

Placer deposits on Ophir Creek, Innoko district, are generally less than 35 ft thick; although most of the ground is frozen, there is a thawed zone in the middle of the pay streak at many places that prevents mining by underground methods. Wedges and masses of ice are found in the muck that forms part of the overburden. Placer ground on upper Little Creek consists of frozen creek placers and bench placers, with a thawed zone in the bench deposits. Frozen ground occurs in Little Creek between 2 and 3 miles above its mouth. The dredge operating in 1933 between claims 13 and 17 above Discovery on Ganes Creek has encountered thawed ground along the creek in all but claim 17.

On Hidden Creek, tributary to Nixon Fork (Takotna River), bedrock depth increases from 12 ft upstream to 200 ft in a short distance; the overburden consists of sticky mud overlying 45 ft of angular gravel.

In the Iditarod district, ground on Willow Creek is frozen, but that along Happy Creek, a tributary of Willow Creek, is 80 percent unfrozen. The semiresidual placers derived from monzonite on Chicken Creek and other streams are unfrozen. Much of the ground on Otter Creek is frozen.

1937a, The Kaiyuh Hills, Alaska: U.S. Geol. Survey Bull. 868–D, p. 145–178.

After deposition of gravel on bedrock extensive silt deposits were laid down on the gravel in the Yuko, Kluklaklatna, and Sulatna Valleys. Most of the silt deposits are frozen from top to bottom and contain wedges and lenses of ground ice which have been formed subsequent to deposition of the silt.

Except near the larger streams where running water keeps the ground unfrozen for some distance back from the banks, most of the ground is permanently frozen. The fact that ground water is immobilized as ice sharply reduces the amount of chemical weathering. However, certain of the granite rocks are deeply weathered, a condition due either to preglacial conditions in which permanently frozen ground was absent or to locally unfrozen ground in which ground water can circulate freely.

1937b, The Yukon-Tanana region, Alaska: U.S. Geol. Survey Bull. 872, 276 p.

Most of the ground is permanently frozen to great depths, except along the larger streams where circulating ground water has thawed the ground, locally, for several hundred feet from the bank. The frozen condition originated during the ice age when the climate was colder, and is preserved partly through the insulating layer of moss. The frozen soil prevents percolation of ground water, thereby encouraging growth of a more lush cover of vegetation than is warranted by the semiarid climate.

In the interior of Alaska the silt or muck deposits and underlying gravel are both likely to be frozen. The silt is more likely to be solidly frozen than the gravel. The silt contains beds and lenses of clear ice. The mean annual temperature of 9° below the freezing point is sufficient to form ground frost.

The customary distinction between the water table and the zone of weathering above the water table is in this region hardly valid, for much of the subsurface water, where present, is frozen. Hence the solvent and depositional effects of circulating ground water are almost lacking, and the chemical effects of oxygen and carbon dioxide are sharply restricted, because these reagents are not carried in solution. Chemical weathering, therefore, is much less important as an agent of weathering than in regions farther south.—Author's report, p. 194–195.

Most of the alluvial deposits were frozen in Pleistocene and Recent times, except where gravel lies close to or below the level of present streams. In such places the gravel may be thawed in irregular patches by cold water of the stream. Bench deposits of alluvium are generally solidly frozen. It is characteristic of buried placers that they are thawed and require timbering and pumping to be worked by underground methods. Deposits of recent stream placers are generally unfrozen, to a large extent.

Mertie, J. B., Jr., 1938a, The Nushagak district, Alaska: U.S. Geol. Survey Bull. 903, 96 p.

A water well drilled for Alaska-Portland Packers Association at Snag Point near Dillingham, on Nushagak Bay, penetrated frozen ground to a depth of 8–10 ft and encountered lenses of ice at irregular intervals. Drilled in 1927 to a depth of 213 ft, the well developed artesian water which rose to 15 ft below the surface from the contact between fluvial deposits and the underlying Nushagak formation.

At Clark Point, a 186-ft well drilled for Columbia River Packers Association a few hundred yards east of Nushagak Bay encountered a 2- to 3-ft ice lens between depths of 20 and 30 ft; other thicker ice lenses were encountered at greater depth. Beneath the lowest ice lens, at a depth of 175 ft, a flow of coffee-colored water, full of mossy detritus, was obtained; the water was unpalatable. Gravel was found in the bottom of the hole, and bedrock was not encountered.

1938b, Gold placers of the Fortymile, Eagle, and Circle districts, Alaska: U.S. Geol. Survey Bull. 897–C, p. 133–261.

Placer ground on Walker Fork is frozen and must be thawed ahead of the dredge. Much of the alluvium of Wade Creek is not completely frozen, so that it has been inadequately prospected by shafts and has not been drilled; it consists of a few to 10–12 ft of partly frozen gravel overlain by a veneer of muck as much as 20 ft thick, the thickest accumulation being along the sides of the valley. On Chicken Creek from Myers Fork downstream the alluvium is frozen and consists of a few to 20 ft of muck on 5–15 ft of gravel, but near the creek the alluvium is 40–50 ft or more thick and much of it is thawed. A shaft on claim 5 below Discovery, and 150 ft from Chicken Creek, penetrated 16–17 ft of muck and ice and 7–8 ft of gravel on Tertiary bedrock. On claim 3 below Discovery, 21 ft of frozen alluvium was encountered in a shaft near Chicken Creek. Dredging on Mosquito Fork near Chicken in 1936 was done in the riverbed and along the south bank, where a narrow strip of unfrozen ground occurred.

Broken Neck Creek, a tributary of Seventymile River, has a bench along its western side 20 ft above the stream; the bench deposits are frozen. Placer deposits on Fourth of July Creek, tributary to the Yukon River, are frozen; the muck is sluiced off and the gravel allowed to thaw naturally before mining.

In the Circle district on the North Fork Harrison Creek the gravel is 4–12 ft thick and is unfrozen.

Frozen ground occurs in placer ground on upper Portage Creek, tributary to Crooked Creek, near Circle Hot Springs. Alluvial deposits on placer ground on Coal Creek, tributary to the Yukon River, are 5–18 ft thick and are covered by 5–10 ft of muck; these deposits are frozen.

Mertie, J. B., Jr., and Harrington, G. L., 1916, Mineral resources of the Ruby-Kuskokwim region [Alaska]: U.S. Geol. Survey Bull. 642–H, p. 223–266.

On Long Creek the gravel deposits are generally frozen, but on the Mascot Bench thawed ground was encountered. On lower Spruce Creek, a tributary of Sulatna River, the ground is generally frozen to bedrock at a depth of 55–70 ft, but at least in one place thawed ground with circulating water was encountered. On Trail Creek placer shafts expose 30–35 ft of frozen muck and gravel on the upper reaches of the creek. Deep ground on Glen Gulch is frozen. On Birch Creek, between Straight and Crooked Creeks, efforts at mining and prospecting have been rendered ineffective because of live water in the thawed ground which is commonly encountered below 80 ft.

The deposits of Poorman Creek are 45–80 ft deep and are frozen to bedrock. In the Iditarod district the gravel deposits of Willow Creek are unfrozen.

1924, The Ruby-Kuskokwim region, Alaska: U.S. Geol. Survey Bull. 754, 129 p.

In the Ruby district numerous isolated mounds occur on gentle slopes in wide valleys near the streams. They occur in Little Dome, Poorman, Tamarack, Glacier, and Main Creeks. The mound in Main Creek, 5½ miles southwest of Dead Man Hill, is 25 ft high and has a spoon-shaped depression 10 ft deep on the top. A small stream of water flowed from the depression through an outlet on its northeast side. Bedrock is at least 50 ft deep, and the mound is composed of fine sand or silt. Although the origin is not clear, the mound on Main Creek may have formed as the spring brought up fine material from below. The mounds on Poorman and Glacier Creek may be remnants of an old alluvial fill.

Ground ice in sheets and lenses ranging in thickness from a few inches to several feet occurs in the frozen silt that underlies stream valleys and lowlands throughout practically the entire area. The ice probably is formed in several ways: (1) by sealing small shallow lakes with vegetation, (2) by freezing of water along lines of parting in silt, with a later thickening of these thin ice seams by the freezing of water that has percolated downward, and (3) by gullying, filling the gully with sediment and vegetation and ice, and subsequent shifting of the gully-forming stream elsewhere.

On Long Creek the placer ground is generally frozen, but on the Mascot bench thawed ground was encountered. Only one occurrence of thawed ground and water is reported on Spruce Creek; at all other prospects and mines the materials are frozen to bedrock. Placer ground on Trail Creek consists of 30–35 ft of frozen muck and gravel. The deep ground on Glen Gulch, tributary to Flint Creek, is frozen.

Mining and prospecting on Birch Creek are made difficult by thawed ground and live water encountered below 80 ft. The section on Poorman Creek consists of 2–12 ft of gravel at the base, ½–12 ft of fine sharp gravel, and muck with ice lenses to the surface; the entire section is frozen.

Otter Creek, tributary to Iditarod River, has frozen ground in the creek gravel being dredged, and thawing is required ahead of the dredge.

Mertie, J. B., Jr. *See also* Smith, P. S., 1930.

Mikhailova, M. P., and Tolstikhin, N. I., 1946, Mineral springs and mud lakes of eastern Siberia and their hydrogeology and medicinal use at health resorts [Mineral'nye istochnik i griazevye ozera vostochnoi Sibiri i ikh gidrogeologiia i kurortologicheskoe lecheni]: Materialy geologii i polezmy iskopaemym, Vostochnoi Sibirim Biull. 21.

Miller, D. J., 1946, Copper deposits of the Nizina district, Alaska: U.S. Geol. Survey Bull. 947–F, p. 93–120.

Tunnels driven at 4,000–4,400 ft a mile east of the head of Glacier Creek lead to workings of the Erickson prospect. Ice fills a 55-ft-deep winze that leads down from the workings accessible through tunnel 2.

Miller, D. J., Payne, T. G., and Gryc, George, 1959, Geology of possible petroleum provinces in Alaska, with an annotated bibliography by E. H. Cobb: U.S. Geol. Survey Bull. 1094, 131 p.

A water well at the Alaska Native Service hospital at Bethel penetrated 403 ft of permafrost and extended 300 ft below sea level, encountering possible sandstone between 450 ft and the bottom of the well at 454 ft.

Gas was encountered at a depth of 122 ft in a well at Hastings Creek, east of Nome. At Kotzebue, a test well encountered gravel and blue mud from 0 to 79 ft, thawed gravel containing salt water from 79 to 83 ft, frozen blue clay containing sand and gravel from 83 to 238 ft, and thawed brown silt saturated with salt water from 238 to 325 ft. At 238 ft gas under high pressure was encountered. Gas chiefly methane, was encountered at the base of permafrost at approximate depth of 200 ft in a water well at Seaton's on the Alaska Highway near the Canadian boundary; another well in this vicinity was drilled 350 ft and encountered gas between 195 and 220 ft and 250 ft of permafrost.

On the Arctic coastal plain, wet ground conditions, despite low precipitation, are caused by the impermeable permafrost which extends from a few inches to about 1,000 ft deep.

Miller, M. M., 1953, Glaciothermal investigations on the upper Taku Glacier, Alaska [abs.]: Alaskan Sci. Conf., 4th Juneau 1953, Proc., p. 236.

Englacial temperatures were taken to a depth of 170 ft in boreholes at 4-month intervals. Maximum penetration of the annual temperature wave at the 3,600-ft elevation was 65 ft. Minimum persistent firn temperature in the chill zone was −9.5°C. Dissipation of "the annual chill zone" involved a simultaneous rise in temperature from both above and below. The ablation season approximates the period of isothermal conditions, during which a water table fluctuates between 50 and 80 ft beneath the surface.

Mining and Scientific Press, 1909, Nome, Alaska—Artificial freezing of flooded mines, etc.: Mining and Sci. Press, v. 99, p. 315.

In the Nome region underground workings in unconsolidated deposits were kept stable by freezing by ventilation during the winter. In June a geyser broke from the shaft of the Bessie Mine, sending a column of water 70 ft in the air. The flood subsided only when nearly all the contiguous workings were drowned out, the operators and miners barely escaping with their lives. The flow of water was 6–10 miner's inches. The ammonia freezing method was used to shut off the water, and its cost on one claim was $1,000 and 8 days' time. The owners combined to start a 2-mile drainage tunnel leading to the sea to prevent a recurrence of the disaster, caused apparently when a steam point penetrated the frozen walls of the shaft or drift, causing ground water to emerge under pressure.

Misener, A. D., 1949, Temperature in the Canadian shield: Canadian Inst. Mining and Metallurgy, v. 42, no. 446, p. 280–287; Trans., v. 52, p. 125–132.

Moffit, F. H., 1905, The Fairhaven gold placers, Seward Peninsula, Alaska: U.S. Geol. Survey Bull. 247, 83 p.

Permafrost is reported in the fine-grained overburden in placer mines on Inmachuk, Kugruk, and Kiwalik Rivers and their tributaries. The greatest depth of permafrost is not known, but near Nome the base of permafrost in gravel is about 90 ft deep, and at Chicago Creek in the Kugruk basin it was much deeper.

1906, Gold mining on Seward Peninsula [Alaska]: U.S. Geol. Survey Bull. 284, p. 132–144.

Shafts 30–50 ft deep for prospecting buried beach placers on Little Creek near the railroad from Nome show that the muck is 12–23 ft thick, and that the deposits are frozen from the moss downward.

1907, The Nome region, Alaska: U.S. Geol. Survey Bull. 314–G, p. 126–145.

As a rule the deposits of the beaches and of the tundra in general are frozen from top to bottom, but there are places where this is not the case. One such area is located near the intersection of the third beach and Holyoke Creek and has caused difficulty in working the Bessie Bench claim because of the large amount of water circulating through the gravel. The boundary between the thawed and frozen ground was here located by drilling, and care was taken not to bring the workings too close. Thawed ground is in some places overlain by frozen ground and here and there is underlain by it also. The reason for the presence of unfrozen areas is not entirely understood, but they are probably due in part at least to the circulation of water through the gravel.—Author's report, p. 136.

1909, Mining in the Kotsina-Chitina, Chistochina, and Valdez Creek regions [Alaska]: U.S. Geol. Survey Bull. 379–D, p. 153–160.

Some of the bench gravels on Daisy Creek, Chistochina district, were found to be frozen.

1911, The upper Susitna and Chistochina districts [Alaska]: U.S. Geol. Survey Bull. 480–E, p. 112–127.

On Slate Creek, Chistochina district, the first three claims above the mouth are difficult to work because of the depth of gravel and large amount of water; a hole 21 ft deep failed to reach bedrock. On claims 4, 8, and 9 above, the bank on the south side of the creek consists of 5–25 ft of frozen talus which overlies glacial deposits.

1912a, Headwater regions of the Gulkana and Susitna Rivers, Alaska, with accounts of the Valdez Creek and Chistochina placer districts: U.S. Geol. Survey Bull. 498, 82 p. *See* annotation, Moffit, F. H., 1911.

1912b, The Chitina copper district [Alaska]: U.S. Geol. Survey Bull. 520–C, p. 105–107.

On Rex Creek, a northern tributary of Chititu River, frozen gravel was encountered in the placer mine on the lower reaches of the stream.

1913, Geology of the Nome and Grand Central Quadrangles, Alaska: U.S. Geol. Survey Bull. 533, 140 p.

Frozen ground occurs in placer mines on Anvil Creek. On Bourbon Creek the frozen ground occurs in gravel away from the stream course. Underground

cavities, or sinks, in limestone are the loci of moving water, and on Dexter Creek gold-bearing gravel has been found to a depth of 30 ft in a sink. At the Snowflake claim, near Dexter, frozen ground extends to a depth of 90 ft, beneath which the ground is dry. The tundra exposed in the escarpment facing the modern sea beach is locally frozen. All the deposits of the second beach are permanently frozen from the surface down. Gravel of the third beach is generally frozen from top to bottom; however, locally there is no frost. No system to the distribution of unfrozen zones has been discovered. The unfrozen zones are reservoirs for collecting surface water which, when tapped from below during mining, can flood workings. Presence of unfrozen ground is believed due, in part, to the circulation of water through the ground; it seems more probable that the thawed areas have been slowly encroaching on frozen areas, than the reverse. Deposits of the submarine beach are frozen. The so-called Monroeville beach deposits are overlain by 50 ft of frozen gravel and muck.

Moffit, F. H., 1927, Mineral industry of Alaska in 1925: U.S. Geol. Survey Bull. 792–A, p. 39.

In the Kobuk Valley, gold placers on California, Dahl, and Lynx Creeks and the Shungnak River are in ground that is unfrozen in places; seepage water is a problem in most areas of unfrozen ground.

1934, The Suslota Pass district, upper Copper River region, Alaska: U.S. Geol. Survey Bull. 844–C, p. 137–162.

Extensive underground drainage is shown by the disappearance of streams, which sink into their beds of gravel, and by their reappearance as springs. A large landslide between Platinum and Totschunda Creeks has formed a lake on one side, and below the slide are two cold mineral springs with which are associated with deposits of calcareous tufa. Ore deposits on the Bear vein of the White Mountain mine of Nabesna Mining Corp. are perennially frozen.

1937, Recent mineral developments in the Copper River region [Alaska]: U.S. Geol. Survey Bull. 880–B, p. 97–109.

Crushed frozen vein matter is found in the upper workings of the mine of Nabesna Mining Corp. on the mountain between Jack and Jacksina Creeks, Nabesna Valley. Water for mill operation is obtained from springs near camp and in winter freezing in the pipeline is prevented by a parallel line in which hot water is circulated.

1938, Geology of the Chitina Valley and adjacent area, Alaska: U.S. Geol. Survey Bull. 894, 137 p. [1939].

The Pleistocene and Recent unconsolidated deposits of the Copper River lowland are frozen a short distance below the surface, and little underground drainage occurs. Attempts to obtain a supply of well water in this lowland have failed at different places.

1941, Geology of the upper Tetling River district, Alaska: U.S. Geol. Survey Bull. 917–B, p. 115–157.

Prospect holes sunk along a segment of Cheslina Creek for a distance of 2 miles above the forks and on benches of different height show that thawing was used, but it is not known whether it was used to eliminate seasonal frost or permanent frost. The shafts show thick surficial deposits of silt or muck, which were filled with water at the time of the visit.

1943, Geology of the Nutzotin Mountains, Alaska, with a section on the igneous rocks by R. G. Wayland: U.S. Geol. Survey Bull. 933-B, p. 103-174.

Placer deposits that lie in old channels at various levels above Bonanza Creek, Chisana district, consist of frozen gravel, silt, and slide rock. Claims 3 and 6 are being worked in frozen alluvium. The older volcanic rocks in the valleys of Gravel and Baultoff Creeks are leached white or are strongly colored by the agency of circulating water; many of the small tributaries of these valleys are charged with iron oxide. Some of the springs are undrinkable, and are so acid that they corrode a hammerhead with a few minutes' immersion.

1954, Geology of the eastern part of the Alaska Range and adjacent area: U.S. Geol. Survey Bull. 989-D, p. 63-218.

Most of the unconsolidated deposits are perpetually frozen to a depth of many feet, except a shallow surface zone that thaws in summer. Efforts to obtain water from dug wells have not been successful except from shallow wells near stream courses, some of which cannot be used in winter. A well at Kenney Lake on the branch road leading from the Richardson Highway to Chitina was reported many years ago to have been sunk 80 ft in frozen ground without finding water and gradually was closed by the formation of ice. More recently several holes were drilled between Copper Center and Gulkana in an effort to get water for use at the new airfield. It is reported that the drill went through about 190 ft of frozen ground and then entered unfrozen gravel that yielded water. The water at that place, however, was too strongly charged with mineral substances to be usable.—Author's report, p. 157.

Frozen ground occurs on Ober Creek, Delta River district, and in the Chisana mining area. At the Nabesna mine the Bear vein, which crops out at an approximate elevation of 4,000 ft, consists of angular fragments embedded in a matrix of ice.

Moffit, F. H., and **Capps, S. R.,** 1911, Geology and mineral resources of the Nizina District, Alaska: U.S. Geol. Survey Bull. 448, 108 p.

A "pothole" at the lower end of Kennicott Glacier marks the lower end of a subglacial channel from which the Kennicott River emerges as a giant spring. When frozen during especially severe winters, water is backed up beneath the glacier until its pressure breaks the ice barrier and causes winter floods as far down the Chitina River as its confluence with the Copper River.

Rock glaciers contain interstitial ice ranging in depth from a foot or two in the high cirques to below the level of easy excavation at their lower end.

Joints and fractures in the copper deposits of Bonanza mine are filled with ice, as is also the loose talus material below the mine.

Moffit, F. H., and **Maddren, A. G.,** 1908, The mineral resources of the Kotsina and Chitina Valleys, Copper River region [Alaska]: U.S. Geol. Survey Bull. 345-C, p. 127-175.

A tunnel driven on the west side of Ames Creek, tributary to Kotsina River, encountered frozen slide rock at an elevation of 1,400 ft. A tunnel at One Girl claim, on the west slope of the hill between Nugget Creek and Kuskulana Glacier, encountered 91 ft of frozen slide rock, before reaching solid greenstone. The auriferous bench gravel deposits on Chititu Creek, Nizina drainage, are not frozen.

Moore, E. W., 1949, A summary of available data on quality of Arctic waters: Natl. Research Council, Div. Med. Sci. Rept. to Subcomm. on Water Supply of the Comm. on Sanitary Eng. and Environment, 14 p.

Wells in Yukon Territory, Canada, near rivers yield water of good quality; those in permanently frozen ground freeze up in winter and cannot be relied on for permanent water supplies. Analyses of ground water from sandpoints in permafrost near Mayo and from a shallow well near Klondike River (Dawson area) show, respectively, 132 and 148 ppm dissolved solids, including 0.07 and 0.02 ppm iron.

Analyses of shallow ground water in permafrost regions of Northwest Territories, Canada, are given for Fort Resolution and Sawmill Bay, and other sites in which total calculated dissolved solids range from 486.7 to 3,600 ppm. The waters are hard and contain much iron; they contain organic matter, ammonia, and albuminoid nitrogen. Wells in permafrost seem to be unreliable in both yield and quality of the water.

Anaylses of ground waters at Ladd A.F.B. (well 6), Tanana, Anvik, and Sinuk, Alaska, are given; dissolved solids range from 178 to 458 ppm, including iron content of 0.03–11.8 ppm. The waters are apparently moderate to high in hardness and mineralization.

1950, Summary of additional data on Alaskan waters: Natl. Research Council, Div. Med. Sci. Rept. to Subcomm. on Water Supply of Comm. on Sanitary Eng. and Environment, app. E, 25 p.

Ground waters of Alaska are moderate to high in hardness and mineralization; some contain considerable iron. From wells in permafrost areas the samples analyzed are 50–100 percent higher, as shown in parentheses below, and the water may be unpalatable. Except for pH, results are given in parts per million.

Silica (SiO_2)	20–30	
Iron (Fe)	0–14	
Calcium (Ca)	40–75	
Bicarbonate (HCO_3)	100–200	(400–500)
Sulfate (SO)	5–25	
Dissolved solids	150–300	(350–650)
Total hardness ($CaCO_3$)	250–400	(350–450)
Noncarbonate hardness ($CaCO_3$)	0–50	
pH	7–8	

Mordvinov, A. I., 1940, Relief and permafrost of the left bank of the middle course of the Byssa River and of the adjacent foothill zone of the western slope of the Turan Range [Rel'ef i vechnaia merzlota levobereg'ia srednego techeniia r. Byssy i prilegaiushchkh predgorii zapadnogo sklona Turanskogo Khrebta]: Akad. Nauk SSSR, Kom. vechnoi merzlota Trudy, v. 9, p. 50–134.

The top of permafrost was not encountered at a depth of 4.5 m below the bed of the Byssa River, a meandering stream flowing near the Turan Mountains (52°30′ N., about 132° E.). Permafrost was encountered, however, at shallow depth beneath former stream channels now covered with sedge hummocks and grass. Moisture content of the ground in boreholes below the areas adjacent to the riverbeds was not abnormally high, but beneath the abandoned channels the ground was supersaturated. Boreholes on opposite banks of the river show different temperatures at the same depth, the lower values occurring in the cut bank. Since the migratory cycle of a river meander is around 1,000 yr, the cut bank side has not been occupied by the river during that length of time, and has been less subject to warming action of the river. The talik follows the migration of the riverbed. The ground under the oxbow is a talik until the oxbow is filled and covered with moss.

In this valley, taliks are commonly associated with pingolike mounds; many of the taliks are of the perforating type.—From unpublished condensation and emendation by I. V. Poiré, 1949.

Morozov, K. D. *See* Liverovskii, A. D., 1941.

Moshchanskii, V. A., 1958, New data on the temperature and structure of permafrost in the Salekhard region [Novye dannye o temperaturnom rezhime i stroeni mnogoletnei merzloty v raione g. Salekharda]: Nauchn. Doklady Vysshei Shkoly, Geol.-geog. nauki, no. 2, p. 175–179.

Permafrost investigations in the region since 1927 are outlined with emphasis on data collected during engineering surveys in 1953–57. Continuous permafrost in strata to 300–500 in thick with temperatures to −4°C were observed along the left bank of the Ob' River. Data on temperature distribution in frozen strata obtained from several hundred holes indicate degradation. Permafrost thickness in the flood plain and under the riverbed varies from 15–80 m. Numerous thawed islands occur, usually in newly formed sections of the flood plain and in areas covered with trees. Double-layered permafrost was discovered along the right bank, 40–60 m thick in the upper layer and 80–100 m in the lower. The depth of the table of the lower layer varies from 90–100 m.—From SIPRE 16793.

Moxham, R. M., and **Eckhart, R. A.,** 1956, Marl deposits in the Knik Arm area, Alaska: U.S. Geol. Survey Bull. 1039–A, p. 1–23.

Test holes were drilled west and south of the shore of Lake Lucile near Wasilla; some of the holes were abandoned when permafrost was encountered.

Mukhin, N. I., 1960, Definition of the concept "thermokarst" [K opredeleniiu pontaitiia "termokarst"]: Akad. Nauk SSSR, Inst. Merzlotovedeniia im V.A. Obrucheva Trudy, v. 16, p. 108–110.

The shortcomings of existing definitions of thermokarst are discussed, and a new definition is proposed. The term "thermokarst" was introduced in 1932 by M. M. Ermolaev to describe a specific form of relief, having a certain similarity to karst formations, but resulting from the action of heat. The present definitions of thermokarst, such as "a process of differential settling or caving of the soil surface," do not properly describe its real nature and often distort it, since depressed relief may form as a result of other processes. Other definitions are too complicated, long, and contain unnecessary information. Thermokarst should be defined as the process of thawing of ice in the ground (except in bedrock), which is accompanied by the local settling of the soil surface and the formation of negative relief forms.—From SIPRE 18320.

Muller, E. H., 1952, The glacial geology of the Naknek district, the Bristol Bay region, Alaska: Illinois Univ., Ph. D. dissert. 98 p.

For formation of permafrost soil temperatures must be consistently below 32°F. Since the mean annual temperature at King Salmon is 34.9°F, permafrost cannot be forming extensively at present. However, permafrost occurs at depth and also in a few places where soil microclimates are favorable to near-surface permafrost. Conditions favoring permafrost are weak ground-water circulation and thick vegetal mat covering the silt and organic silt soils. Shallow permafrost (within 10 ft of the surface) may be formed under present climatic conditions where silty soils lie above the level of actively circulating ground water, because of lowering of the water table or differential heaving of the soils in turf mounds.

Deep permafrost is reported by Dall (1896) in bluffs near Cape Suvarov, 1 mile west of Naknek village. Observations made in 1951 at Cape Suvarov confirm the existence of permafrost. Permafrost was reported also by Mertie (1938) north of Kvichak Bay. Permafrost was encountered in a well drilled at Libbyville (located on the coast 4 miles from Naknek) where ice masses 6–8 ft thick were encountered at a depth of 40 ft. Similar ice masses were found in a second well drilled 300 ft from the first one.

The deeper permafrost may have been formed during the Brooks Lake glaciation which was followed by thawing during the thermal maximum, and the shallow permafrost may be related to the so-called Little Ice Age and the present climate, which is colder than that during which the thawing of the upper part of the deep permafrost took place.

Muller, E. H., and Coulter, H. W., 1954, Observations on the Knife Creek glaciers, Katmai National Monument, Alaska [abs.]: Am. Geophys. Union Trans., v. 35, p. 383. *See* annotation, Muller, E. H., and Coulter, H. W. 1957.

1957, The Knife Creek glaciers of Katmai National Monument, Alaska: Jour. Glaciology, v. 3, no. 22, p. 116–122.

Permafrost has aggraded and frozen the pumice from the 1912 eruption of Mount Katmai that covers the lower parts of the Knife Creek glaciers. The active layer in the pumice is 4 ft thick.

Muller, Fritz, 1959, Beobachtungen über Pingos: Medd. om Grønland, v. 153, no. 3, 127 p. [English summary.]

Pingos are cone-shaped hills rising to about 160 ft which, in active form, occur only in permafrost regions. The pingos of the area south of Werner Njerge and in the central part of Traill Ø, East Greenland, and those in the northeastern part of the Mackenzie delta, Northwest Territories, Canada, were studied.

In East Greenland the pingos are composed of a cover of mineral material 10–60 ft thick, of either bedrock or frozen loose material. Beneath the cover is an ice body of unknown size closely resembling ice of very slow moving or dead glaciers; some drill holes 40 ft deep failed to reach the base of the ice. Water and gas were rising through the ice body in some pingos. The water and gas are not of juvenile origin, but are of local meteoric origin; the high content of mineral salts in the water supports the hypothesis of a subpermafrost and intrapermafrost origin, both water and gas having been stored below and within the permafrost for a long time. The East Greenland pingos develop where subpermafrost or intrapermafrost waters penetrate into the permafrost zone, forced up by hydrostatic pressure, with a small temperature difference between this water and the frozen ground, and at a low rate of flow. Within the upper permafrost zone the rising water produces a hydrolaccolith, which, with further reduction of temperature becomes the ice body. The pressure of crystallization of this process together with hydrostatic pressure will exceed the pressure and force of cohesion of the overlying layers of frozen or unfrozen materials. Except where the water rises along fissures which weaken permafrost, the upward forces are concentrated within a small area, and the resulting pingo will be of volcanic shape.

The formation of subsidiary pingos and secondary springs with an initial high concentration of mineral salts is explained by a "cold accumulation" within the mature main pingo. The destruction of these pingos is caused by (1) rupturing of the top during growth; (2) melting of the ice by the summer warmth penetrating through a weakened mineral cover; (3) the subpermafrost and intrapermafrost water rising through and melting the ice body and feeding the lake; and (4) overflow from the lake breaking down the containing walls. The chief genetic force, hydrostatic pressure, is the result of the altitude of the surrounding mountains.

In the Mackenzie delta region, the pingos occur on gently rolling, subdued landscape with little relief, and are concentrated in the geometric center of shallow lakes or former lake basins. The structure was like that of the East Greenland pingos, namely a cover of mineral matter consisting of clay with peat overlying the older deltaic sand, beneath which lay the ice body. The physical properties of the ice were like those of East Greenland ice. No outflow of subpermafrost or intrapermafrost water was observed. In the Mackenzie delta, the pressure which results in updoming is developed by the penetration of the permafrost into "talik" normally beneath a lake. When permafrost advances above a water-bearing stratum, a closed system is set up; the water trapped under increasing pressure, as the gap closes, initiates the upward growth of the pingo. Its destruction is caused chiefly by melting of the ice body by the outside warmth.

The name pingo is preferred to bulgunniakh. In East Greenland and probably also in the Mackenzie delta the permafrost is about 300 ft thick. A belt of pingos occurs between 65° and 75° N., where the permafrost is still continuous but thinning out. The pingos of East Greenland are formed under an open system; those of the Mackenzie delta are formed under a closed system. Those in East Greenland develop because of an increase or new formation of talik, signifying a local degradation of permafrost; in contrast, the Mackenzie delta pingos are formed through a decrease in talik space and, thus, an aggradation of permafrost.

Muller, S. W., 1945, Permafrost or permanently frozen ground and related engineering problems: U.S. Army, Office, Chief of Engineers, Mil. Intelligence Div., Spec. Rept., Strategic Eng. Study 62, 231 p.; repr., 1947, Ann Arbor, Mich., J. W. Edwards, Inc.

This summary of the progress and results of Russian work and of other foreign and American sources includes sections on definitions and glossary of terms, origin, geography, thickness, climatic effects, thermal regime, hydrology, and ice content of frozen ground; destructive action, including icings; engineering problems in construction of buildings, roads, bridges, airfields, dams; problems of water supply; and means of conducting permafrost surveys in engineering projects.

Hydrology of frozen ground is the study of the amount of surface and ground water, direction and rate of flow or percolation, source of water, and changes of phase of water from liquid to solid and from solid to liquid. The flow of rivers is controlled by the nature of the source of water; those rivers that are largely fed by deep springs or underground channels have a fairly uniform flow throughout most of the year. Large rivers that do not freeze solid in winter have a warming effect on the underlying riverbed; the ground beneath them is unfrozen and commonly contains freely percolating ground water. Water-bearing strata may also occur beneath streams that are completely frozen. Thawed ground occurs beneath some lakes. Ground near large rivers and lakes should be prospected thoroughly when water supplies are sought. Unfrozen zones in river ice may be an indication of springs, which may be suitable as year-round sources of water. Icings or naledi are formed during winter freezing, as the river channel becomes constricted and too small to pass the volume of water contained in the river. The confined water permeates the porous alluvium bordering the stream and, ultimately, reaches the surface either through the ground bordering the stream or through cracks in the ice. The water then forms sheets on the river ice, where it freezes. An icing mound may be formed at the point at which the water emerges from the ground or from the river ice.

Intermittent springs are fed by precipitation and by melting ice and snow, and may also occur where the freezing of superficial ground exerts pressure on water-saturated layers below and forces water to the surface. Springs fed from within or below permafrost are generally perennial and, if not mineralized, are excellent sources of water.

Ground water in permafrost regions consists of water above the permafrost (suprapermafrost water), water within the permafrost (intrapermafrost water), and water below the permafrost (subpermafrost water). The water above permafrost has its source in rain or melt water, surface water, vapor that condenses near the cold surface of the ground, and seepage from within and beneath the permafrost; most of the water freezes in winter, but where the permafrost table lies deeper than the base of winter freezing, some water remains liquid all winter. Suprapermafrost water moves by gravity and percolates down slopes of the irregular surface of the frost table. In winter, as the ground freezes from the surface, the suprapermafrost water becomes confined at a pressure proportional to the thickness of the overlying frozen part of the active layer. Under pressure the water may emerge at the surface to form icings, or may be wedged between the frozen and unfrozen layers where it freezes to form ground ice. The water may split already-frozen layers. The water above permafrost is the main cause of swelling ground, frost mounds, and icings, and does not provide reliable water supplies.

Water within permafrost is fed by either infiltration of surface water or water from below the permafrost, or both. It is commonly in considerable volume, and may yield a steady supply of ground water. In certain areas, especially along the Arctic coast, the water within permafrost is strongly mineralized and remains fluid even though the surrounding ground has a temperature below 0°C. Water within permafrost is always fluid and is generally under considerable hydrostatic pressure. It is common in alluvial fans at the bottom of recent and old valleys, and even in bedrock. Water beneath permafrost is a good water supply, except where strongly mineralized, but is difficult to obtain where more than 100 m of permafrost must be penetrated.

Search for suitable springs should be carried out at the "critical period" at the close of winter, when the ground is frozen to its maximum depth. Springs may be recognized by seepages, icings, and frost mounds.

Water above permafrost can furnish constant supplies only when the seasonal frost does not extend to permafrost in winter. Favorable sites are located along the banks of large rivers, in oxbow lakes, lakes with constant inflow and outflow, flood plains of large rivers and their lower terraces; the most common occurrence of water is in the riverbed beneath the stream or near the edge of the stream. Water above permafrost also may occur at the mouths of valleys and the heads of alluvial fans. Maximum yield of suprapermafrost sources is measured in the autumn; minimum yield is determined during the "critical period" of spring. Yield during the winter is determined by pumping tests, of at least 10–15 days' duration, accompanied by chemical analysis. Prospecting for suprapermafrost water should be supplemented by study of aquifer fluctuations of water level, quality of water, temperature, rate of freezing, all correlated with meteorological data. These waters are easily contaminated and require protection of the surface area.

Water within permafrost occurs most frequently in thick alluvial deposits near rivers or old river channels, but it is found also in strongly jointed rocks, along faults, or in rocks cut by veins and dikes. It may be found in alluvial fans and in areas with widespread ground ice, and is frequently encountered near springs fed by water from beneath the permafrost. Water within permafrost occurs chiefly in the southern part of the permafrost zone. It percolates through permeable layers or flows through pipelike fissures. If developed, care must be taken to avoid overpumping which might reduce the flow to the point where the waterbearing layer will freeze.

Water from below permafrost is most dependable and usually is of good quality and abundant. Prospecting requires a thorough hydrogeologic survey to determine the extent of permafrost, its continuity, and temperature. Attention should be given to large nonfreezing springs, wet icings, "hydrolaccoliths," existing deep drill holes, and their relation to the geologic structure. Deep water is generally warmer than shallow water and can be piped a considerable distance without the danger of freezing. Alluvial water below permafrost may be found in broad valleys of large rivers where alluvial deposits are thick and not completely frozen; there is little chance of water occuring in valleys where the alluvium is thin and permafrost thick. In east-west valleys (in southern Eastern Siberia and the Far East) exploration should proceed from the foot of the south-facing slope toward the middle of the valley. In north-south valleys test holes should be placed near the river channel and extended toward the valley margin which receives the greatest insolation; if seepage of water from beneath permafrost is noted at the foot of the slope, prospecting should be started from the spring. The depth of drill holes should be not less than the distance to the base of permafrost. Best results are obtained by penetrating the entire thickness of alluvium and 1–2 m of bedrock and spacing holes 50–200 m apart across the valley; additional holes should be at distances of 500–1,000 m from the first line of holes. The aquifer is tested in February and March by prolonged pumping and measurement of water levels. Water may be found beneath permafrost in older terrace alluvium.

Water below permafrost in bedrock aquifers may be prospected in sedimentary rocks wherever the aquifer is believed to lie beneath permafrost—as, for example, in a syncline where wells are drilled in the low point. The deepest aquifer beneath permafrost generally has the warmest water. In areas of inclined beds the aquifer should be tapped well below the base of permafrost to intercept warm water. Recharge of bedrock aquifers in regions of continuous permafrost is assumed to be practically nil, unless there is evidence that it is fed from some outside source. It is important to determine the relation of permafrost islands and taliks to the aquifer and whether or not the aquifer is recharged through taliks from meteoric waters

Water beneath permafrost may occur in fissures or joints in the zone of weathering where it has a continuous water table and in fissures produced by tectonic action in which the water-bearing zones are disconnected. The best means of prospecting for water in fissures is to locate seepages or springs, or by lithologic, structural, geomorphic, or tectonic considerations—along faults, intrusive contacts, weathered zones at unconformities.

Water may occur below permafrost in solution channels in limestone. Permafrost, however, may prevent recharge from the surface, and the amount of water to replenish that pumped must come from within the rock, and depends on its porosity, structure, and areal extent beneath the permafrost.

Wells should be lined to prevent silting and caving of unconsolidated materials; they should be insulated from cold air, preferably in heated buildings. Wooden casing is subject to deformation during winter swelling of the ground. Where swelling is pronounced, wells tapping water above permafrost should have casing anchored 1–2 m in permafrost to prevent heaving of casing. In operating a well, care should be taken to maintain normal water level to prevent a change in ground-water hydrology that may result in freezing of the well or a sharp decline in the yield of water.

Drilled wells are better protected from silting and pollution and less susceptible to deformation than dug wells, but water in drilled wells, especially those of small diameter, is subject to freezing. Freezing may be prevented by developing the deeper warmer waters, by not interrupting the pumping, or by introducing a heated cable in the well. During drilling, use of heated mud or salt water in the drilling mixture will prevent freezing. Tools should be withdrawn from the hole when drilling is suspended to prevent their freezing to the walls of the well. Winter test pumping should be done in an enclosed heated building or tent to prevent freezing of pump and pipes, should pumping be suspended. Wells should be drilled where permafrost is relatively thin and where the ground temperature is high; near the southern boundary of the permafrost zone the most dependable wells are those sunk through a talik.

Methods and problems of laying water-distribution lines, means of calculating the heat distribution in underground mains, pressure tests, and hazards of freezing of the mains when the water is first turned on are summarized. An outline of necessary equipment and procedures for conducting a survey for ground water in permafrost regions is presented.

Mulligan, J. J., 1959a, Sampling stream gravels for tin, near York, Seward Peninsula, Alaska: U.S. Bur. Mines Rept. Inv. 5520, 25 p.

The ground is frozen throughout the area. The upper 1–3 ft, where covered by moss, is thawed in summer; where the ground is not insulated, the summer thaw extends deeper than 3 ft.

Holes were drilled to bedrock with Fairbanks-type churn drill, using 5-in. casing in thawed ground and an open hole in permafrost. The gravel deposits along Lost River are medium coarse, unconsolidated, and largely thawed; one hole encountered frozen ground at 6 ft. On York Creek, drilling in early July encountered no frozen ground beneath the vegetation-free streambed, but holes drilled beneath sites covered with vegetation encountered permafrost. Conditions on Anikovik River and Kigezruk Creek duplicated those on York Creek. The deposits of Baituk Creek were frozen everywhere except under the stream channels.

1959b, Tin placer and lode investigations, Ear Mountain area, Seward Peninsula, Alaska: U.S. Bur. Mines Rept. Inv. 5493, 53 p.

Except for the top few feet, which thaws during the summer, the detritus, tundra, and underlying bedrock remain permanently frozen. Thawed zones of varying extent are found within the permafrost and are believed to result from the action of surface water. The thawed zones probably make up only a very small proportion of the permafrost area.—Author's report, p. 9.

Several small springs are reported to occur near Winfield shaft. A spring that flows during winter is reported from the west bank of Kreuger Creek a short distance above the mouth of Eldorado Creek. The Winfield shaft, 29 ft deep and timbered, is on North Mountain; workings from the bottom of this shaft have apparently intercepted the old Eunson shaft, which is not open to the surface and has its upper parts choked with ice. The upper 22 feet of the Winfield shaft was filled with ice.

Drilling was done with a churn drill and frozen unconsolidated deposits as deep as 40 ft were encountered.

Mulligan, J. J. *See also* Rutledge, 1953.

Nadezhin, A. M., ed., 1934, Ground water of the USSR [Issledovaniia podzemnykh vod SSSR]: Leningrad gos. gidrolog. inst., no. 5, 121 p.

Fifth in a series that contains papers by L. F. Semenova, O. K. Lange, I. P. Gerasimov, V. IA. Grinev, V. V. Shtilmark, and E. P. Tsytovich.

Nagel', A. A., 1931, The rivers of the Nerchinsk region [Ocherk rek Nerchinsko-ravodskogo raiona]: Materialy po gidrografii, gidrologii i vodnym silam SSSR, v. 6, p. 1–126.

At Potoskui village on the Srednya Borza River the base of permafrost was measured at 32 m. Shallow stretches of rivers freeze solid and icings are formed.—From SIPRE 9006.

1937a, Pecularities of winter conditions in some rivers of Yakutia [Anomaliia v zimnem rezhime nekotorykh rechek IAkutii]: Meterologiia i gidrologiia, v. 3, no. 4–5, p. 170–171.

Ice-cover anomalies observed during the winter in the rivers and lakes of Yakutia are described. An ice-free channel between Altan and Luuku Lakes was found in December 1932, when the surrounding ice cover on the lakes was as thick as 0.6–0.7 m and air temperatures had been about −40°C for a long time. The channel was 0.2–0.4 m deep and the speed of flow measured about 0.3–0.4 m per sec. The phenomenon was possibly connected with peculiarities of ground runoff. Surface runoff is the ordinary source of water supply in the area.—From SIPRE 8694.

1937b, Karst distribution in permafrost [K voprosu o rasprostranenii karsta v usloviiakh vechnoi merzloty]: Gos. geog. obshch. Izv. v. 69, no. 2, p. 261–263.

The development of karst processes in permafrost areas is studied by tracing the ground-water movement in permafrost. Brief accounts by Kruglov, Ognev, Stefanovich, Egorov, Middendorf, and Grigor'ev on the erosive action of permafrost waters in the Lena Basin limestone deposits are presented.—From SIPRE U–2810.

1939, Concerning the winter behavior of small and medium rivers in eastern Siberia [K voprosu o zimnem rezhime malykh i srednikh rek Vostochnoi Sibiri]: Meteorologiia i gidrologiia, v. 5, no. 10–11, p. 92–99.

Observations made along the Krestovka River valley in the vicinity of Angara during the winter and spring of 1937 revealed the presence of large icing mounds scattered along the river. Studies of these mounds showed that they were formed by the freezing of successive layers of water seeping from fissures in the river ice. A majority of the icings were encountered at points along rapids, where accumulation of anchor and frazil ice and its subsequent freezing blocked the water flow underneath the ice. Theories on prevention of icing mound formation are presented.—From SIPRE U-2913.

Nazarevskii, N. V., 1937, On the permafrost, cave-in lakes, and ice mounds of Bukachachi [O vechnoi merzlote, proval'nykh ozerakh i ledianykh bugrakh Bukachachi]: Akad. Nauk SSSR, Kom. izuch, vechnoi merzloty Trudy v. 5, p. 165–178. [English Summary.]

A hydrogeological survey made of the Bukachachi region (Transbaikal, 54° N. 118°30′ E.) for possible hydroelectric installations in the Bukachachi Valley, 10 km long and 2 km wide, sloping toward the Agita River. Permafrost 68–84 m thick was found by drilling the valley floor. Two cave-in lakes are in the valley; in the larger lake are two funnels (deep places), 15.3 m and 10.2 m deep in their deepest parts. Until 1932 both the deep places contained water, but in the summers of 1931 and 1932 the water level of the lake fell suddenly and the lake became dry. In late April after melting of heavy snow, the lake filled with water, but it began to drain again despite the contributions of brooks draining into it at the rate of at least 30 liters per sec. It dropped 1 m overnight and in 10 days was dry once more. The lakebed was covered with clay which retarded drainage of the water, and a well in the deep hole did not encounter permafrost at 6.5 m. This lake apparently is a cave-in lake resulting from thaw of ground ice. Evidence for the former cover of larch forest at the site of the lake is found in numerous stumps in the lakebed. The smaller lake in an embryonic cave-in lake.

Water seeping from fractured granitic rocks feeds a number of brooks during the winter; many of these brooks have ice mounds in winter. In a well dug near one of the mounds, water encountered at 2 m started a fountain and filled the well; the water had a slight H_2S odor. Excavations were made in icing mounds on the Agita River. In one mound the ice was 1.5 m thick, and once broken the water under pressure spread over the river ice. In another, the water was under pressure and was preceded by air under pressure and contained an H_2S odor; this mound is reported to form each winter.—From SIPRE U-1750; unpublished abstract by I. V. Poiré, U.S. Geol. Survey.

Nazarov, G. N., 1959, Permafrost distribution in the watersheds of the Lower Tunguska and Stony Tunguska Rivers and in the basin of the Nyuya River [K voprosu o rasprostranenii mnogoletnemerzlykh porod na vodorazdele rek Nizhnei i Podkamennoi Tunguski v basseine reki Niui]: Akad. Nauk SSSR, Inst. Merzlotovedeniia im. V. A. Obucheva Trudy, v. 15, p. 194–211.

The results of electrical-resistance soundings and bore-hole studies conducted in 1953–54 are described, graphed, and mapped. Permafrost in the region occurs in the form of islands, generally ranging from 10 to 15 m in thickness, and covering not more than 20–35 percent of the area where the permafrost was previously thought to be continuous and 80–120 m thick. The main factors determining the distribution of permafrost are geological structure and lithology.—From SIPRE 18241.

Nesterenko, I. M., 1959, Observations on ground water during the snow melting period [Nabliudeniia nad pochvogruntovymi vodami v period snegotaianiia]: Meteorologiia i gidrologiia, no. 6, p. 31–32.

The results of observations in Karelia in soil frozen 25–35 cm deep are reported. Measurements were made in boreholes every morning before snow melting began. The ground consisted of an upper layer 20–30 cm thick of clay soil with a filtration coefficient of 0.003 cm per sec, a layer of medium to heavy clay with a filtration coefficient of 0.0002–0.00005 cm per sec, and a layer of highly mineralized peat at a depth from 40 to 45 cm, underlain by impervious clay. Water appeared in boreholes reaching below the frozen layer and was absent in those within the frozen layer, indicating the presence of water under pressure below the frozen ground. The pressure can be explained by the presence of the impervious frozen layer. In areas where ground water was under pressure, frozen soil was observed up to May 18 at a depth of 20–22 cm, while in well-drained areas, the entire frozen area disappeared by May 12–13. The difference between the speeds of thawing can be explained by the fact that seepage in porous ground displaces warm air, which accelerates thawing as it rises.—From SIPRE 17629.

Nichols, D. R., 1956, Permafrost and ground-water conditions in the Glennallen area, Alaska: U.S. Geol. Survey open-file rept. 392, 18 p.

Ground water available at a depth of 300–400 ft (beneath the surface into which the modern streams are incised 50–300 ft) is confined beneath impervious glaciolacustrine clay or permafrost; the water is commonly under considerable hydrostatic pressure. It contains 1,055 to nearly 25,000 ppm of dissolved solids, including 230 to nearly 8,000 ppm chloride. Hardness ranges from 240 to 15,500 ppm. Potable water at depth of about 200 ft may occur as local reservoirs supplied by seepage beneath the flood plains of Moose Creek and Dry Creek; this water may require some treatment.

A 65-ft flowing well is on the low terrace near the mouth of Tazlina River; the water is hard and has 695 ppm sodium and 650 ppm chloride. The Alaska Road Commission wells at Glennallen are 180 and 205 ft deep and produce potable water that requires some treatment. At Gulkana airfield, wells 330 and 433 ft deep encountered unpotable water; however, the deeper well was plugged to 293 ft, and a small supply of potable water was developed at that level. A well near mile 119, Richardson Highway, was drilled to 354 ft, but produced water containing 10,200 ppm total dissolved solids, of which 6,470 ppm was chloride. The quality of water failed to improve after 120 hr of continuous pumping at 100 gpm. Near Dry Creek two 200-ft wells are reported to have provided potable water. At Gateway Lodge a 321-ft well produced hard water which was high in chloride and other constituents. At the Territorial Police Station in Glennallen, a 90-ft well in the incised valley of Moose Creek produces the best-quality water in the area, but it is harder and more highly mineralized than the chlorinated municipal water at Anchorage.

Elsewhere, shallow wells in the Moose Creek flood plain and in marshes west of Moose Creek have been generally unsuccessful. However, a few of these wells have provided sufficient water for household use during summer and fall, but they have dried up in winter. Water from a 12-ft well at Mile 182 Glenn Highway is reported to provide sufficient quantity for roadhouse use. Wells of this type and depth generally are supplied by seepage from nearby marshes into shallow gravel deposits, and may be subject to contamination.

Nichols, D. R., and **Yehle, L. A.,** 1959, Mud volcanoes in the Copper River Basin, Alaska [abs.]: Internat. Symposium on Arctic Geology, 1st Calgary, Canada, 1960, Abstracts of papers in Canadian Oil and Gas Industries, v. 12, no. 12, p. 59.

Two groups of mud volcanoes, consisting of clayey silt cones which discharge gas and highly mineralized spring water, occur within 15 miles of Glennallen. The four cones of the Tolsona group lie west of the Copper River near coal-bearing rocks of Tertiary age; the three active cones emit methane and nitrogen gas and sodium and calcium chloride water. Three cones of the Drum group, east of the Copper River, lie near volcanic rocks of the Wrangell Mountains, and discharge carbon dioxide gas and warm sodium chloride and bicarbonate waters. Water in Tolsona springs may be a mixture of meteoric, connate, or highly saline ground water; the Drum springs may also include small amounts of volcanic water. Formation of the cones was by quiet intermittent accretion, and in the Drum cones probably included eruptive phases. Most cones formed largely before or during the last major glaciation.

Nichols, R. L. *See* Ball, D. G., 1960.

Nikiforoff, C. C., 1928, The perpetually frozen subsoil of Siberia: Soil Sci., v. 26, 61–77.

Although known in Siberia from 1672 to 1692, the first real study of perpetually frozen ground was by Middendorf in the midnineteenth century. The distribution of frozen ground in Siberia and in other parts of the Northern Hemisphere is sketched, and its thickness in Siberia ranges from several hundred feet in the north, perhaps 550–650 ft at Yakutsk, to less than 250 ft to the south near the 50th to 55th parallel. The mean annual temperature of the ground below the level of seasonal change is 0° to several degrees below zero. Where subject to seasonal change, in the upper layers, the minimum temperatures lag several months behind minimum air temperatures, the length of lag being proportional to the depth.

The problem of whether the southern boundary of permafrost in Siberia is advancing or retreating northward is unanswered; however, 16 places are known where permafrost lies so deep that it has no connection with contemporary freezing of the surface and must therefore be an inheritance from the past.

Two hypotheses have been advanced to explain origin of perpetually frozen ground: (1) that it is a result of contemporary climatic conditions and (2) that it is an inheritance from the glacial period. The hypothesis of origin through contemporary climatic processes is suggested by the close correlation between the southern boundary of perpetually frozen ground and the line north of which the mean annual temperature is considerably below 0°C. Wild, who in 1882 first proposed the hypothesis that the ground is frozen because it freezes deeper in winter than it thaws in summer, concluded that if mean annual air temperature is lower than −1.6°C, the ground temperature at 23 m (the depth of unvarying soil temperature) would be lower than 0°C and permafrost would be present. Under the glacial hypothesis it was believed that very little of the soil of Siberia was protected from deep freezing by glacial ice and that perpetually frozen ground is inherited from the ice age. This theory has been strengthened by presence of well preserved extinct mammals; however, Nikiforoff points out the difficulties involved in melting the glacial ice from North America and northern Europe by a climatic warming that would have preserved the permafrost in unglaciated Siberia, assuming that climatic fluctuations are synchronous.

The impermeability of the perpetually frozen ground causes rain and snowmelt water to collect above the frozen ground and favors development of swamps on mountain sides as well as in lowlands. In summer a layer of water under the firm and apparently dry surface soil was found to creep to lower levels. At times the pressure was so great the water would crack the dry soil crust and liquid mud would pour out over the surface. In some cases the layer creeping down was too dense to pour, but after bursting through the surface soil it formed small convex mounds which were resilient under foot like elastic cushions. This process is known as the "suffosion" process.

In autumn and winter after the surface soil has frozen, the water between the frozen surface and the ever-frozen subsoil becomes frozen and is accompanied by very high pressure due to expansion of volume in the formation of ice. High pressures raise surface layers like blisters as much as 20 ft high. Some mounds have geyserlike discharges of water; others were punctured to drain water and were found to have large ice caverns beneath the uparched soil. Some caverns were 6–7 ft high and 30 ft across, and were covered with 2–3 ft of soil and vegetation.

In winter rivers frequently freeze to the bottom, and the ice dams the riverbed. Water from upstream seeks outlets through the soil near the stream and often appears on the ground surface far from the banks of the river. The water-soaked snow or the "taryn" at these places is dangerous for winter travel.

On the basis of the mean annual air temperature, the distribution of perpetually frozen ground is sketched, with the suggestion that investigation be made of its distribution and origin, especially in the glaciated part of Canada.

Nygard, I. J. *See* Kellogg, C. E., 1951.

Obidin, N. I., 1958a, The problem of ground water and permafrost on the islands of the Soviet Arctic [K voprosu o podzemnykh vodakh i vechnoi merzlote na ostrovakh Sovetskoi Arktiki]: Inst. geologii Arktiki Inf. Biull. 11, p. 48–53.

Sources of ground water in various deposits and permafrost on Novaya Zemlya, Franz-Joseph Land, and other islands are examined, and the physiography and climate of these islands are outlined. The thickness of permafrost on the islands of Novaya Zemlya varies from 150–200 m in coastal areas to 300–450 m in valleys and old terraces rising more than 50 m above sea level. Ground water in Quaternary deposits seems to be completely frozen, except for subglacial waters, water in taliks, suprapermafrost water in the active layer, and pseudotaliks. Fresh water in Permian deposits is to be found only below the permafrost or in the form of subglacial water. In Carboniferous strata fresh water is of subglacial origin and occurs primarily north of 74° N. lat. Fresh water in Silurian deposits is exclusively of subglacial origin. Permafrost in the islands of the Franz-Joseph Archipelago has not been studied yet. Ground water in Quaternary deposits in the islands originates from old and new glaciers, lakes, and rivers and is frozen throughout. The importance of suprapermafrost water in the 1-m active layer is practically nil, except for water below lakes and rivers and in the areas of pseudotaliks. Permafrost and ground water on Victoria Island have not been studied, but permafrost may be estimated as ranging in thickness from 100–150 m in coastal areas to 350–400 m in the central part.

1958b, New data on ground waters and permafrost in the Soviet mines on Spitsbergen according to the investigations in 1952–1954 [Novye dannye o podzemnykh vodakh i vechnoi merzlote sovetskikh rudnikov ostrova Shpitsbergen po issledovaniiam 1952–1954 gg]: Leningrad, Nauchno.-issled. inst. geologii Arktiki Trudy Sbornik statei po geologii Arktiki, no. 9, p. 129–140.

Describes results of previous work and investigations in 1952–54 at Barentsburg, Grumant, and Pyramiden on West Spitsbergen. The geologic conditions and source, circulation, mineralization, and chemical composition of the ground water are described. Records of deep wells and mines are given, and occurrence of gas and hydrocarbonaceous water, and temperature variations are discussed. The effect of permafrost is considered.—From Arctic Bibliography 60609.

Obidin, N. I., 1959a, Classification of ground waters in the West Siberian lowland and the Siberian platform north of the Polar Circle [Klassifikatsiia podzemnykh vod Zapdno-Sibirskoi nizmennosti i Sibirskoi platformy severnee Poliarnogo kruga] : Leningrad, Nauchn.-issled. ins. geologii Arktiki Trudy, v. 65. Sbornik statei po geologii Arktiki, no. 12, p. 150–154.

Presents results of investigations in 1956–58, including data from shafts, pits, and drillholes in the Amderma, Salekhard, Ust'-Yeniseisky Port, Igarka, and Noril'sk areas, in the Lake Khantayskoye and Lake Yessey areas, and in the Ambarnaya, Imangda and other regions. The ground-water classification presented includes discussion of the geologic characteristics of the rocks, source and value of water horizons, depth, temperature, pressure, output, mineralization and chemical composition, type of water, suitability for water supply, and other data.—From Arctic Bibliography 60608.

1959b, Permafrost and ground waters of the West Siberian Mesozoic trough and Siberian platform north of the Arctic Circle [Vechnaia merzlota i podzemnye vody Zapadno-Sibirskogo mezozoiskogo progiva i Sibirskoi platformy k severy ot Poliarnogo kruga]: Leningrad, Nauchn.-issled. inst. geologii Arktiki Trudy, v. 65, Sbornik statei po geologii Arktiki, no. 13, p. 159–173.

A review of previous and recent studies of the distribution and thickness of permafrost in the central part of the Soviet Arctic between the Ural Mountains and the Lena River. Ninety-nine percent of the area is covered by permafrost, and only 1 percent has taliks or islands of unfrozen ground. Temperature variation in the frozen ground, character of permafrost formation, distribution of taliks in the arctic zone, chemical analyses of ground waters, and temperature curves for the drillholes are evaluated. Upper and lower limits of permafrost are illustrated by schematic cross sections.—From Arctic Bibliography 60610.

Obidin, N. I. *See also* Tolstikhin, N. I., 1936, 1937.

Obruchev, S. V., 1938, The chessboard (orthogonal) forms in permafrost regions [Shakhmatnye (Ortogonal'nye) formy v oblastiakh vechnoi merzloty]: Vses. geog. obshch. Izv., v. 70, no. 6, p. 737–746.

ed., 1949–50, Reference book for travellers and regional explorers; written by a group of authors, edited by S. V. Obruchev [Spravochnik puteshestvennika i kraeveda; sostavlen gruppoi avtorov pod redaktsei S. V. Obrucheva]: Moscow, Gos. geog. literatury Izd., 2 v., 808 p.

Includes study of effects of ground water by N. I. Nikolaev (p. 53–70) which deals with springs and their water, karst phenomena, landslides, and a study of mineral springs by N. I. Tolstikhin (p. 108–114).—Arctic Bibliography 47123.

Obruchev, S. V., and **Tolstikhin, N. I.**, 1941, Mineral springs of the upper Oka River (Eastern Saian) [Mineral'nye istochnik verkhov'ev R. Oki (Vostochnoi Saian]: Vses. geog. obshch. Izv., v. 73 no. 3, p. 379–392.

The springs are subthermal (temperature less than that of the human body) and weakly mineralized. They occur along lines of tectonic weakness in Quaternary lavas. Their chemistry is treated in detail.—From Geol. Soc. America, Bibliog. and Index of Geology Exclusive of North America, v. 11, 1945–46, p. 234, 1947.

Obruchev, V. A., 1945a, Eternal frost: Natl. Rev. [London], v. 124, no. 745, March, p. 220–227.

The full impact of permafrost on engineering was first encountered during construction of the Transbaikal Railway in 1900, when many buildings failed because of subsidence of the frozen ground. Nikolai Bagdanov wrote a book on engineering on frozen ground in 1912, and other scientific work was done between 1900–1930, but the planned scientific work on a national scale in the USSR was initiated by Vernadskii and the great authority, Sumgin. In 1930 a commission for the study of frozen ground was formed under the leadership of V. A. Obruchev; in 1936 it became a committee, and in 1939 it became the Institute for the Study of Frozen Soil, and was later named the Obruchev Institute for the Study of Frozen Soil. The institute in 1945 had both theoretical and practical projects which were being carried on in the Moscow laboratories and at four stations in the eternally frozen regions at Igarka, Yakutsk, Anadyr, and Vorkuta.

Some investigators regard eternally frozen soil as being the retarded reflection of the climatic changes of a century and not of a year. The warm centuries have not affected the deeper frozen soil. The approach of the warm epoch can already be felt in the soil of the northern sections of European Russia, but in the Asiatic north the temperature balance is still in favor of the cold. Sumgin postulated that eternally frozen soil is being degraded in modern times, citing as an example the Mezen area where, since the middle of the last century, the southern edge of the frozen belt has shifted northward 60 miles.

Subsoil water cuts underground passages, but when reaching eternally frozen soil it may be trapped between the eternal frost below and seasonal frost above. The water thus trapped may flow under foundations of new buildings from which the warmth has penetrated through the frozen ground, providing a passageway for ground water. Or it may break through to the surface, already at a temperature below freezing because of its pressure and motion, and form ice cascades or fountains. Water is both a friend and an enemy—it aids in sluicing in gold-mining operations, but it forms frost mounds along roads and railways. The road, lacking a snow cover, freezes very deep, and forms a barrier to streams flowing deep down in the frozen soil. The frost beneath the road dams these waters until, under pressure, they burst through to the surface. In the Kolyma, Yana, and Indigirka headwaters, ice caps have been discovered over an area of nearly 400,000 square miles. On the Moma River, tributary to the Indigirka, an ice hummock 16 miles long, 4 miles wide, and 12 ft thick has been found. Chekotillo called this district "the land of great hummocks." Frost belts or snow-free ditches uphill from, but parallel to, the road may prevent ice formation along the roads.

The fact that farmers encounter blocks of ice in farming does not worry them, for without the stratum of underground ice the fields in many places would become desert land. The ice serves to keep the subsoil water near the surface, condenses evaporation, and thus enables plants to live.

Work of the institute on construction techniques, in developing the active and passive method, agricultural techniques, and working out methods of ice storage houses has had economic importance. Artificial and natural freezing of soils and water have been used for construction of wartime fortifications, particularly at the seige of Leningrad.

1945b, Subpermafrost water in the Yakutsk region: Work of the Obruchev Inst. Permafrostology in 1944, Acad. Sci. U.S.S.R., Div. Geol. Geog. Sci., p. 114–132. [Russian.]

Obruchev, V. A., 1945c, Developmental trends of permafrostology in the USSR [Puti razvitiia merzlotovedeniia v SSSR]: Akad. Nauk SSSR, Ser. geol., no. 3, p. 34–44.

Work of the Committee and Commission on permafrost, six permafrost conferences to 1941, and data from the Igarka, Yakutsk, Anadyr, and Vorkuta permafrost stations have been used to solve problems of origin, mapping, degradation, determination of thickness and extent of permafrost. These data were used to solve practical problems and to establish specifications for construction in increasing development of permafrost regions under the Soviet regime. Knowledge of icings, their causes, and measures effective against them have been developed. Use of subpermafrost artesian water has been increased, and studies of ground ice undertaken.—From SIPRE U–5766; author's English summary.

1946, The one-hundredth anniversary of the first Academy of Sciences expedition to study permafrost [K 100-letiiu pervoi akademicheskoi ekspeditsii po izucheniiu vechnoi merzloty]: Vses. geog. obshch. Izv., v. 78, p. 468–474.

Von Middendorf's 1842–46 expedition to Siberia had as one of its objectives verification of reports of thick frozen ground in the Shergin shaft at Yakutsk. His temperature data enabled prediction that permafrost was 187 m thick, not greatly different than the thickness of 200–214 m determined by modern work. The Academy of Sciences did not pursue these pioneer investigations until 1930.—From abstract by E. A. Golomshtok; SIPRE U–754.

Ognev, G. N., 1927, Geological observations in the Lena-Amga watershed [Geologicheskie nabliudeniia na Lensko-Amginskom vodorazdele]: Materialy po izucheniiu IAkutskoi ASSR, v. 22, p. 1–71.

Ice mounds, icings, and large masses of fossil ice were frequently observed in the permafrost areas. Numerous mineral springs along the Lena River remained unfrozen at air temperatures of −55°C as far as 300 m from their source; these springs produced thick icings.—From SIPRE U–6614.

Olchowik, Julia. *See* Dylikowa, Anna, 1954.

Olchowik-Kolasinska, Julia. *See* Dylikowa, Anna, 1955–56.

O'Neill, J. J., 1924, The geology of the arctic coast of Canada, west of the Kent Peninsula: Canadian Arctic Exped. 1913–18, Rept., v. 11, Geology and Geography, pt. A, 107 p.

Orlova, L. M., 1955, Ground water in the Chita district [Podzemnye vody Chitinskoi oblasti]: Soveshch. podzemnym vodam Vostochnoi Sibiri, Irkutsk.

Orlova, L. M., and Osadchii, P. I., 1959, Permafrost in the Chita region [Mnogoletnemerzlota Chitinskoi oblasti], *in* Materialy po obshchemu merzlotovedeniiu: Akad. Nauk SSSR, Inst. Merzlotovedeniia, p. 111–113.

Three permafrost zones, running from north to south, are (1) a zone of continuous permafrost of the valley type; (2) permafrost of the valley type with taliks; and (3) a zone of island permafrost. The lower permafrost boundary in the first zone lies at a depth of 8–150 m, the greatest depths being found under depressions and north slopes. In the second zone, the lower permafrost boundary lies 10–30 m deep. The third zone is characterized by the predominance of unfrozen ground with island permafrost at depths of 0.5–5 m; hydrolaccoliths, frost mounds, and icings are frequent in this zone.—From SIPRE 17936.

Osadchii, P. I. *See* Orlova, L. M., 1959.

Osipova, E. E. *See* Tolstikhin, N. I., 1934.

Ovchinnikov, A. M., 1939, Mineral water investigations during the third 5-year plan in Russia [Problemy mineralnykh vod v tret'ei piatiletke]: Sovetskaia geologiia, v. 9, p. 14–19.

1946, On the hydrothermal conditions of the earth's crust (in Russian): Akad. Nauk SSSR Comptes rendus (Doklady), new ser., v. 53, no. 7, p. 645–648.

If one considers the part of the earth's crust accessible to investigation as constituting fundamentally the subsurface hydrosphere, geothermal conditions in the crust become essentially hydrothermal. Adapting this viewpoint, the author studies questions of the heat balance of the earth's surface and its variation in time, the geothermal calculation of the depth of rocks, the depth of the zone of constant secular temperature, and the variation in average normal hydrothermal depth.

Observations in areas of permafrost, according to which the depth of penetration of solar heat is considerably greater than the zone of constant annual temperature, appear to indicate that the depth of the heat wave equals that of the cold wave and thus place the zone of constant secular temperature at a depth of about 1,000 m. They suggest that the average normal hydrothermal depth, when put at the generally accepted value of 33 m/°C, does not adequately characterize the actual state of the heat flow for various regions and that its true value actually may vary within a wide range, from 1 to 200 m/°C. The view that in young folded areas the zones of high temperature lie everywhere at shallow depths is questioned.—Geophys. Abs. 9864, U.S. Geol. Survey Bull. 959–A, p. 52–53, 1948 [1949].

Ovchinnikov, A. M. *See also* Kamenskii, G. N., 1953.

Overbeck, R. M., 1920, Placer mining in the Tolovana district [Alaska]: U.S. Geol. Survey Bull. 712–F, p. 177–184.

On Amy Creek the shafts are 25–100 ft deep in frozen ground which locally includes masses of ice.

Paige, R. A. *See* Péwé, T. L., 1959; Williams. J. R., 1959.

Parker, G. L. *See* Ellsworth, C. E., 1911.

Parkhomenko, S. G., 1938, Permafrostology as the science of cryophilic rocks [Merzlotovdenie kak uchenie o kriofil'nykh gornykh porodakh]: Akad. Nauk SSSR, Kom. vechnoi merzlote Trudy, v. 6, p. 177–194.

Although much information has been collected on permafrost, the lack of a general work on the subject is due to overemphasis on the geothermal approach and lack of work on the geological and petrographical aspects of permafrostology. Permafrost is regarded as a special class of igneous or metamorphic rocks and sediments that contain various amounts of ice or other cryophile minerals (those which are solid only below 0°C) at a depth where they are not affected by meteorological processes. The lower limit of permafrost is determined by the inner heat of the earth. The cryophilic formations originated under certain conditions either of the geologic past or of recent time; the formations are altered only when the conditions that produced it are altered.

Icings (naledi) are regarded as extrusive or intrusive rocks and are called cryovolcanic rocks. If there are no cryophile minerals in the ground, the ground cannot be called frozen, even if below 0°C. Geothermal studies are only a part of the science of frozen ground.—From SIPRE U–5822, author's English summary; unpublished summary by I. V. Poiré, 1949.

735–894—65——11

Parmuzin, IU. P., 1953, Distribution and peculiarities of caves in Siberia [Rasprostranenie i osobennosti karsta Sibiri]: Moskovskogo obshch. ispytatelei prirody Biull., Otdel. geol., v. 28, no, 4, p. 103.

Cave formations in Siberia are associated with permafrost and are usually discovered at considerable depths in regions of permafrost degradation. Caverns appear more frequently under permafrost layers as a result of subpermafrost water, or in thawed spaces of frozen soil. The processes of cave formation favor permafrost degradation.—From SIPRE 7108.

1954a, Karst effects on the Siberian landscape [Landshaftoobranzuiushchee znachenie karsta Sibiri]: Moskva, Univ., Uchenye Zap. 170, Geografiia, p. 7–43.

Permafrost produces a peculiar geological type of karst and causes formation of ice caves. The impervious permafrost strata cause heavy moisture concentration in the active layer and intense karst processes in summer. These processes continue throughout the year in the subpermafrost zone and where thermal springs flow through fissures in the permafrost. These springs also cause permafrost degradation.—From SIPRE 12992.

1954b. Problems of study of cave formation in Siberia [Voprosy karstovedeniia Sibiri]: Vses. geog. obshch. Izv., v. 86, p. 34–49.

Investigations of caves in Siberia are reviewed and their origin discussed. Lower soil temperatures in permafrost result in lower evaporation from the soil surface in summer and cause intensive condensation of water vapor around the frozen layers. Water accumulation in permafrost is an important factor in cave formation. The caves formed in permafrost regions must be classified as a peculiar geographical type, produced by subpermafrost waters. Cave-forming processes favor permafrost degradation.—From SIPRE 8093.

Patterson, P. R. *See* Boyle, R. W., 1956.

Patty, E. N., 1951, Solar thawing increases profit from subarctic placer gravels: Mining Eng., v. 3, p. 27–28.

In the placer mines of Alaska and Yukon a few inches to 100 ft of frozen ooze to sandy silt containing peat and dikes and lenses of ice lies above the perennially frozen gravel. On Coal Creek, Alaska (Yukon drainage), Alluvial Golds, Inc., experimented with solar thawing in a thoroughly stripped dredge section consisting of 9 ft of gravel and 2 ft of bedrock. After exposure to the sun for one season the ground was completely thawed. Preliminary prospecting in this ground with a churn drill, before stripping the muck, showed that the ground was frozen; however, thawed ground invariably occurred wherever Coal Creek had eroded the muck and exposed the underlying gravel.

On Woodchopper Creek the ground was 25–28 ft deep. It was shown that by stripping every bit of the muck from the surface of the coarse gravel 3 yr in advance of dredging, solar heat had thawed the permafrost completely.

Payne, T. G. *See* Miller, D. J., 1959.

Pearce, E. E., 1922, Cold-water thawing of frozen gravel: Mining and Sci. Press, v. 124, p. 154–156.

Tests of the new process of thawing frozen gravel by means of cold water were made by Johnson and Pearce on Candle Creek, Seward Peninsula, Alaska. In 1918 and 1919 an effective method of cold-water thawing was developed using small-diameter points; effectiveness was proved by dredging, but it was limited

to relatively shallow ground. More recent tests on Candle Creek required thawing of perennially frozen alluvium beneath the stream and along the inside of a stream bend. The ground was not covered with muck, but a 2-ft layer of muck lay on bedrock. Creek water was led along channels made in the margins of the block of frozen ground to be thawed, and the surface of the frozen layer to a sump in a shaft which was tightly timbered to exclude surface water. The water is pumped from the shaft, and the continuous flow of surface water along the surface of perennial frost lowers the frost level. The entire area 790 ft upstream and 235 ft downstream from the shaft had been thawed into bedrock by this method with only 80 hr pumping time in 15 days. In another test a stream is bordered by a bare gravel bar, and the bar is bordered by gravel covered with muck and sod. A shaft placed through the muck and gravel to bedrock at the outer edge of the area to be thawed is used as the sump. Points are driven through the muck to the top of gravel to establish the initial thawing and seepage of surface water toward the sump. With pumping from the shaft, river water percolates through the gravel, thawing frost, to the sump.

Pekar, E. L. *See* Boyle, R. W., 1956.

Perekrestov, P. P., 1946, Icings in the Imachinsk cut on the Amur Railroad and their control [Naledi v Imachinskoi vyemke Amurskoi zheleznoi dorogi i bor'ba s nimi] : Merzlotovedenie, v. 1, p. 142–149.

The problem of icing formation in permafrost regions and railroad protection from icing damage is discussed on the basis of investigations in the Imachinsk cut. The cut, over 1 km long and as much as 15 m deep, was made in slate on a slope near Skovorodino Railroad Station in 1911–12. Hydrogeological conditions in the cut area and the process of annual icing formation are described in detail on the basis of A.V. L'vov's study "Water-Supply Survey and Tests in Permafrost Along the Western Section of the Amur Railroad," published in 1916. Additional investigations in 1934 showed that the intense icings are associated with ground-water penetration through fissures in the slate. Drains, gutters, and other structures were built without consideration for the severity of the winter, so that the deep soil freezing caused them to be blocked with ice. Drain reconstruction in 1934, which is described in detail, protected the cut from icings and frost heaving, which were never observed during the next 8 winters (1936–44).—From SIPRE 15987.

Perry, O. B., 1915, Development of dredging in the Yukon Territory [Canada] : Eng. Mining Jour., v. 100, 1042–1044.

All the creek deposits in the Klondike placer district have areas of unfrozen ground. The percentage of frozen and unfrozen ground varies in different parts of the same valley, and even greater variations occur from valley to valley.

Petitot, E., 1875, Geography of the Athabasca-Mackenzie and of the great lakes of the Arctic basin [Géographie de Athabaskaw-Mackenzie et des grands lacs du bassin Arctique] : Soc. géog Bull., 6th ser., v. 10, p. 5–42, 126–183, 242–290.

Many lakes in areas underlain by sand and gravel between Anderson and Horton Rivers have underground drainage.—Cited by Mackay, J. R., 1955.

Petrica, James, 1951, Relation of frost penetration to underground water lines: Am. Water Works Assoc. Jour., v. 43, p. 911–916.

Petrov, L. S., and Rakitov, L. I., 1940, Oil fields in the Arctic, their survey and exploitation [Usloviia zaleganiia nefti i osnovnye voprosy razvedki i razrabotki neftianykh mestorozhdenii v Arktike]: Problemy Arktiki, no. 3, p. 98–109.

The geology of the Soviet Arctic and the effects of permafrost on the exploitation of petroleum deposits are described. Problems of survey, drilling, and operation are discussed. Permafrost in the Soviet Arctic reaches maximum thicknesses of 360 m (at Ust'-Port) to 600 m (at Nordvik), and affects the physical properties of petroleum. The impermeable frozen layers increase the gaseous content of the oil and prevent migration of the deposits; and the hydrostatic pressure of subpermafrost water increases the output of the wells. The increase in oil viscosity and paraffin crystallization under the influence of the low permafrost temperatures cause difficulties in oil-well operation.—From SIPRE 9887.

Petrov, V. G., 1930a, The icings of the Amur-Yakutsk Highway [Naledi na Amurskogo-IAkutskoi magistrali]: Leningrad, Akad. Nauk SSSR i Nauchn.-issled. avtomobil'no-dorozhnogo inst., 177 p.

Icings along the Amur-Yakutsk Highway were studied in 1927–28 by a special field party which covered 728 km of the highway. The party studied 122 ground and river icings, and analyzed the effects of permafrost, orography, and climatic conditions. Data on icing size, snow-cover depth and the thickness and depth of permafrost are tabulated. Permafrost was found at depths of about 1.5 m, and icings were observed in areas where seasonal frost reached the permafrost table. A deep snow cover at the beginning of winter prevents seasonal frost penetration to the permafrost table and thus prevents icings. Icing formation under a thin snow cover begins in December and reaches a maximum in March, when the depth of the seasonal frost is at a maximum. Icings in this region form more frequently on east and west slopes. The construction of belts of various types to promote deep soil freezing at some distance from the highway is recommended as a measure against icing damage to highways.—From SIPRE 9611.

1930b, Protection of road constructions from icings [K voprosu o zashchite dorozhnykh sooruzhenii ot vrednogo vliianiia naledi]: Sovetskaia Aziia, v. 6, no. 3–4, p. 69–74. *See* annotation, Petrov, V. G., 1930a.

1934, An attempt at ascertaining the pressure of ground water in icing mounds [Opyt opredeleniia sily davleniia gruntovykh vod v nalediakh]: Akad. Nauk SSSR, Kom. izuch. vechnoi merzloty Trudy, v. 3, p. 59–72.

In engineering practice it is helpful to know the pressure of the water in an icing in order to determine whether it is cheaper to strengthen the building or dig a frost belt. An experiment was conducted at the Skovorodino Permafrost Station in 1930–31. The icing mounds investigated were 10–30 m in diameter and 1–2.5 m high. In cross section the mounds consisted of a layer of surface ice, peat, clay (with loam, sandy clay, and pebbles), charcoal, ground ice, ground water, red sand, and bedrock. Freezing of ground under the peat, a poor conductor, began later than in the surrounding area where the clay with sandy clay and pebbles predominate. Ground water in the clay expanded on freezing and forced the remainder of liquid water toward the edge of the peat island, creating pressure which allowed water to reach the surface to form naleds.

Apparatus was designed on the basis that (1) liquid water conducts electric current, and ice does not; (2) water expands on freezing; and (3) the freezing point of water lowers with pressure. The apparatus consisted of a soil thermometer, rubber cylinder full of water with ends of two electric wires submerged in the water, and a hermetically sealed metal cylinder covered all around with a rubber sleeve and full of water. On top of the water is a piston, one end of which moves upward to make contact with the second wire.

The rubber cylinder is where the ground water under pressure freezes at a temperature below the freezing point, and the metal cylinder is where freezing occurs under the same conditions as on the surface. The metal cylinder's importance is that it provides a means of determining the freezing point of water with corrections for supercooling due to chemical constituents.

The water in the metal cylinder froze at a temperature of —0.1°C and the water in the rubber cylinder froze at —0.5°C, or 0.4° lower because of the pressure of ground water. Since lowering of the freezing point of water by 0.01°C corresponds to a pressure of 1.3 atmos., it was concluded that the pressure of ground water in the icing was 52 atmos.—From abstract by E. A. Glomshtok for Stefansson Collection, Darthmouth College, Baker Library, Hanover, N.H., SIPRE U-732.

Péwé, T. L., 1947, Permafrost and geomorphology in the lower Yukon River Valley [Alaska] [abs.]: Geol. Soc. America Bull., v. 58, no. 12, pt. 2, p. 1256.

Permafrost in the flood plain of the Yukon River is correlated with the geomorphic features of the terrain, which is divisible into four phases, each having different permafrost characteristics. As the river moves from side to side in its valley, it acts as a thawing agent and lowers the permafrost table. When the river meander advances, the permafrost rises into the newly deposited sediments.

1948a, Permafrost investigations, Fairbanks area, Alaska: Permafrost Program Prelim., Rept., 16 p., pub. by Engineer Intelligence Div., Office, Chief of Engineers, U.S. Army, Sept.

The Fairbanks area is divided into three terrain divisions: the flood plain, the hills, and the depositional slope between the flood plain and the hills. In the flood plain, the permafrost table is in many places lower than the water table, and water is available to shallow wells. Water in large quantities is available from wells penetrating gravelly beds below permafrost at depths of 50–200 ft, or at even shallower depths where permafrost is absent beneath existing and recently abandoned channels, sloughs, and some lakes. The alluvium of the flood plain is highly permeable, and in many places hundreds of gallons per minute are available to shallow wells. Large-diameter wells less than 100 ft deep are known to yield as much as 3,000 gpm with 10–15 ft of drawdown. Most ground water is reported to be hard, containing calcium bicarbonate. In many wells iron and organic content is high. Some wells yield clear tasteless water, but because of limited extent of lenticular aquifers, most wells which are pumped heavily yield water of medium-poor quality.

On the depositional slope, permafrost forms a wedge that is thin near the hills but about 175 ft thick near the flood plain. Ground water is generally not available above permafrost or from talik within permafrost. Permafrost acts as a confining layer to water in the local aquifers, and one flowing artesian well in coarse sand beneath permafrost produced more than 40 gpm. In many areas, however, water is scarce even beneath the permafrost.

In the hills, the silt yields water slowly, and wells must penetrate bedrock. The water table is generally low, but moderately large yields might be obtained from wells intersecting major fissures. The few existing wells in bedrock, however, have small yields of water of the same general quality as that found beneath the flood plain.

Péwé, T. L., 1948b, Ground-water data for Fairbanks, Alaska: U.S. Geol. Survey open-file report. *See* annotation, Cederstrom, D. J., and Péwé, T. L., 1948.

1949, Preliminary report of permafrost investigations in the Dunbar area, Alaska: U.S. Geol. Survey Circ. 42, 3 p.

The Dunbar area lies within the Yukon-Tanana Upland; its lower slopes and valley bottoms, the depositional slope, are underlain by perennially frozen silt or muck. The hills are of Birch Creek schist mantled with 1–40 ft of tan silt. In the depositional slope area ground water is not available to shallow wells at most places. Beneath the confining layer of permafrost, water is generally available, but at depths that locally exceed 150 ft; quality of the subpermafrost water is poor, as, for example, at Berg, where it is unpalatable. On the hills ground water must be obtained at depth in bedrock; springs along the base of the hills may provide limited amounts of water.

1952, Permafrost investigations in the Fairbanks area, Alaska [abs.]: Sci. in Alaska 1952, Alaskan Sci. Conf., 3rd, Mount McKinley Park 1952, Proc., p. 169.

Permafrost is discontinuous in the Fairbanks area. It is absent on hilltops and south-facing upper slopes. It is discontinuous, but is as much as 180 ft thick in the sand and gravel of the flood plain. Permafrost beneath the flood plain contains no large ice masses; ground water is available above and below permafrost. Permafrost is continuous and about 175 ft thick beneath the lower slopes of alluvial silt fans north of the flood plain. On these slopes permafrost contains large ice masses, and ground water is absent above and scarce below permafrost.

1953, Brief review of Pleistocene events and climatic changes in Alaska [abs.]: Sci. in Alaska 1953, Alaskan Sci. Conf., 4th, Juneau 1953, Proc., p. 186–189; U.S. Geol. Survey open-file report, 14 p.

Evidence from the Fairbanks area indicates an absence of permafrost in the interval separating Wisconsin from pre-Wisconsin glaciations, and that the climate was warmer than the present. The record of Wisconsin events includes a complex history of deposition, erosion, freezing and thawing silt. In early Wisconsin time, more than 30,000 yr ago, an extensive blanket of loess was deposited; ice wedges formed during formation of permafrost. The cold period was followed by a period of 18,000 yr of a climate warmer than that of the present, in which valleys cut in the loess were filled with organic sediments containing vertebrate animal and vegetable remains. In a subsequent cold period the muck deposits became perennially frozen, and large ice wedges formed in the cold period less than 12,000 or 13,000 yr ago. This cold period, accompanied by additional loess deposition, is correlated with late Wisconsin glaciation. During the climatic optimum, 3,500–4,000 yr ago, permafrost near Fairbanks thawed a few feet, but not completely, and additional muck was deposited. A slight cooling of the climate followed, and was marked by refreezing of the muck near Fairbanks. Most of the recent massive ice wedges of the Arctic coastal plain which overlie truncated wedges are less than 3,500 yr old.

1954, Effect of permafrost on cultivated fields, Fairbanks area, Alaska: U.S. Geol. Survey Bull. 989–F, p. 315–351.

Sediments of the Tanana River flood plain are frozen to depths of at least 265 ft, but permafrost thickness varies widely. Permafrost is absent beneath existing or recently abandoned river channels, sloughs, and lakes. Locally, frozen sand and silt is intercalated with thawed layers and lenses of gravel. Ground ice in the flood plain is restricted to granules and cement between mineral grains. Depth to permafrost is 2–40 ft, depending on local cover. In many places permafrost is lower than the local water table, and water may be obtained in shallow wells; water in larger quantities is available from gravelly beds beneath permafrost at depths of 50–200 ft, or even at shallower depths where permafrost is absent.

Permafrost in the alluvial fans, colluvial slopes, and silt lowland is probably continuous from the flood plain, where it is about 175 ft thick, to the hills, where it pinches out either at the base of steep south-facing slopes or on the upper middle north-facing slopes. It lies between 3 and 20 ft deep, and is characterized in many areas by large masses of clear ice occurring as horizontal sheets, vertical sheets, wedges, and irregular masses 1–15 ft thick and 1–50 ft long. The muck and silt deposits of alluvial fans, colluvial slopes, and silt lowland reach a thickness of 175 ft and are generally underlain by coarse gravel at depths of 50–200 ft.

Hilltops and steep south-facing slopes are permafrost free. Depth to ground water is generally more than 100 ft, and only small quantities are available.

1958a, Permafrost and its effect on life in the north: Oregon State Coll. Biol. Colloquium, 18th, Corvallis, Oreg., Proc., p. 12–25.

Distribution of ground water in many parts of the North is affected by distribution of permafrost; the ground water, in turn, also is an important factor in influencing the distribution of perennially frozen ground, especially in the discontinuous and sporadic permafrost zones. At Fairbanks, Alaska, ground water in the flood plain circulates freely below permafrost, through unfrozen channels within permafrost, and above permafrost. Water supplied through the municipal continuously circulating water system is derived from deep wells. Hundreds of private wells draw water from above permafrost at depths of 15–20 ft, from unfrozen zones within permafrost, and from beneath permafrost through wells 100–250 ft deep. On slopes bordering the flood plain, artesian water has been found in sandy beds beneath perennially frozen ground; a well drilled in 1946 flows at more than 40 gpm. On upper slopes of alluvial fans, water table is 100–200 ft deep, but water is scarce owing to general lack of permeable beds. Small-diameter wells through permafrost may freeze if not used regularly, but may be thawed by use of salt, hot water, or steam. Periodic applications of hot water or use of an electric-heating unit prevent freezing.

1958b, Geology of the Fairbanks (D–2) quadrangle, Alaska: U.S. Geol. Survey Geol. Map GQ–110.

Permafrost consists of two types: (1) continuously frozen silt with large ice masses and (2) discontinuously frozen silt, sand, and gravel with relatively low ice content and no large ice masses. The discontinuous frozen ground occurs in Chena-Tanana River alluvial deposits; the continuous frozen ground occurs in flood-plain swale and slough deposits, undifferentiated silt, and silt deposits of alluvial fans, organic silt, and peat. Quaternary loess was reworked to form organic silt in creek valleys where it became perennially frozen. During the erosional period just before the Wisconsin glaciation, much of the loess and most of the creek-valley silt was removed; permafrost thawed and perhaps disappeared during this warm interval. Additional loess was deposited, and the reworked material in creek valleys became perennially frozen; these deposits incorporated animal remains and vegetation, and include large ground ice masses.

About 5,000–6,000 yr ago a slight warming of climate caused thaw of the upper few feet of permafrost, but since that time, cooling of the climate has caused reformation of permafrost.

Logs of 175 wells, pits, and other excavations show the unconsolidated deposits and presence or absence of permafrost and bedrock. Thickest permafrost is in South Fairbanks where a well penetrated permafrost from a depth of 23–242 ft; in a few places, layered permafrost occurs in the alluvial deposits.

Péwé, T. L., Hopkins, D. M., and **Lachenbruch, A. H.,** 1958, Engineering geology bearing on harbor site selection along the northwest coast of Alaska from Nome to Point Barrow: U.S. Geol. Survey Trace Elements Inv. Rept. 678, 57 p. [Open-file report.]

Most of the area lies within the continuous zone of permafrost where temperature of the ground at a depth of 50–75 ft is less than −5°C. Permafrost is defined on a temperature basis and includes both rock and unconsolidated materials and ground in which saline or brackish soil moisture remains in liquid state, even though at negative temperature. Because the surface flow of streams diminishes sharply during winter, the most reliable sources of water are from the underflow in beds of the larger streams. A year-round supply of ground water may be available from gravel lenses in the delta deposits of Singoalik River. Permafrost might extend between 100 and 200 ft from shore, but sea-bottom deposits need not contain ice, even though below 0°C.

Péwé, T. L., and **Paige, R. A.,** 1959, Frost heaving of piles with an example from Fairbanks, Alaska: U.S. Geol. Survey open-file report; pub. 1963, *as* U.S. Geol. Survey Bull. 1111–I, p. 333–407.

Frost heaving is not due alone to the freezing of water originally contained in the voids, but is due chiefly to formation of clear-ice segregations in the sediments. The segregations form as water is drawn to points of freezing from unfrozen ground; this growth is possible because some water in the ground remains liquid and can migrate even though at temperature below 0°C. The amount of heaving depends chiefly, therefore, on temperature of the air and texture and moisture content of the ground.

Three wood-pile bridges on the Alaska Railroad at mile posts 456.7, 458.4, and 460.4, in the Goldstream Valley, are considered as examples of frost heaving. Data are presented on moisture content, position, thickness, and temperature of seasonal frost and permafrost at these places. Some of the piles were found to be not deep enough in permafrost to prevent the upward heave of seasonal frost. Permafrost conditions in the Fairbanks area are reviewed (see Péwé, 1948 to 1954), and those in the Goldstream Valley outlined. The upland ridges are permafrost free, and the lower slopes and valleys are underlain by frozen silt, locally containing ice masses. At the mile 460.4 site, a boring showed that permafrost extends from 2 to more than 109 ft in a nearby forested area, but no shallow permafrost occurs near the stream. A prospect hole 600 ft west of the mile 458.4 bridge indicates permafrost from 2 to more than 52 ft, and a boring near mile 456.7 shows permafrost from 2 to more than 37 ft.

Péwé, T. L. *See also* Cederstrom, D. J., 1948; Williams, J. R., 1959.

Peyton, H. R., 1959, Engineering research in Arctic Alaska: Civil Eng., v. 29, no. 9, p. 52–53.

Engineering problems in the Arctic are outlined and research conducted by various organizations in Alaska is reviewed. In general, engineering difficulties in the Arctic are related to the presence of ice where water would be found in temperate climates, low temperatures themselves being a minor problem.

Research conducted for 11 yr by two members of the Geological Survey on soil temperatures in various areas led to the design of a road on a thermal basis which has remained stable for 4 yr. The Navy Civil Engineering Laboratory is studying reinforcement of sea ice by flooding the ice surface with sea water. The Cambridge Research Center has studied a technique of flooding that would keep the salinity of the ice down by allowing only a small part of the flooding water to freeze into low-salinity ice and removing the remaining high-salinity water. The center is also investigating the strength of lake ice to determine the structural strength of ice sheets for use by airplanes and other equipment. A project sponsored by the Office of Naval Research seeks to determine the mechanical properties of fresh-water ice, sea ice, and permafrost. Most of the research in Alaska is oriented toward the acquisition of information leading to a rational solution of engineering problems peculiar to arctic climates. There are several problems, however, on which little current work is being done, such as water supply and waste disposal.—From SIPRE 18285.

Pihlainen, J. A., 1955, Permafrost and buildings: Canada, Natl. Research Council, Div. Bldg. Research, Better Bldg. Bull. 5, 27 p.

In this guide for building on permafrost, the southern boundary of continuous permafrost is traced from southern Yukon through southern Northwest Territories, and into Saskatchewan, Manitoba, and northern Ontario along the south shore of Hudson Bay, and eastward into northernmost Quebec. Permafrost ranges in thickness from about 1,000 ft at Resolute to only 5 ft at Hay River, Northwest territories. Among the factors for a suitable building site, are included freedom from ground-water seepage (causing icing in winter) and convenient location near adequate water supply and safe sewage disposal.

Pihlainen, J. A., Brown, R. J. E., and **Johnston, G. H.**, 1956, Soils in some areas of the Mackenzie River delta region: Canada, Natl. Research Council, Div. Bldg. Research Tech. Paper 43, 26 p.

Deposits of the alluvial fans lying between the Richardson Mountains and the Husky Channel are frozen silt and sand containing ice lenses and layers 1/32 to 3/4 in. thick. On the fans downslope from Black Mountain in the Richardson Mountains is an area of knobby hills, a landslide in which are exposed horizontal ground ice bands, 1 ft thick, in silt and clay. Among the knobby hills are several pingolike structures in silty material; one has a crater lake 40 ft in diameter and 20 ft above the alluvial fan. At the base of Black Mountain is another pingolike hill with a crater lake from which two trenches carry the discharge of water. Still another ridge 100 ft in diameter ranges from 4 to 12 ft in height and is formed of silt and stony material. Water from a lake at the center flows across a low part of the ridge to the east; the water is colored rusty red by algae.

Pihlainen, J. A., Brown, R. J. E., and **Legget, R. F.**, 1956, Pingo in the Mackenzie Delta, Northwest Territories, Canada: Geol. Soc. America Bull., v. 67, p. 1119–1122; repr., Canada, Natl. Research Council, Div. Bldg. Research, Research Paper 27 (NRC 4009).

A pingo, 100 ft high and 560 ft in diameter, located at 69°02′ N., 134°25′ W. in the Mackenzie Delta, was studied in 1954 during a search for a new location for Aklavik. The circular, off-center crater in the pingo had a pool of water 10 ft wide, 30 ft long, and 1½ ft deep. Satellite pingos are located 300 ft southeast and 1,000 ft west of the main cone. The main pingo was drilled; in the crater adjacent to the pool drilling revealed, from top to bottom, 3 ft 8

in of blackish-gray silt, fine sand, and decomposed organic material, 13 ft 4 in of ice containing air bubbles, 15 ft 3 in of milky ice containing small air bubbles. A hole drilled at the lower edge of the pingo showed, from top to bottom, 9 ft of blackish-gray silt with some clay and fine sand and much organic material, 4 ft of brownish sandy silt with streaks of peat and white shells and yellow seeds, 4 ft 8 in of blackish-gray sandy silt with clay and streaks of peat containing pebbles as much as 1 in. in diameter, and 10 ft of light-gray fine sand with large stones as much as 1 in. in diameter. The soil temperatures were measured by a string of thermocouples in the summer of 1954 and 1955; in June 1954, 13 days after drilling, temperatures decreased from 28.3°F at 2 ft 6 in to 23.6°F at 25 ft; in August 1954 and 1955 temperatures decreased from 33.4°F at 2 ft 6 in to 24.6° at 25 ft.

Piip, B. N., 1937, Thermal springs of Kamchatka [Termal'nye kliuchi Kamchatki]: Akad. Nauk SSSR, SOPS, Ser. Kamchatkaia Izd. 2.

Pinkow, Hans-Heinz, 1943, Occurrence of oil in the Arctic regions of the Soviet Union [Erdolvorkommen in den artischen Regionen der Sowjet Union]: Zeitschr. prakt. Geologie, v. 51, no. 12, p. 132–136.

In the Il'ia structure on Kozhevnikov Beach, oil traces were noted at a depth of 205 m, and sandstone horizons of various thicknesses that are highly impregnated with oil have been encountered at 222 m and below. Permafrost occurs to a depth as great at 620 m (2,037 ft), and its temperature at a depth of 300–330 m is −12° to −14°C.—From unpublished abstract by I. V. Poiré, Nov. 1947.

Plashchev, A. V., 1956, Rupture of ice mound [Vzryz ledianogo bugra]: Priroda, v. 45, no. 9, p. 113.

A mound located in the estuary of the Kontrand'e River originally 50 by 10 m in plan and about 3 m high was shattered into pieces about 4 m sq and 80 cm thick by an explosion that hurled the pieces a distance of 15–20 m. The explosive shattering was caused by sudden freezing of supercooled water due to soil vibrations.—From SIPRE 14395.

Pod'iakonov, S. A., 1903, Icings of eastern Siberia and their origin [Naledi Vostochnoi Sibiri i prichiny ikh vozniknoveniia]: Vses. geog. obshch. Izv., v. 39, p. 305–337.

Icings were studied in Yakutia for 3 yr. The rate of icing formation increases with an increase of frost penetration, water flow, and thermal conductivity of the soil. Icings form over ice-covered river surfaces and over frozen soil surfaces. Icing formation is favored when permafrost forms an impermeable layer over veins of ground water. River icings form when the river freezes solid, when the flow under an ice cover is increased, or over a multilayered ice cover. A sudden increase in water level, whether underground or under ice-covered rivers, is the main cause of icings and icing mounds.—From SIPRE U–6428.

Poiré, I. V., 1949, Review of Russian literature on permafrost: Unpub. ms. in files of Alaska Terrain and Permafrost Section, U.S. Geol. Survey, Washington, D.C. 20242.

Poliakov, S. S., and Sergeev, Ye. M., 1958, Engineering-geological characteristics of the valley of the lower Ob' River: Nauchn. Doklady Vysshey Shkoly, Geol.-geog. nauki, no. 1, p. 124–132.

From an engineering-geological survey for hydroelectric utilization of the lower Ob' Valley, three broad regions are distinguished: (1) a glacial plateau on the right bank, 60–100 m above the river from the mouth of the Kazym

River upstream to the mouth of the Nazym River and the area around Salekhard and Labytnangi; (2) a lake alluvial plain (or Third Terrace above the Ob') along both banks of the Ob' at a height of 20–45 m above river level from Salekhard to the mouth of the Kazym, and still farther south along the left bank; and (3) the valley proper of the Ob' including flood plain and terraces as high as 20 m above the river.

Within the glacial plateau, that part in which Tertiary rocks are associated with moraine and fluvioglacial sands lacks permafrost. The area of near-surface Tertiary rocks is bordered to the north and south by areas in which Quaternary continental deposits have accumulated; the southern area of Quaternary deposits does not have permafrost, and in the northern area permafrost is of the island type 4–10 m deep between the mouth of the Kazym River and Vezhakorskiye. From Vezhakorskiye to Peregrebnoye, pereletoks as thick as 4 m occur in otherwise unfrozen ground. Permafrost is found in the area near Salekhard, where Quaternary marine and continental deposits occur. On the right bank, permafrost consists of large continuous bodies 30–80 m thick that are cut by taliks; below the upper permafrost layer is thawed ground which, in turn, is underlain at a depth of 90–170 m by another permafrost layer. The left bank has permafrost to depths of 250–350 m.

The lake alluvial plain encompasses an area without permafrost from Muzhi to Lake Un-Tor, an area with pereletoks, and to the north an area of permafrost along the left bank north of Lake Leyvgortskiy-Sor and along the right bank north of the Tugiyan-Yugan River. Permafrost temperatures are lower along the left bank of the Ob' than along the right bank.

Within the valley proper, the second terrace (16–20 m above the river) has permafrost north of a line between Berezevo and Polnovat. The frozen strata are found in separate islands and small massifs, which occupy about 50–60 percent of the area. The first terrace, 6–10 m above river level, has a more extensive cover of peat that the second terrace. The first terrace is zoned as to permafrost in roughly the same manner as the second terrace. The flood plain, rising to 5 m above the river, is divided into a no-permafrost zone south of the confluence of the Big and Little Ob' Rivers, a zone of pereletoks between the Igorskiy Ob', Poluy, and Ob' Rivers, and a permafrost zone north of the mouth of the Poluy River where the permafrost is 20–80 m thick.—From Translation 59–11477, Office Tech. Services, Dept. Commerce, 30 Mar. 1959.

Ponomarev, V. M., 1936a, Permafrost and mine waters in the Arctic ["Vechnaia" merzoloty i rudnichnye vody v Arktike]: Sovetskaia Arktika, v. 2, no. 4, p. 111–116.

Temperatures along a mine shaft in Yakutia and Amderma are plotted to depths of 120 and 216 m, respectively. The temperature at 216 m was −5°C and at 120 m −3°C. The curve of Amderma permafrost penetration indicates the degradation which can be observed in any Arctic region having a similar climate. The geothermal gradient law does not apply to permafrost at Amderma, where permafrost reaches a depth of 400 m. Permafrost begins under the Amderma River at a depth of 2 m and lower under the larger rivers. The distribution of the permafrost table under the sea is graphed.

Some of the mines at Amderma have been flooded by sea water, but conditions in permafrost there are more favorable for prevention of flooding than at Nordvik, where there is a threat by mine waters.—From SIPRE U-5826; Arctic Bibliography 13711, par. 2.

Ponomarev, V. M., 1936b, Hot springs of the Chukotsk Peninsula [Goriachie istochniki Chukotskogo poluostrova]: Sovetskaia Arktika no. 12, p. 98–100, map.

Notes on location, thermal regime, chemical composition, and medicinal value of hot springs in the region.—Arctic Bibliography 13708.

1936c, The study of permafrost in 1936 [Izuchenie "vechnoi" merzloty v 1936 godu]: Sovetskaia Arktika, no. 2, p. 111–112.

Little if any work up to 1935 had been done on permafrost in the Soviet Arctic within the area of interest of the Department of the Northern Sea Route. In 1935 systematic investigations were begun by establishing the Anadyr, Yakutsk, and Amderma permafrost stations along the route, by studying permafrost in connection with hydrogeological and engineering geology research related to industrial construction at Noril'sk, Spitzbergen, and at mouths of the Ob' and Khatanga Rivers, and consolidation of these studies with results obtained in the Moscow laboratory. Work in 1936 was planned at Nordvik and Ugol'naya Bay, and increasing emphasis should be placed on the relationship between permafrost and agriculture, actinometry, solar radiation, subterranean waters beneath permafrost and their possible penetration into mines and shafts; origin of permafrost should also be studied. Permafrost temperature of —4.8°C at Amderma at a depth of 214 m, contrary to widespread opinion, shows that permafrost is thicker than 200 m.—From SIPRE 11372; abstract by E. A. Golomshtok for Stefansson Collection, Dartmouth College, Baker Library, Hanover, N.H.

1937a, Hydrogeological outline of the Amderma region [Gidrogeologicheskii ocherk Amderminskogo raiona]: Leningrad, Izd. Glavsevmorputi, Gornogeol. upra, Trudy, v. 1, 56 p.

Hydrological conditions and water supply within the permafrost zone are described, including the mine-water problem. Geothermal observations of the frozen zone indicate that the liquid phase of water is present below the normal freezing point at 0°C. Appearance of underground water in the permafrost region, conditions for freezing and circulation are discussed in detail, also climatic conditions and soil characteristics, with illustrations and observational data. Analyses of ice are given. Stratigraphy and structure of the Silurian limestones and slates are described. Unconsolidated Quaternary deposits are of gravel, sandy loam, turf, and peat. Characteristics of peat mounds are noted. The permafrost region is described with maps and diagrams of temperature distribution and ground composition. Boring indicated decreased temperature with depth; a temperature of —4.5°C was measured at a depth of 216 m.—From Arctic Bibliography 41935; SIPRE U-6972.

1937b, Recent data on permafrost [Vechnaia merzlota po noveishim dannym]: Problemy Sovetskoi Geologii, v. 7, p. 360–370.

Data on permafrost thickness and temperature and on chemical composition of the water in the frozen soil were collected in 1935–36 investigations of the Arctic coast of Siberia. Heavily mineralized ground water in the liquid state was found in permafrost at a temperature of —5°C; these waters are of marine origin and occur in a 2-km wide belt along the coastline. Similar waters at negative temperatures occur at the bottom of the seas where there are no currents.

The term "frozen ground" does not include the waters at negative temperatures, and a more suitable term would be "zone of negative temperatures of the lithosphere."

Minimum permafrost temperatures were —12°C at Nordvik, —5.1°C at Amderma, and —2.4°C at Barentsburg. The thickness of frozen ground in the central Arctic region near Nordvik and near Amderma is no less than 400 m. Permafrost thickness decreases westward toward Spitzbergen, presumably due to the warming influences of the Gulf Stream. In the central Arctic permafrost thickness is increasing, but degradation is recorded west of Spitzbergen and Amderma.—From SIPRE 9709; author's English summary.

1938. Study of permafrost for mine construction [K voprosu izucheniia vechnoi merzloty v sviazi s shakhtnym stroitel'stvom]: Akad. Nauk SSSR, Kom. vechnoi merzlote, Sbornik instruktsii i programmnykh ukazanii po izucheniiu merzlykh gruntov i vechnoi merzloty.

Permafrost in the Amderma region near the coast of the Kara Sea is studied in relation to mining operations. Permafrost at Amderma is 400 m deep. The soil temperature varies from —3.6° to —4.8°C at depths of 10–216 m. Air temperature curves in mine pits and insulated drill holes are given. A method of boring holes and measuring the temperature in mine pits and boreholes is described. Temperature is measured at various intervals from 1–10 m up to a depth of 150–200 m. A series of investigations were made regarding the hydrological and frost conditions, structure of water-bearing horizons and water permeability through the rock strata, surface icings, peat mounds, and taliks.—From SIPRE U–6265.

1940a, The Quaternary history of the Kozhevnikov Bay region [Ob istorii raiona bukhty Kozhevnikova v chetvertichnyi period]: Sovetskaia geologiia, v. 8, no. 11, p. 82–93.

In this typical polar area of northern Siberia, the Quaternary deposits indicate three periods of marine transgression alternating with two glacial periods and a Recent interval which included both a period of peat building and one of low sea level. The maximum known thickness of permafrost is 500–600 m. Temperature in two locations at a depth of 503 m measured from —2.4° to —1.5°C. Temperature in the upper layers ranged from —12° to —10°C. The fossil ice as much as 10 m thick occurs everywhere at various depths and even under a vegetation cover. The ice is heavily mineralized, especially with $CaSO_4$, except for certain ice from a coal mine at Cape Ilia. Stratification and structure of the ice indicates that it was formed from snow during the glacial epoch.—From Geol. Soc. America, Bibliography and Index of Geology Exclusive of North America, v. 9, 1936, p. 232, 1937; SIPRE 9269.

1940b, More on the hydrogeological conditions of Razdelnyi Peninsula (Vaigach Island) and Amderma [Esche raz o gidrogeologicheskikh usloviiakh polustrova Razdel'nogo (ostrov Vaigach) i Amdermy]: Problemy Arktiki, no. 4, p. 81–91.

P. V. Vittenburg's (1939) "The thermal regime and underground waters in the permafrost of Vaigach Island and Amderma" is critically discussed. Vittenburg's claim that permafrost reaches a thickness greater than 500 m and that no permafrost exists under the sea bottom does not agree with observations. Insufficient exploration of the thermal soil regime in the Razdelnyi Peninsula makes it impossible to determine the permafrost thickness. Permanent negative temperatures under the Varnek Bay were observed and led to the conclusion about the presence of permafrost under the sea bottom.—From SIPRE U–5749.

1952, Permafrost and ground water in the Ust-Yenisei Port [Vechnaia merzlota i podzemnye vody Ust'-Eniseiskogo porta]: Akad. Nauk SSSR, Inst. Merzlotovedeniia Trudy, v. 10.

Ponomarev, V. M., 1956, The main characteristics of ground water formation in permafrost regions [Osnovnye osobennosti formirovaniia podzemnykh vod oblasti rasprostraneniia mnogoletnei kriolitozony], *in* Tezisy i plany dokladov * * * k soveshchaniiu 1956 g. merzlotovedeniiu: Akad. Nauk SSSR. Inst. Merzlotovedeniia, no. 2, p. 29–32.

The characteristics of ground-water circulation, exchange, and chemical composition in permanently frozen rock are discussed. Three types of water are distinguished: fresh water at the surface, saline water in the middle layer, and water vapor in the bottom zone. The distribution of ground water in permafrost in given areas is closely related to their Quaternary history. Areas of young rock folds correspond to areas of the most intense ground- and surface-water exchange, plateaus to those of medium water exchange, and lowlands to those of very weak water exchange. Surface water forms the water-bearing horizon of the active layer and remains in the liquid state only a limited period of time, while ground water above the local erosion level is usually always frozen. The upper artesian water horizons in the north are frozen, while the temperature of those in large geological basins is depressed. Artesian water supply occurs through unfrozen areas under rivers, lakes, and along tectonic faults. In north coastal regions the ground water is high in marine mineral content and is in constant motion due to geothermal gradients.—From SIPRE 17045.

Ponomarev, V. M., and Filosofov, G. N., 1960, Unusual frozen ground phenomena [Svoibraznye proiavleniia merzloty]: Priroda, v. 49, no. 5, p. 90–91.

The characteristics of icing mounds in the Chul'man Basin and their formation are described. The mounds are found in depressions, reach a height of 3–4 m and a width of several tens of meters, and contain an ice core more than 1 m thick. A mound forms as the pressure of ground water increases in the autumn and the water breaks through the surface, lifting the upper soil layer. Later, water fills the cavity thus formed and freezes. The mound grows as more water is supplied from below, until a fissure forms at its surface. Water penetrates into the fissure in summer, destroys the ice; the soil settles, and a small thermokarst lake forms in the place of the mound, the edges of which often contain ice. Water was observed to well up in a thin spray 4 m high from a fissure at the top of a mound; as a result, the mound was covered with a thick ice crust.—From SIPRE 18685.

Ponomarev, V. M., and Tolstikhin, N. I., 1959, Ground water in permafrost areas [Podzemnye vody territorii s mnogoletnemerzlymi gornymi porodami], pt. 1, chap. 10, *of* Osnovy geokriologii (merzlotovedeniia): Akad. Nauk SSSR, Inst. Merzlotovedeniia, p. 328–364.

The origin and characteristics of ground water in permafrost areas and their interaction with the permafrost are discussed in detail. The various types of ground and artesian waters are described individually, and a table is presented giving for each type the state of the water (whether liquid or solid), its temperature, pressure, quality, mode of alimentation, and possible use. A map showing the distribution of various types of ground water in the permafrost regions of the USSR is included.—From SIPRE 17920.

Popov, A. I., 1945, Permafrost-geological sketch of the central part of the Vitim Plateau [abs.] [Merzlotno-geologicheskii ocherk tsentral'noi chasti Vitimskogo ploskoror'ia]: Akad. Nauk SSSR, Referaty nauchn.-issled. rabot 1944 Moscow, Otdel. geol.-geog. nauk, p. 128.

Permafrost formations were noted in the tectonic depressions of the Vitim Plateau. The temperature of the permafrost varied from —1.6° to —0.9°C at a

depth of 70 m. Permafrost was found under the Vitim River shoreline. It is suggested that the permafrost between the mine shaft and the bed of the Vitim River be preserved in the exploitation of oil shales.—From SIPRE U–1441.

Popov, A. I. *See also* Tolstikhin, N. I., 1937.

Popov, V. N., 1955, Features of ground water investigation in permafrost zones [Osobennosti izucheniia podzemnykh vod v oblasti mnogoletnei merzloty], *in* Organizatsiia i proizvodstvo nabliudenii za rezhimom podzemnykh vod: Moscow, Gos. nauchn.-tekh. Izd., Literatury po geologii i okhrane nedr, p. 73–75.

Factors influencing growth and degradation of permafrost are listed, and the probable effects of various hydraulic structures on permafrost and ground water are discussed. It is recommended that a thorough study should be made of thermal conditions of frozen strata and of supra-, intra-, and subpermafrost water before construction is begun, and the physical properties of frozen ground and the chemical composition of ground water should be analyzed in detail. Annual variations of ground water level and the dynamics of ground freezing (frost heaving, naleds, pingos) should also be considered in designing hydraulic structures.—From SIPRE 14062.

Porsild, A. E., 1925, Observations of Greenland "fountain ice" (sersineq) and its effects on vegetation and soil [Iagttagelser over den gronlandske kildeis [sersineq] og dens verkninger paa vegetationen og jordoverfladen]: Geog. Tidsskr., v. 28, p. 171–179. [English summary.]

Description from the Disko Bay region, of ice formed by brooks originating from hot springs, and the effect of these ice formations on soil and vegetation.—From Arctic Bibliography 13811.

1938, Earth mounds in unglaciated Arctic Northwestern America: Geog. Rev., v. 28, p. 46–58.

The Eskimo name "pingo" is proposed for the conical hills that occur on the low featureless Arctic coastal plain of North America from Point Barrow eastward past the Mackenzie delta to the Horton River area. These hills have also been termed "gravel mound" or "earth mound."

Porsild classifies pingos into two types, the type formed by hydraulic pressure occurs on sloping ground and pervious soils; the mounds are small, oblong, or ridgelike in outline or may simulate a moraine or esker. Some have been ruptured early in growth and show evidence of outflow of water. Other than seasonal mounds of the Greenland type, all those formed by hydraulic pressure are old and no longer active. Porsild suggests that in unglaciated northern Alaska ground water traveling seaward may have become trapped under the frozen surface soil to form ground or fossil ice, and that it formed local mounds or ridges by hydraulic pressure; these conditions seem particularly applicable to the northern Seward Peninsula and Kotzebue Sound area.

The second type of pingo is believed to be formed by local upheaval due to expansion following the progressive downward freezing of a body or lens of water or semifluid mud or silt enclosed between bedrock and the frozen surface soil. Pingos of this type are situated in or near a shallow lake or in the basin of a former lake that has become filled with vegetation and sediment; in many places the beds of sediment containing lacustrine shells and aquatic plants lie parallel to the slopes of the mound. The summits are commonly ruptured, and many contain small freshwater ponds.

A number of pingos in the Mackenzie District are described and illustrated.

Potapov, S. G. *See* Kolesov, G. G., 1933.

Presniakov, E. A., 1933, East Siberia and the Buryat-Mongol'skaya ASSR (A Symposium) [Vostochno-Sibirskii Krai s Buryato-Mongol'skoi ASSR]: Vses. geol. razved. ob"edinenie, Materialy dlia kharacteristiki resursov podzemnykh vod po raionam SSSR, 76 p.

Presniakov, E. A., and **Tkachuk, V. G.**, 1957, Problems in the further investigation of ground waters in eastern Siberia [O zadakh dal'neishikh issledovanii podzemnykh vod Vostochnoi Sibiri], *in* Materialy po podzemnym vodam Vostochnoi Sibiri: Irkutsk, Nauk SSSR, Vostochno-Sibirskii Filial. p. 177–181.

The problems discussed at the conference on ground water resources of eastern Siberia, held at Irkutsk in October 1955, are outlined, and future tasks are discussed. There is a need for large scale hydrogeological maps of the region and a systematic hydrogeological survey, especially in permafrost areas, using geophysical methods, and also for at least 2–3 stations to study the ground-water regime. In addition, the extensive material available on the ground water of various ore-bearing areas must be generalized and published. The almost complete absence of information on hydrogeological conditions in the permafrost areas of eastern Siberia should be remedied, and the work of permafrost and hydrogeological stations of the Academy of Sciences should be resumed in the region.—From SIPRE 18018.

Prindle, L. M., 1905, The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, Alaska: U.S. Geol. Survey Bull. 251, 89 p.

Frozen ground was encountered in placer mining operations in the Fortymile River area, along Wade Creek, Franklin Creek, Chicken Creek, and Lost Chicken Creek. In the Fairbanks area, frozen ground occurs on Pedro Creek, Twin Creek, Cleary Creek, Chatham Creek, Wolf Creek, and Fairbanks Creek. Claim 8 below Discovery on Cleary Creek had a shaft in which 30 ft of muck covered 22 ft of gravel resting on bedrock; "live water" was encountered, and pumping was required. On many claims the presence of ground water has frequently caused difficulty, and because of the need for pumping, has increased the cost of mining.

1906a, Yukon placer fields [Alaska]: U.S. Geol. Survey Bull. 284, p. 109–127.

In the Yukon region creek-valley deposits are a few to more than 100 ft thick and are mostly frozen. The deposits consist of muck, ranging in thickness from a few to 70 ft and of gravel from 10 to 60 ft. Underground mining under dry conditions is possible because the frozen gravel is impermeable to surface water and whatever ground water is present. In some places, however, unfrozen zones occur, and in the deeper placer ground live water adds to the expense of mining. In some valleys in the Yukon-Tanana country the deposits are so "spotted" with unfrozen zones in which live water occurs that it is practically impossible to mine by underground methods. The presence of live water is commonly shown by winter overflows to which the streams are subject and by unexpected filling of prospect holes by water from below. It is possible that the extent of unfrozen ground is greater than generally supposed.

Frozen ground, in addition to most of the creeks around Fairbanks, also occurs in placer mines and prospects on Tenderfoot Creek near Richardson, and on Butte Creek and Caribou Creek, tributaries of the Salcha River. Live water occurs in some of the claims on Butte Creek.

1906b, The Yukon-Tanana region, Alaska: Description of Circle quadrangle: U.S. Geol. Survey Bull. 295, 27 p.

Most of the unconsolidated deposits throughout the quadrangle are permanently frozen. The placer ground less than 20 ft deep is worked by opencut methods, but deeper ground, chiefly in the Tanana watershed, is worked by steam thawing and drifting. Live water has been encountered on Butte Creek, a tributary of Salcha River.

1908a, The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska, with a section on the Rampart placers, by F. L. Hess, and a paper on the water supply of the Fairbanks region, by C. C. Covert: U.S. Geol. Survey Bull. 337, 102 p.

Bedrock in the Fairbanks area is covered by unconsolidated deposits that are as thick as 300 ft, and consist of a few feet to about 70 ft of muck overlying gravel 10 to more than 60 ft thick. The deposits, for the most part, are frozen throughout the year. In many places unfrozen ground associated with "live water" increases the cost of mining deep placer deposits because of the need for pumping. On Smallwood Creek frozen unconsolidated deposits extend to a depth of 317 ft.

1908b, The Fortymile gold placer district [Alaska]: U.S. Geol. Survey Bull. 345–D, p. 187–199.

Much of the ground is permanently frozen to bedrock, but in many areas free water occurs in the ground during winter. In many streams water breaks through the ice to form overflows which build up thick accumulations of ice or "glaciers" in the stream valley, commonly burying placer mining improvements and equipment. Dredging ground on Walker Fork near Twelvemile Creek ranged in thickness from 6 to 14 ft and was covered by 1½ to 4 ft of muck; the alluvial deposits are frozen and are being thawed by steam points ahead of the dredge. The dredging ground on Fortymile Creek at the international boundary was unfrozen, for the most part. Ground to be worked on Pump Bar below the mouth of Franklin Creek was all unfrozen.

1910a, Auriferous quartz veins in the Fairbanks district [Alaska]: U.S. Geol. Survey Bull. 442–F, p. 210–229.

Most of the surficial deposits are permanently frozen. About a mile above the mouth of Chatham Creek a shaft sunk on an auriferous quartz stringer near the creek reached a depth of 24 ft, where water was encountered.

1910b, Sketch of the geology of the northeastern part of the Fairbanks quadrangle [Alaska]: U.S. Geol. Survey Bull. 442–F, p. 203–209.

Quaternary deposits, for the most part, are permanently frozen. The gravel in Bachelor Creek, tributary to Preacher Creek, is 7–8 ft thick and is unfrozen.

1913a, A geologic reconnaissance of the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, 82 p.

Alluvial placer ground on Harrison Creek is generally unfrozen and has circulating ground water that has deterred prospecting by sinking of shafts.

1913b, A geologic reconnaissance of the Fairbanks quadrangle, Alaska, with a detailed description of the Fairbanks district, by L. M. Prindle and F. J. Katz, and an account of lode mining near Fairbanks, by P. S. Smith: U.S. Geol. Survey Bull. 525, 220 p.

The greater part of the unconsolidated deposits, amounting to as much as 300 ft, is perennially frozen near Fairbanks, but a considerable part remains unfrozen and contains circulating ground water. The unconsolidated deposits consist of (a) gravel, commonly cemented by ice, and (b) muck which includes masses of clear ice as thick as 40 ft.

The extent of the consolidation of alluvial deposits by ice, although dependent primarily on the climate, is greatly modified by local conditions. Though most of the deposits that are being mined are frozen, there is a considerable circulation of underground waters, and in nearly every valley some workings have been flooded. The "live" water is very frequently encountered just above the productive gravels, the common clay content of the latter forming an impervious stratum. It is probable that where deposits are of such a character and so located as to be easily drained, they will not be subject to permanent consolidation by ice.

It does not seem that climatic conditions essentially different from those of the present time would be necessary to account for these deposits.—Author's report p. 97–98.

On the banks of Chatanika River near Our Creek, a prospect hole was sunk 218 ft to bedrock entirely in frozen grounrd; another hole 1 mile south of the Chatanika was sunk 317 ft. The bedrock floor of Ester and Cripple valleys is suprisingly flat, and the hill that separates the valleys consists of 134 ft of muck, 5 ft of quicksand, and 35 ft of gravel, all being unfrozen. Mines in unfrozen ground in Ester Creek pump the water and use it for sluicing, the cost of pumping being offset in part by lack of costs for thawing and for providing water.

Gravel deposits in the bed of Bachelor Creek, a tributary of Preacher Creek, are not frozen.

The problem of winter water supply for stamp mills has required location near a large stream which flows all year or attempts by drilling or using mine water to develop suitable water convenient to the mine in order to save transportation charges for hauling the ore from mine to mill. The attempts to develop sufficient water through drilling have been unsuccessful, as has been using the seepage water from the mine.

At the Pioneer mine on Chatham Creek a mile above Cleary Creek, foundations for the stamp mill were on frozen ground containing ground ice. Water for use in the mill was to be obtained from an abandoned shaft more than 100 ft deep on the west side of Chatham Creek. Earlier miners had been unable to control the flow of water in this shaft.

Prindle, L. M., and Katz, F. J., 1909, The Fairbanks gold placer region [Alaska]: U.S. Geol. Survey Bull. 379–E, p. 181–200.

Much of the superficial material is permanently frozen to depths that may exceed 300 ft. "Differences in the material and the position of the material with reference to drainage, however, have exerted a modifying action on the processes of freezing and there are considerable areas of deep deposits that are unfrozen." (See p. 183.) In some of these unfrozen deposits, circulating waters complicate the mining problem. The gravel deposits are overlain by muck in which occur ice masses as much as 40 ft thick.

On Ester Creek, workings have been extended into unfrozen ground carrying live water; the water is pumped to the surface for use in sluicing operations. The cost of mining ground that requires drainage is commonly twice that of frozen ground.

Prokhorov, S. P., 1954, Study of ground water in mines [Izuchenie rezhima shakhtnykh vod], *in* Metodicheskoe rukovodstvo po izucheniiu rezhima podzemnykh vod: Vses. nauchn.-issled. Inst. gidrogeologii i inzherernoi geologii p. 80–87.

Methodology of the study is discussed; also (p. 91–92) ground-water conditions in mines in permafrost regions, especially near the seacoast.—From Arctic Bibliography 47462.

Pryor, W. T. *See* Eager, W. L., 1945a.

Purington, C. W., 1905a, Methods and costs of gravel and placer mining in Alaska: U.S. Geol. Survey Bull. 263, 273 p.

Problems of mining and prospecting in areas of permanently frozen ground are discussed throughout the text. In prospecting, drill holes are best for deep ground where an excess of water prevents sinking of shafts. Ground that is partly frozen is the most difficult to prospect; for example, in the Birch Creek and Fortymile districts, shafts 15–25 ft deep penetrate frozen ground and require no timbering until they are within 5 ft of bedrock, where they encounter a "rush of water." In such cases, the entire shaft may be flooded and the costs of its construction lost. On American Creek (Fortymile area) prospecting is difficult because of running water at bedrock, even in winter. In the Nome and Council areas the ground is solidly, lightly, or only partly frozen, but in the Kougarok and other parts of northern Seward Peninsula the ground is solidly frozen.

Drifting operations on a bench of Anvil Creek, Seward Peninsula, consisted of a 500-ft adit the length of the ground transverse to the creek and 10 ft below the bedrock surface. The adit served as a drain for the workings. The ground was partly frozen, and as in parts of the interior of Alaska, the constant draining of the ground is believed to assist in a gradual thaw of the frozen ground.

Partly frozen ground was encountered in placer operations on Eagle Creek, Birch Creek district.

Quantity of water in frozen gravel of the placer mines of the interior averages about 25 percent; in muck the water content is 50–75 percent. On Seward Peninsula it is noted that thawed ground commonly occurs where willows grow, but the ground is generally frozen beneath a cover of moss. Studies by G. W. Pichard for this report show that use of any form of electric furnace for thawing ground is impracticable.

In constructing the Miocene ditch on Seward Peninsula, ground ice sheets as long as 800 ft were encountered. These were crossed by either (1) lining the ditch with clay on top of the ice or (2) building a wooden flume across the ice, with footings set in the ice and packed with moss to prevent thaw.

In a small island opposite Eagle, a shaft sunk through rolled Yukon River gravel to a depth of about 40 ft in the winter of 1904 penetrated perpetually frozen ground to almost 40 ft, at which point a strong underflow of water prevented further prospecting.

1905b, Methods and costs of gravel and placer mining in Alaska: U.S. Geol. Survey Bull. 259, p. 32–46. *See* annotation, Purington, C. W., 1905a.

Quackenbush, L. S., 1909, Notes on Alaskan mammoth expeditions of 1907 and 1908: Am. Mus. Nat. History Bull., v. 26, p. 87–130.

Radforth, N. W., 1954, Paleobotanical method in the prediction of subsurface summer ice conditions in northern organic terrain: Royal Soc. Canada Trans., 3d ser., v. 48, sec. 5, p. 51–64; repr., 1955, Canada Natl. Research Council, Assoc. Comm. on Soil and Snow Mechanics Tech. Memo. 34.

The active layer, termed "climafrost," and its relation to organic terrain are described with emphasis on terrain interpretation. The conclusions are based on examinations for frost behavior made during the summer months in the Churchill (Manitoba) area over a period of 3 yr. Isolated effects of frost action visible at the ground surface and due to ground ice are classified as vertical free lift, vertical confined lift, and displacement fault. More widespread effects can be noted in typical climafrost contour patterns which are classified as polygon differential, pond hole, ridge elevation, boulder locus, and multiple knoll.—From SIPRE in Arctic Bibliography 36954.

Rakitov, A. I., 1940, The stability of petroleum deposits in permafrost regions [Migratsiia nefti v usloviiakh vechnoi merzloty]: Problemy Arktiki, no. 6, p. 40–57.

The petroleum deposits were formed before the appearance of permafrost, and the frozen ground prevented the penetration of the oil into surrounding strata. The high gaseous content of the oil under the influence of low permafrost temperatures and the pressure of subpermafrost water, especially mineralized water with a lower freezing point, are important factors increasing the output of wells in these regions.—From SIPRE 9867.

Rakitov, L. I. *See* Petrov, L. S., 1940.

Rankka, W., 1930, The use of underground drainage to lessen damage caused by soil freezing [Salaojituksesta routimishaittojen lieventajana]: Teknillinen aikakauslehti, v. 20, p. 181–187.

Contains a general outline of the types of frozen soil and ground waters and their interrelationship; effect of underground drainage and its use in decreasing damage to railroad and road beds.—Arctic Bibliography 25358.

Raspopov, M. P., 1931, Permafrost and hydrogeological conditions in permafrost regions [K voprosu o vechnoi merzlote i gidrogeologicheskikh usloviiakh merzlotnykh raionov]: Leningrad. gos. gidrolog. inst. Izv., no 41, p. 36–44.

Views of Russian and American scientists on the problem of permafrost, its origin, and distribution are presented. Observations made in eastern Siberia emphasize the importance of hydrochemical processes affecting the thickness and depth of the permafrost layer. Underground waters are closely interrelated with permafrost. The high degree of water mineralization reduces permafrost thawing. Investigations made in the Borzinsk region (Siberia) showed that where the permafrost was 11.2 m thick, the mineralization of the water was 97.5 mg per liter in a well, and 1078.0 mg per liter in another well where the permafrost was only 1.5–2 m thick.—From SIPRE U-5174.

1933, The problems and planning of underground water observations by second class stations in permafrost regions [Zadachi i programma rabot statsii 2 klassa po nabliudeniiam za rezhimom podzemnykh vod v merzlotnykh raionakh] *in* Issledovaniia podzemnykh vod SSSR: Leningrad, gos. gidrolog. inst., v. 4, p. 85–94.

The peculiarities of hydrogeological conditions in permafrost regions are described, and a program of study of factors relevant to permafrost formation

and degradation is presented. Long severe winters with scant snow cover, short dry summers, and low annual precipitation are favorable factors for permafrost formation. Vegetative and peat covers prevent deep heat penetration into soil. Permafrost-table variations, change of the underground water table, study of naleds and measurements of soil temperature should be the principal elements of observations on any second class station.—From SIPRE 7473.

Rathgens, G. W., 1944, The saga of the Greenland bases: Eng. News-Rec., v. 133, p. 274–278.

1951, Arctic engineering requires knowledge of permafrost behavior: Civil Eng., v. 21, no. 11, p. 645–647.

Permafrost temperature and depth vary widely, from 15° to 32°F and from a few feet to a thousand feet. In Siberia permafrost has been reported at a depth of 2,000 ft. In design work in permafrost the engineer must consider, first of all, whether to disturb some of the permafrost or keep it undisturbed. Three examples illustrate solution of engineering problems in permafrost areas.

Example 1.—A diversion dam 800 ft long with a 100-ft spillway was built in 1927. Preparatory studies showed considerable water moving through gravel in the riverbed and its vicinity; the packing and grading of the gravel varied considerably at different points on the damsite. Water temperature at the point of diversion was 32°–36°F; the water was required to thaw permanently frozen ground at placer mines 100 miles distant. Estimates of project requirements were for 125 cfs plus seepage, evaporation, and other losses. The river runoff varied greatly from below this amount in dry years to many times that required during flood stages. Pondage of water was not practicable. Bedrock was 15–20 ft below the riverbed. Ice forming on a bar below the water surface near the damsite indicated that some of the bedrock below the sand and gravel was permanently frozen. Investigation showed that, except for the decomposed zone at the base of the alluvium, bedrock was frozen.

Because of water shortage in dry years, it was decided to intercept water moving through gravel at the damsite; in addition, the subsurface water during fall was warmer than surface water. To conserve the water by sealing off its flow would mean that permafrost would aggrade in thawed bedrock and in the thawed stream gravel. This aggradation might cause damage to a concrete structure because of difficulty in maintaining a proper seal with frozen bedrock. Instead, the subsurface water was intercepted by driving interlocking sheetpiling well into the bedrock. Wooden piling was also driven to support the wooden superstructure of the dam. The connection between the superstructure and the steel sheetpiling was designed to allow differential movement to take place without serious damage until such time as permafrost aggradation should occur in materials surrounding the piling. Each winter the structure is covered with ice and most of the pondage upstream is ice.

Example 2.—A deep oil well to be founded on permafrost posed a problem, for it was recognized that the flow of drilling mud from the well would be a heat source (approx 110°F) and tend to thaw permafrost, especially the upper 20 ft which consisted of frozen clay and sand with ice lenses. To minimize thaw of permafrost, hollow steel piles were set in previously thawed holes and permitted to backfreeze; the piles were used to transfer weight of the rig to undisturbed permafrost. A certain amount of refrigeration was required to maintain the permafrost.

Example 3.—In 1926, near Fairbanks, a 6,500-KVA-steam powerplant was installed on what appeared to be thawed gravel. However, only part of the gravel was thawed, and the site proved to be located on a large kidney of dry permafrost in sand and gravel in which the particles were closely packed. Water was running with measurable gradient in the more open-textured gravel next to the kidney of permafrost. The design was altered to thaw a part of the dry permafrost in the center of the kidney and to use the thawed confined gravel and sand to support and distribute the load to the permanently frozen materials which surrounded them on all four sides and below. The thawed area extended about 100 ft farther in each direction and 30 ft deeper than the building foundations. To disturb the permafrost so that live ground water could move through the fractured zones might have caused thawing of the surrounding frozen materials accompanied by continuous serious settlement over a number of years.

Compiler believes that the dam mentioned in example 1 is that built on the Chatanika River near McManus Creek as the intake for the Davidson Ditch by the U.S. Smelting, Refining, & Mining Co. (Fairbanks Exploration Co.), that example 2 is a well from the U.S. Naval Petroleum Reserve No. 4, and that example 3 is the Fairbanks Exploration Co. powerplant north of Fairbanks.

Rathgens, G. W., 1956, Construction techniques (developed in mining, powerplant construction and electrical distribution in Alaska), *in* The Dynamic North, U.S. Navy, Tech. Assistant to Chief of Naval Operations for Polar Projects (Op–03A3) : book 2, table 10, 17 p.

Ground water in permafrost areas is a conveyor of heat and is subject to conversion to ice by subtraction of heat; ground water has established a temperature equilibrium which should not be disturbed in construction. For example, even light loading by fill beneath a road will cause compaction of the moss covering; the compaction may restrict flow of water, and in winter may cause development of hydrostatic head on the overlying frozen cover, when icings form. Ice blisters also form from hydrostatic pressure of ground water, and release of the water at the surface is generally through cracks in the frozen ground formed by this pressure.

Experiments in storing water were undertaken by compacting the moss cover after early freezeup and before significant snow cover. By this compaction, icings were formed to considerable thickness and provided storage of the water. Construction of siphons in 1926 to carry the water of a mining hydraulic ditch across a tributary valley showed that disturbance of the ground to place piling caused icing conditions that lifted the siphon pipe off its supports. The next year the natural ground-water drainage was restored, and no further trouble was encountered.

Spores of crenothrix and similar bacteria are present in some frozen gravel deposits in the Arctic, and any change in the thermal balance may result in development of the organism and changes in the permeability of the gravel. It is known that where thawed sand and gravel occur in permafrost, they are the most permeable beds; the frozen material is generally tighter, less permeable material. Packing and moisture content of gravel and sand are important in construction, for if in "dry frost" little subsidence can be expected, but if not dry frozen, some subsidence may occur. For example at the powerplant of Fairbanks Exploration Co. at Fairbanks, a frozen kidney of dry frost beneath the building foundations was surrounded by ground in which water was moving. A part of the kidney of permafrost was thawed by locomotive steam; no settlement has occurred since construction of the plant in 1928, and no refreezing has taken place. Large California-type wells drilled 150–360 ft upstream from the powerplant produced 9,000 gpm for use in the cooling condensers.

Areas where ground-water movement occurs only part of the year may be indicated by the character of the vegetation or by stains at the lower part of the cover, between the cover and permafrost, or in sand and gravel forming a contact zone between the cover and permafrost. Fort example, in one area, spruce indicated frozen muck and absence of ground water beneath the cover of moss. The valley fill consisted of windborne brown muck and waterborne black muck containing ice masses; the gravel beneath the muck lay at a depth of a few inches to 200 ft. On higher ground bordering the valley, birch and aspen grow on thawed zones where migration of moisture upward may have taken place along a fault; salt licks occur among the birch and aspens. Wells encountered artesian flows of warm water and some methane gas. One small lake had three openings in line with zone of birches and alders, along which warm water and methane gas were emitted from the bedrock below; these spots remained open all winter for three or four winters.

Mention is made of driving sheet piling into gravel deposits beneath the river and into bedrock in an effort to seal off the subsurface flow.

Ravdonika, O. V., and **others**, 1959, Ground waters in the West Siberian low- land according to deep boring data [Podzemnye vody Zapadno-Sibirskoi nizmennosti po dannym glubokgo bureniia].: Sibirskii nauchn.-issled. Inst. geologii, geofiziki i mineral' n. syr'ia, Materialy po geologii * * *, p. 106–109.

Reviews Mesozoic ground water studies carried out since 1949 by "Zapsibneftegologiia", "Tiumen'neftegeologiia", and "Minusinneftegeologiia." Methods and work are evaluated; results are summarized, including the ground water properties of the Berezevo, Khanty-Mansiysk, Chulym-Yenisey and other regions. Some data are given on mineralization, temperature, chemical composition, and on gas and oil content.—Arctic Bibliography 61124.

Ray, L. L., 1951, Permafrost: Arctic, v. 4, no. 3, p. 196–203.

A general summary of knowledge of permafrost to 1951, the report states that free circulating water cannot exist within continuous permafrost; in these areas the suprapermafrost water supplies are generally unreliable, except surface water in deep lakes and streams. In discontinuous permafrost, steady supplies of ground water are commonly available from talik either below or within permafrost; this type of water may be highly mineralized. Wells drilled through permafrost are difficult to maintain, especially where the permafrost has a high percentage of ice. Distribution pipes laid in the active layer are subject to heaving and freezing; those in permafrost are subject to freezing unless a large volume is kept in circulation.

1952, Perennially frozen ground, an environmental factor in Alaska: Internat. Geog. Union, 8th Gen. Assembly, 17th Cong., Washington 1952, Proc., p. 260–264.

Ray, P. H., 1885, Report of the International Polar Expedition to Point Barrow, Alaska: Washington, Govt. Printing Office, 695 p.

A shaft near Point Barrow begun December 8, 1881, and completed February 17, 1883, reached a depth of 37.5 ft. The upper 15 ft exposed frozen clay and gravel; from 15 to 24.7 ft is sand; 24.7 to 26.3 ft is clay; and from 26.3 to 37.5 ft sand and a little fine gravel. The clay between 15 and 24.7 ft was quite dry but firmly cemented by ice and locally smelled of chlorine. Four days after encountering the top of the sand and fine gravel at 26.3 ft, salt water at 15°F entered the hole. From February 17, 1883, to closing of the station, the ground

temperature, measured by a thermometer lowered on a string to the bottom of the hole, was constant at +12°F.

Redozubov, D. V., 1946, The temperature field laws of permafrost in Vorkuta [Zakonomerosti temperaturnogo polia vechnoi merzloty na Vorkute]: Akad. Nauk SSSR, Inst. Merzlotovedeniia im. V. A. Obrucheva Trudy, v. 1, p. 137–166. [English summary.]

Reece, G. M. *See* Hyland, W. L., 1951a.

Reed, I. McK., 1943, How Dawson keeps its water mains from freezing: Pacific Builder and Engineer, v. 49, no. 8, p. 54.

Water for Dawson, Yukon Territory, is obtained from a well, supplemented at extra demand from the Klondike River.

Reed, J. C., 1958, Exploration of Naval Petroleum Reserve No. 4 and adjacent areas, northern Alaska, 1944–53; part 1, History of the exploration: U.S. Geol. Survey Prof. Paper 301, 192 p.

This chronological summary of the exploration for petroleum by the U.S. Navy and its contractors gives a valuable insight into the importance of permafrost in all aspects of Arctic operations. Geological investigations were made by the Geological Survey in cooperation with the Navy. All test holes and exploratory wells encountered permafrost; in some places oil occurred within permafrost or was trapped beneath its base. No ground water occurs within the permafrost zone, except in local situations. In winter the water that lies above permafrost is frozen to a depth of 7–9 ft, and the only source of water is in the deeper lakes and streams below the ice cover.

Reed, J. C., and **Bostock, H. S.**, 1954, Research in geology and geomorphology in the North American arctic and subarctic: Arctic, v. 7, nos. 3 and 4, p. 129–140.

Although ground-water principles, as generally understood, apply in large parts of the subarctic, new principles and new factors need to be appraised for permafrost areas. Thus, ground-water geology in the north is closely related to both the permafrost and the geomorphologic fields.

Reiniuk, I. T., 1959, Condensation as one of the sources of ground-water recharge in permafrost areas [Kondensatsiia kak odin iz istochnikov pitaniia podzemnykh vod v oblasti mnogoletnemerzlykh porod [vechnoi merzloty]]; *in* Materialy po obshchemu merzlotovedeniiu: Akad. Nauk SSSR, Inst. Merzlotovedeniia, p. 244–261.

The results of studies since 1949 in the Kulu, Kolyma, and Magadanka River basins to determine the contribution of condensed vapor in the active layer to the water balance are reported, and the methods of measurement are described in detail. The amount of condensation water contributing to runoff averaged 90 mm per yr, with a maximum of 140 mm, or 30–50 percent of total precipitation. The zone of condensation increased as the ground thawed, and air temperature and relative humidity rose. Condensation in the active layer seems to depend on local conditions, especially the composition of the ground. Condensation amounted to 100 mm per yr in rock waste on slopes, to 50 mm in peat and loam, and 200–600 mm in sand. The absolute air humidity in the soil decreased sharply with depth and decreasing soil temperatures, from 7.6 mb at a depth of 0.5 m to 6.5 mb at 1.3 m. Condensation is attributed to disturbance of the vapor equilibrium in the active layer with the invasion of

warm air and the migration of vapor to the disturbed area.—From SIPRE 17947.

Riabukhin, G. E., 1939, Certain manifestations of permafrost in the Ust'-Port region [O nekotorykh proiavleniiakh vechnoi merzloty v raione Ust'-Porta]: Problemy Arktiki, no. 6, p. 82–85.

Prospect drilling for oil and observations on permafrost were conducted in 1939 by the Arctic Institute at Ust'-Port at the mouth of the Yenisey River. The region is part of the Taimyr depression and is covered with Quaternary glacial deposits and marine sand which covers Tertiary and Upper Cretaceous rocks. Because borehole walls thaw during drilling, it is necessary to drill rapidly and to use a salty frost-stable drilling solution. Borehole 3 on the high bank of the Yenisey encountered ground at a depth of 300 m that was not consolidated by ice, but had a negative temperature. Temperatures ranged from −6.2°C at 6 m to −3.7°C at 145 m. Borehole 5 in the flood plain encountered thawed ground at a depth of 130 m; the temperature ranged from −3.0°C at a depth of 10 m to −0.7°C at 122 m. The increased temperature in borehole 5 was due to the warming effect of the Yenisey River. No ground water was encountered beneath the frozen ground in this hole.

Peat and ice mounds (pingos) as much as 22 m high and 50 m in diameter occur near the mouth of Mala Kheta River. The pingos are believed to have been formed during the postglacial thermal maximum and are now in a state of degradation.—From SIPRE U–1849; unpublished condensation and emendation by I. V. Poiré.

1940, New data on the geology along the lower course of the Yenisei River [Novye dannye po geologii nizhnego techeniia Eniseia]: Sovetskaia geologiia, v. 8, no. 11, p. 21–34.

The results of investigations during 1936–40 are reported. The region is in the zone of permafrost which is 50 m thick in the south near Igarka and has a temperature of about −1°C in the upper layer. Permafrost in the Ust'-Port region is about 300 m thick with upper-layer temperatures of about −6°C, and near Gol'chikha reaches a thickness of about 400 m with upper-layer temperatures near −12°C.

During construction of the oil well near Ust'-Port no special difficulties were encountered drilling through permafrost. However, the walls of the hole soon began to collapse because the ground began to thaw, and some of the machinery was damaged. No remedy has been worked out for this problem.—From SIPRE 9268 (par. 1); abstract by E. A. Golomshtok for Stefansson Collection (par. 2), Dartmouth College, Baker Library, Hanover, N.H.

Richards, H. G., 1950, Postglacial marine submergence of Arctic North America with special reference to the Mackenzie delta: Am. Philos. Soc. Proc., v. 94, no. 1, p. 31–37.

Fossil ice or ground ice possibly of great antiquity dating from late Pleistocene occurs along the shore of west branch of Mackenzie River about 5 miles northeast of Kittygazuit opposite Richards Island. About 15 ft of ice was overlain with 3 ft of sand; the base of the ice was not exposed; other deposits of ice are known from Herschel Island. The several small pingos observed between Aklavik and Kittygazuit probably formed in the manner postulated by Porsild (1938).—From p. 34.

Richardson, John, 1841, On the frozen soil of North America: Edinburgh New Philos. Jour., v. 30, p. 110–123.

Data on permanently frozen ground and its temperature were collected personally in 1825–26, and with the cooperation of the Hudson's Bay Co. in Canada beginning in 1835.

At Fort Simpson, frozen ground was found to extend at least 17 ft below the surface; mean temperature of the air is about 25°F. The pits dug at Fort Chipewayan and Great Slave Lake encountered rock and were abandoned. Frozen ground was found at Severn Outpost on the west side of Hudson's Bay. At York Factory a pit 30 yd from the river was found to be thawed in the upper 3 ft in October 1835; between 3 and 20½ ft was permanent frost, beneath which was thawed mud whose temperature was 33°F. At Fort Simpson a pit dug 80 yd from the riverbank exposed 10 ft 7 in of thawed mixed sand and clay underlain by 6 ft 3 in of frozen material, beneath which was 8 ft more of loose sandy soil; a rod was thrust from the bottom of the pit 4 ft deeper, to a total depth of 29 ft beneath the surface. At Fort Franklin on Great Bear Lake ground was frozen from 21 in. to more than 6¾ ft deep. On an island in the Arctic Ocean at 70°10′ N., 129°15′ W. the thaw in July had penetrated scarcely 1 ft.

1854, The zoology of the voyage of the H.M.S. Herald under Captain Henry Kellett, during the years of 1845–51: London.

Rickard, T. A., 1908, Dredging on the Seward Peninsula: Mining and Sci. Press, v. 97, p. 734–740.

Operations of the Nome Mining Co. on Bourbon Creek near Snake River, less than half a mile from Nome, included prospect drilling. Nine holes per 20-acre claim were drilled, and the 200 holes ranged in depth from 28 to 80 ft; unfortunately, they were poorly logged. Bedrock was as deep as 80 ft. Experience in dredging shows that there may be 6 in. to 6 ft of frozen ground, usually well above bedrock in the Ophir area near Council, 85 miles southeast of Nome. The frozen ground was formed by freezing of pools of water in old workings (ventilated during winter cold to encourage freezing of shafts and drifts), and it is not original frost, for most of the creek gravel was naturally thawed originally. Scrub willows are an unfailing sign of unfrozen ground. This secondary frost in the old workings is not so bad as the original frost.

Some difficulty was reported in using steam points in partly thawed ground because the drill hole chokes before the point can be positioned. Ignoring frozen ground is the cause of numerous accidents to dredges. On Solomon Creek a good program of prospect drilling was done by one of the miners (Leland). Dredging was started in the thawed areas covered by scrub willow, then shifted later in the season to places like gravel bars where seasonal frost penetration was deep.

1909, Drilling in alluvial ground in Alaska: Mining and Sci. Press, v. 99, 558–559.

At Nome some 25 Keystone drills are in operation. Drilling is done in the winter; for example, on Thanksgiving Creek in the Hot Springs district near Fairbanks, drilling was done in all months but January and February of 1908. The casing was used in the upper 5 ft, but the rest was drilled as an open hole in areas of frozen ground. As a general rule, however, casing is advisable because varying proportions of ice may cause formation of a pothole. If the ground is thawed deep, casing should be used all the way. Only heavy casing is used. In summer when the surface water entering the hole is warm enough

to slough slides, casing may be used. Costs for drilling forty 25-ft holes without casing was $1.01 per ft at Hot Springs and $1.50 per ft at Nome, or about half the normal cost.

A. L. Hamilton, of Fairbanks, stated that in using a No. 3 Keystone drill he got live water in every case by penetrating 12–15 ft of bedrock. In frozen muck he once drilled 135 ft in 11 hr. On claim 11 below, on Dome Creek, a shaft sunk 148 ft was filled with 75 ft of ooze and mud which rose from the bottom. On claim 7 below, on this creek, drifts became impassible because of heaving bedrock.

In prospecting it is common practice to thaw ahead of the drill, using a steam point 5 ft long with a pipe than can be lengthened. The point is used in the hole less than 5 minutes, for if left too long, the hole would be larger than the casing. The hole must be cased if it is to be used for sampling.

Rink, H. J., 1863, Concerning the outlet of the water from the interior of Greenland through springs underneath the icecap [Om vandets afløl fra det indre af Grnøland ved Kilder under isen]: Naturh. tidssk. 1861–63, Raekke 3, v. 1, no. 2, p. 311–327.

Discusses the comparative lack of rivers in Greenland; notes that the actual estuaries are covered by ice 1,000–2,000 ft thick; that the watershed divide is closer to the east coast than west coast; compares amount of water from interior and the amount of ice deposited in the fjords in the form of icebergs; projects theory that ice masses are moved by running water underneath; that springs underneath the ice also function in the winter; discusses springs in the sea just offshore.—Arctic Bibliography 14622.

Roberts, Brian. *See* Armstrong, T. E., 1958.

Roberts, W. J. *See* Abu-Lughod, J., 1957.

Robinson, F. M., 1956, Core tests and test wells, Oumalik area, Alaska, *with* Paleontology of test wells and core tests in the Oumalik area, Alaska, by H. R. Bergquist; U.S. Geol. Survey Prof. Paper 305–A, p. 1–70.

Permafrost is reported in the East Oumalik test well 1 to a depth between 740 and 750 ft. Ikpikpuk core test 1 was drilled 178 ft through 30 ft of sand and clay of the Gubik formation into the Chandler formation. Oumalik test well 1 (11,872 ft deep) and 12 foundation core tests, each 40–50 ft deep, and 2 core tests, 190 and 392 ft deep, all penetrated permafrost at least 50 ft thick and produced no water. Attempts to place thermal cables in East Oumalik test well 1 and Oumalik test well 1 immediately after drilling failed when the cables broke a few days after installation. Temperatures measured before cable failure were positive, and reflected the disturbed condition of the temperature regime after drilling.

1959a, Test wells, Titaluk and Knifeblade areas, Alaska, *with* Micropaleontologic study of test wells in the Titaluk and Knifeblade areas, northern Alaska, by H. R. Bergquist: U.S. Geol. Survey Prof. Paper 305–G, p. 377–422.

In Titaluk test well 1 circulation of the drilling mud was lost at a depth of 87 ft. Temperature studies by M. C. Brewer showed that the depth of the bottom of permafrost (temperature continuously below 0°C) was slightly more than 800 ft, but it was not known whether thermal equilibrium had been reached at this time.

Knifeblade test well 2 was abandoned at 373 ft, still in permafrost. Knifeblade test well 1 hit water at 845–850 ft, and Knifeblade test well 2A hit water

at 857 ft, possibly at the base of permafrost. Bailing tests were conducted during drilling of Knifeblade test well 1; when abandoned at a depth of 1,805 ft, the well was producing about 10 gal per hr. Salinity of the water was 4,000–6,380 ppm.

In Knifeblade test well 2A, bailer samples taken at the top and bottom of the water column showed temperatures of 31° and 38°F. Schlumberger equipment was used to try to determine the permeability of sand below 771 ft on the basis of change in the temperature gradient before and after bailing; the experiments did not succeed, as the temperature was 28°F at the top and 29.7° at the bottom in each test. These results could have been caused by temperature-equalizing convection currents or by faulty procedure or equipment.

Robinson, F. M., 1959b, Test wells, Simpson area, Alaska, with a section on Core analyses, by S. T. Yuster: U.S. Geol. Survey Prof. Paper 305–J, p. 523–568.

Simpson test well 1 completed in 1948 to a depth of 7,002 ft encountered tundra, muck, sand, and ice from 17 to 50 ft below the kelly bushing. A temperature survey made immediately after cessation of drilling showed that between the surface and 975 ft the temperature was 52°–54°F and that the rapid increase to 58°F between 975 and 1,050 ft probably represents the base of permafrost. Later measurements, 3 months after completion of the well, indicated negative temperature at a depth of 900 ft and positive temperature at 1,000 ft, but the temperatures had not reached equilibrium. In the core analyses prepared by S. T. Yuster, connate water with chloride content ranging from 3,678 to 11,247 ppm probably would be frozen within the permafrost zone.

In North Simpson test well 1 the electric log shows a high resistivity layer, probably fresh water or ice, down to a depth of about 500 ft. Permafrost depth was not recorded by the driller.

Robinson, F. M., and Collins, F. R., 1959, Core test, Sentinel Hill area and test well Fish Creek area, Alaska: U.S. Geol. Survey Prof. Paper 305–I, p. 485–521.

Permafrost was encountered at the site of Sentinel Hill core test 1, but installation of thermal equipment was prevented by mudslides that covered the site of the test after completion of the drilling. Anomalies in the electric log of Fish Creek test well 1 suggest that the ground is permanently frozen to a depth of some 600 ft.

Rodriguez, Raul *See* Schmitt, R. P., 1960.

Rogatko, G., 1940, Water supply on the Northern Sea Route [O vodosnabzhenii na Severnom morskom puti]: Sovetskaia Arktika, no. 11, p. 37–38.

Encouragement for organizing bases of water supply for ships along the Northern Sea Route; in particular, a plan for a water pipeline on Novaya Zemlya from Lake Otradnoye to Cape Zheliniya on the northern tip of the island.—Arctic Bibliography 14745.

Rogers, G. W., 1956, Water development projects are begun in three Alaska villages: Alaska's Health, v. 13, p. 1, 7, June.

Pilot projects at Chevak, Hooper Bay, and Kwethluk include a dug well, pump, and pumphouse. The projects, financed by Alaska Rural Development Board and Alaska Public Works Agency funds, were preceded by an investigation by the U.S. Geological Survey.—From Arctic Bibliography 47642.

Rogozin, N. A., 1958, Naleds of the Izvestokovaya-Urgal section of the Amur Railroad [Naledi na linii Izvestkovaia-Urgal Amurkskoi zheleznoi dorogi]: Akad. Nauk SSSR, Inst. Merzlotovedeniia, Materialy k osnovam ucheniiu o merzlykh zonakh zemnoi kory, v. 4, p. 179–195.

The results of personal studies from 1951 to 1953 on the formation, responsible factors, and effects of naleds are reported. The types of water feeding the naleds, the preferred sites of naled formation, the effect of naleds on railroad operations and associated installations, the duration of naleds, and the influence of individual factors on the degree of naled development are discussed individually. The region studied is characterized by the presence of numerous active naleds (200 in a stretch of 340 km), forming as a result of the activity of ground water. The intensity of naled formation is determined by air temperatures, snowcover depth and duration, the thickness of the vegetative cover, summer and autumn precipitation, the orientation of the site, and other climatic, hydrological, and relief factors. Water most responsible for naled formation includes diluvial water located at a depth of 1–2.5 m on slopes, and subpermafrost fissure water. Ground naleds are active from mid-December to late March, and river naleds from early January to the end of winter. Naled development is most intense in severe winters with little snow, and depends on the time interval between the onset of freezing temperatures and the first snowfall.—From SIPRE 18424.

Rozen, M. F., 1935, Observations on the permafrost distribution in the Pechora delta [Nabliudeniia nad rasprostraneniem vechnoi merzloty v del'te reki Pechory]: Akad. Nauk SSSR, Kom. izuch. vechnoi merzloty Trudy, v. 4, p. 151–170.

Permafrost was found at shallow depths along the main banks of the Pechora River during drilling operations from 1926 to 1933. Permafrost was not found at a depth of 13.5 m in Nar'ian-Mar, 9 m above river level. Permafrost was present in sandy soils about 1 km southeast of Nar'ian-Mar at a depth of 6.5 m. Its thickness was not determined. Alluvial islands in the southern and central portions of the delta were relatively free of permafrost. Islands in the northern portion of the delta exposed to high tides were found to contain permafrost at depths ranging from 30 to 100 cm.—From SIPRE U-1827.

Rozhkov, B. N., 1935, Salt springs on the lower course of the Lower Tunguska River [Solianye istochniki v nizhenem techenii R. Nizhenei Tunguski]: Materialy po solenosnosti Vostochnoi-Sibiri, Materialy po geologii i podzemnye iskopaemym Vostochnoi Sibiri no. 6, Gos. Oblastnoe Nauchn.-Tekh. Izd., Novosibirsk.

R. R., 1947, Permafrost: Federal Sci. Prog., v. 1, no. 4, p. 8–11.

Permafrost is found in regions of long cold winters and short dry summers, where annual precipitation is low and mean annual temperature is below freezing. Its origin may have been in the ice age, from glaciers, or some other source. The maximum depth is cited as 1,400 ft at one place in Siberia. The term "active zone" is used for the layers of ground above the permafrost table; that part of the active layer that thaws and freezes annually is called the frost zone.

Ground water occurs above, below, or within the permafrost. "Under pressure it moves in any channel open to it—through weak spots in the soil, through cracks, joints, and veinlike passages in segments of unfrozen ground." Also ground water may remain fluid at freezing temperatures because of strong mineral or saline content of the water or its natural insulation in very thin capillaries of fine-grained soil. The ground water beneath permafrost seldom freezes.

In summer ground water seeps downward to the permafrost layer where it is stopped. When the active layer is thin the landscape becomes dotted with ponds and temporary lakes. "When the frost zone refreezes in winter, fluid ground water may be trapped between it and the permafrost, setting up tremendous hydrostatic pressures. This forces ground water to find exit—usually through the frost zone to the surface where it forms masses, mounds, or lakes of ice."

"In a moderate winter, only a shallow surface layer may freeze, just barely covering a fluid mixture of fine-grained soil and ground water under pressure. If the frost zone is broken—say by a bulldozer—tons of mudlike 'slud' may ooze through the hole creating a vast quagmire which must be drained and cleared before operations continue."

Ground water often finds its way under foundation supports of structures, and if the foundations are anchored in the frost zone freezing causes ice to form and lift them; during the thaw the foundations rest on soft, thawed material. Moving ground water carries heat which may lower the permafrost table. "Unfrozen water under the surface in large rivers and lakes carries heat which will alter the permafrost table * * *. The free channel under the ice may be too small for volume of water to be carried." Under pressure water either breaks through surface ice and over the banks or seeps through the sides of the river into the ground. It can create an ice field several feet deep and covering many square miles; such masses of ice may not melt for many seasons.

As an example of ground water under pressure seeking release upward, author cites case of the barrel that was placed on end in a yard and left for a period of time. Ground water broke through the bottom of the barrel and flowed out the bunghole, flooding the yard and the temporarily unoccupied dwelling.

Russell, I. C., 1890, Notes on the surface geology of Alaska: Geol. Soc. America Bull., v. 1, p. 99–162.

The banks of the Yukon and its tributaries in the lowlands between the Lower Ramparts and the highlands of the upper Yukon are solidly frozen and exhibit masses of clear ice where they are of peat. In the flood plain of the Yukon and Porcupine valleys frozen ground is encountered a foot below the moss carpet in wooded areas. The Palisades on the south bank of the Yukon below Tanana are reported to consist of frozen sand. The tundra regions of the Yukon delta and St. Michael area are underlain by frozen ground; clear ice strata in the tundra deposits may have been formed by burial of lakelets under a growth of moss from the sides. The frozen deposits exceed 25 ft in thickness, but the base of frozen ground in the tundra has never been determined. A well at Nulato near the riverbank was dug 25 ft through sand and clay and the material was solidly frozen, except for certain sand layers. The same conditions have been encountered in mining operations at Fortymile also to a depth of 25 ft. Freezing must have taken place simultaneously with deposition, to account for the presence of ice beds in sediments. Formulas are developed, with the help of R. S. Woodward, to ascertain whether deep frozen ground can be formed as a result of low air temperatures. Woodward concludes that the freezing of even the deepest frozen ground in the Arctic was possible with a mean annual temperature no lower than that which now occurs in Northern Alaska. Some of the frozen material in unglaciated regions probably began to freeze during the glacial epoch.

Rutledge, F. A., Thorne, R. L., Kerns, W. H., and Mulligan, J. J., 1953, Preliminary report: Nonmetallic deposits accessible to the Alaska Railroad as possible sources of raw materials for the construction industry: U.S. Bur. Mines Rept. Inv. 4932, 129, p.

Springs of moderate flow are reported along the fault near the Windy limestone deposit west of mile 323 of the Alaska Railroad.

Sable, E. G. *See* Chapman, R. M., 1960.

Saks, V. N., 1940, Some data on permafrost in the lower part of the Yenisey River [Nekotorye dannye o vechnoi merzlota v nizov'iakh Enisiia]: Problemy Arktiki, no. 1, p. 62–79.

The permafrost distribution in the vicinity of Ust'Yenisey port was studied through a literature survey and by field investigations in conjunction with a search for oil. Frost, peat, and other types of mounds are described in terms of the mechanism of formation, distribution patterns, and the periods of greatest activity. Compact crystalline ice at a depth of 25 m was found in drill holes in the Ust'Port valley. Several layers of ice lenses ranging to 4 m in thickness were discovered at depths between 28 to 45 m. An ice layer, 15 m thick and 2 km long, was found to the NE of Ust'Port. Permafrost was present in test hole 3 on the left bank of the Yenisey at a depth of 270 m, with temperatures varying between −5° and −6°C on the upper permafrost horizons. Electric resistivity methods indicated permafrost layers from 400 to 500 m thick along the Yenisey plateau, and from 250 to 300 m in thickness on the well-drained terraces. Calculations show that the Yenisey permafrost is aggradating at a rate of 100 m per 3,000 to 4,000 yr.—From SIPRE U-2032.

1948, Permafrost in the Soviet Arctic [Vechnaia merzlota Sovetskoi Arkitiki v chetvertichnyi period]: Leningrad, Arkticheskogo Inst. Trudy, v. 201, p. 101–113.

Permafrost conditions and their variations from the Quaternary period to date are described, and the causes of the variations are analyzed. The thickness of permafrost layers in the arctic decreases near river valleys and in old geological formations. The temperature distribution of sea depths indicates that thick permafrost is unlikely under the sea bottom. The thermal lapse rate is lower under frozen soil than in permafrost-free regions. The lack of permafrost under large rivers leads to the assumption that it is also absent under arctic glaciers.—From SIPRE 7242.

Sanford, R. S. *See* Heide, H. E., 1948.

Saltykov, N. I., 1939, Engineering geology and hydrogeology in the permafrost zone in the years of Soviet rule [Inzhenernaia geologiia i gidrogeololgiia oblasti vechnoi merzloty za gody Sovetskoi vlasti]: Razvedka Nedr, no. 10–11.

Saltykov, N. I. *See also* Meister, L. A., 1958, 1959.

Schmitt, R. P., and Rodriguez, Raul, 1960, Glacier water supply system: Mil. Engineer, v. 52, p. 382–383.

When the water demand of a military camp on the Greenland ice cap reached 10,000 gpd, a well was drilled to supply water from uncontaminated ice at depth. An oil-fired steam generator was used to supply the melting drill-bit assembly and the melting pump-bit assembly which was used to melt the ice and pump water to the surface. The equipment was installed in a trench 10 ft wide, 50 ft long, and 16 ft deep. The bit was 36 in. across, and the hole was started at diameter of 42 in. The drilling was easy through porous snow, but more difficult with depth in glacier ice. At 139 ft the melting pump-bit assembly was substituted for the melting drill-bit assembly. Melting was done with steam for 298 hr, and the total depth reached was 171.5 ft. Total water pumped to the surface at 25 gpm and at 35°–49°F was 138,666 gal. A potential of 8,700 gal per 24-hr day was available. At the end of the test nearly 48,000 gal was in the pool, at depth. The pool was an excellent storage place for liquids, for even 6½ days after the source of heat was removed, the water was still liquid, and crusted with 2 in. of ice; heat loss was only 18 Btu per ft^2 per hr, a low figure when compared with that from surface reservoirs. A man was lowered to check the reservoir, a bell-shaped cavity 50 ft high and 40 ft in diameter. Little leakage of water was noted. To supply the 10,000 gpd needed for 471 days, a cylindrical form was preferable to a broad shallow cavity because of less danger of collapse.

Schneider, Robert, 1958, Correlation of ground-water levels and air temperatures in the winter and spring in Minnesota [abs.]: Assemblée Gén. Toronto 1957, Union Géodésique et Géophysique Internat. Comptes rendus, v. 2, p. 219–228.

The water table declines in winter when mean daily air temperatures remain below 32°F. Within a few days after air temperature rises above freezing, ground-water recharge begins. Return of below-freezing air temperature causes a decline in water table. This decline is due in part to the upward movement of moisture by capillarity from the water table to frozen soil and the resulting accretion to the frost layer. With air temperature above freezing, the water table rises as melt water percolates downward from the bottom of the frost layer. The largest increment of ground-water recharge occurs in the spring. The initial source of recharge is largely spring frostmelt because the frozen soil impedes or prevents downward percolation of snowmelt and rain. After dissipation of the frost layer, recharge from the surface is facilitated.—From author's abstract.

Schultz, J. R., and Cleaves, A. B., 1955, Geology in engineering: New York, John Wiley & Sons, 522 p.

In permafrost regions of the northern hemisphere ground water is the best source of supply in the south, but ground water becomes increasingly difficult to obtain in the north, where permafrost attains great thickness. The water that lies above permafrost is called suprapermafrost water and is fed by rain and melt water, surface water, water condensed by contact with the cold ground surface, and seepage from within or below permafrost. A year-round supply is available only in the parts of the suprapermafrost zone in which permafrost lies below the depth of seasonal frost penetration, particularly along banks of large rivers and lakes with constant inflow and outflow; supplies may occur also at the mouths of valleys and at the heads of alluvial fans. Suprapermafrost water is subject to contamination. In winter the ground freezes from the top downward and the water is subjected to pressure, with the result that water emerges at the surface to form icings or is wedged between frozen and unfrozen layers and frozen in place to form ground ice.

Intrapermafrost water is derived from sources above and below the permafrost. It occurs mainly in thick alluvial deposits near rivers, in old river channels, and, to a lesser degree, in strongly fissured and jointed rocks. Along the Arctic Coast saline water within the permafrost is probably of marine origin; such mineralized water remains liquid at temperatures well below 0°C.

Care must be taken to maintain circulation of intrapermafrost water in permeable layers or in pipelike openings, for freezing will result if flow is retarded or if the well is subjected to excessive or accelerated pumping. Intrapermafrost water may locally be under pressure.

Subpermafrost water is always liquid, being beneath permafrost, and is generally under considerable hydrostatic pressure. It furnishes the most dependable supply of ground water, usually of good quality. In some areas, however, subpermafrost water is highly mineralized. Generally, it is difficult to locate because of scarcity of surface indications.

In addition to the discussion of ground water in permafrost regions, a description of pingos, frost blisters, icing mounds, and peat mounds are included in this publication.

Science News Letter, 1956, Water under permafrost may cause odd behavior: Sci. News Letter, v. 69, no. 1, p. 9.

Summary of preliminary results of work by Muller, Fritz, 1959.

1960, Steam-dug wells to give water for men in ice cap: Sci. News Letter, v. 77, no. 20, p. 312.

In a new technique for drilling water wells on glaciers, a bit using steam at 377°F is employed until homogeneous glacial ice is reached at a depth of approximately 150 ft. At that depth a second bit which shoots lateral jets of steam is used to melt a bell-shaped reservoir as much as 50 ft in diameter. Water from the melted ice fills the reservoir and furnishes the supply to be pumped to the surface.—From SIPRE 18190. *See also* Schmitt and Rodriguez, 1960.

Sedov, V. P., 1954, Study of ground water in permafrost regions [Izuchenie podzemnykh vod v oblasti rasprostraneniia vechnoi merzloty], *in* Metodicheskoe rukovodstvo po izucheniiu rezhima podzemnykh vod: Vses. nauchn.-issled. Inst. gidrogeologii i inzhenernoi geologii, p. 50–53.

The effects of low temperature and impermeability of permafrost on the freezing, chemical composition, distribution, and runoff of ground water are analyzed, and the methodology of studying ground water is outlined. Observations are recommended twice yearly, in the spring and near the end of summer or at the beginning of autumn. Spring investigations are important for measuring minimum temperatures, locating thawed spaces in permafrost, and studying ground icings. Autumn observations are needed to determine permafrost depth, the distribution of ground water, and the effect of microrelief on permafrost. About 400 references to works in Russian on problems of hydrogeology and soil surface processes affecting ground water are included at the end of the book.—From SIPRE 12443.

Sedov, V. P., and Shvetsov, P. F., 1940a, Icings and ground water in the Yana River basin [O sviazi naledei v basseine r. IAny s podzemnymi vodami]: Sovetskaia geologiia, v. 8, no. 12, p. 86–92.

Icings in the valleys of the Dogdo and Khodorop Rivers in Yakutia were studied in 1939. Results of the investigations and the accuracy of Fedortsev's conclusions published in 1937 are discussed. The region is located in a zone of permafrost, which is not less than about 200 m thick. The icings studied form during the freezing season regardless of ice- and snow-cover conditions or the freezing and thawing of the active soil layer. These icings are formed by the surface freezing of water from depths of more than 200 m, which has flowed to the surface through structural fissures in the permafrost.—From SIPRE 9270.

735–894—65——13

Sedov, V. P., and Shvetsov, P. F., 1940b, Across the cold pole in the land of enormous icings [Cherez polius kholoda v oblast' gigantskikh tarynov]: Nasha Strana, v. 4, no. 3, p. 24–27.

Icings of northeastern Yakutia and their origin were studied in May–August 1939 by an expedition of the Academy of Sciences of the USSR. Many surface icings up to several kilometers wide and long were found in the valleys of the Kyra and Dogdo Rivers and on slopes. Ground drilling showed that the icings are associated with the penetration of subpermafrost waters through fissures in the frozen strata. Large admixtures of nitrogen were found in two subpermafrost springs which had a temperature of 0.4°C. Icings up to 6 m thick in summer consisted of layered ice mixed in the upper strata with snow and water. The ice was usually strong and transparent and had a turquoise color, but some weaker ice had an opaque whitish color and many air bubbles.—From SIPRE 11943.

1940c, Underground water and icings in northern Yakutia [Podzemnye vody i naledi v Severnoi IAkutii]: Nauka i Zhizn', v. 7, no. 2, p. 16–18.

The gigantic icings in Yakutia are not caused by seepage of river water, but by subterranean water forced to the surface through fissures in bedrock. These conclusions are based on the findings in the lower reaches of the Kyra River near the Yana-Indigirka divide. The total discharge of these icings is estimated at 3,000 liters per sec. The water remains liquid within the ground even at air temperatures of −70°C. Three icings with a maximum thickness of 6 m were found within an area of 20 sq km. Utilization of these nonfreezing waters as water supply for new settlements will help solve the difficult problem of water supply in Yakutia.—From SIPRE U–6231; Arctic Bibliography 37304.

Sedov, V. P. *See also* Shvetsov, P. F., 1940, 1942.

Sergeev, Ye. M. *See* Poliakov, S. S., 1958.

Sharapov, I. S., 1936, Characteristics and genesis of the salt springs of the upper part of the Lena River basin [Svoistva i genezis soleproiavleniia v verkhnei chasti basseina reki Leny]: Vostochno-sibirsk. geol. tresta Trudy, v. 10, 77 p.

Salt springs issue in the axial zone of folds composed of Cambro-Silurian strata in the upper Lena River basin, USSR. Their possible relation with salt tectonics, which is probably not of a diapir nature, is discussed, and the physical and chemical properties of the waters described.—Geol. Soc. America, Bibliography and Index of Geology Exclusive of North America, v. 14, 1949, p. 234, 1950.

1938, Salt springs of the southeastern part of the central Siberian platform [Soleproiaeniia iugo-vostochnoi chasti Sredne-Sibirskoi platformy]: Vostochno-sibirsk. geol. tresta Trudy, no. 25.

Sharp, R. P., 1942, Ground-ice mounds in tundra: Geog. Rev., v. 32, p. 417–423.

Mounds in the tundra of Wolf Creek area, Yukon, are covered with turf and sod and are cored with ice. Somewhat similar occurrences in Siberia and Alaska are attributed by Tolstikhin and Leffingwell, respectively, to updoming by the hydraulic force of ground water which freezes in the opening so formed. The Wolf Creek mounds are similar to, but smaller than, the second type of earth mound described by Porsild (1938) and are different in origin and constitution from the palsen described in the European literature.

The Wolf Creek mounds are not formed by the hydraulic force of ground water because the flow in the surficial layer is too small and has too small a head, and

because the tundra is weak and permeable. The Wolf Creek mounds are formed through updoming of the tundra surface caused by the vertical and lateral growth of bodies of ice in the thawed layer above permanently frozen ground. The bodies of clear ice are nourished by ground-water seepage at favorable times in spring and fall. The growth of the ice and updoming process may go on for years, but eventually the cover is so cracked that thaw equals, or is greater than, freezing. Change in source or direction of ground-water movement may also stop nourishment, and the mound decays and collapses.

Shchegolev, D. I., 1946, Hydrogeological conditions and mining in permafrost regions [Gidrogeologicheskie usloviia i gornye raboty v oblasti vechnoi merzloty] : Merzlotovedenie, v. 1, p. 129–130.

Conditions of mine seepage in permafrost areas are analyzed, and protective measures are discussed. Thawed strata within the permafrost and the high salinity of the ground water, which decreases the freezing point of the water (to —22°C with NaCl), are the most frequent causes of mine flooding. Increased permafrost temperatures caused by the mining operation, especially when permafrost temperatures are near the freezing point, may also cause melting of fossil ice. Freezing thawed strata with the natural winter cold and drainage of the superpermafrost water are recommended for mine protection. Geological surveys before mine construction are required so that proper precautions may be taken. The structural use of ice in the mines also requires that methods be developed to protect the permafrost from degradation.—From SIPRE 15984.

Shostakovich, V. B., 1916, Permafrost [Vechnaia merzlota] : Priroda, no. 5–6, p. 557–580.

Permafrost distribution in Siberia and the history of permafrost study are described. A revised map of permafrost distribution is suggested. Physiographical factors influencing the formation and degradation of permafrost are analyzed. The negative heat balance is considered the main factor responsible for permafrost formation in Siberia. Annual air temperatures near —2°C or below and a scant snow cover are considered as indicators of the presence of permafrost. The warming effect of moving ground water prevents an increase in permafrost thickness and frequently results in permafrost degradation. Standing ground water increasing the soil thermal conductivity causes deeper soil freezing. The thickness of permafrost layers in Siberia, depending on physiographical factors, varies from 0.43–70.4 m. Peculiarities of ground topography and rivers in permafrost regions are described.—From SIPRE 8243.

Shumskii, P. A., 1959, Soviet glaciological investigations in Antarctica [Sovetskie gliatsologicheskie issledovaniia v Antarktike] : Seism. i gliatsiol. issled. v Period MGG, Sbornik Statei, no. 2, p. 77–83.

The mean temperature of the upper ice layers decreases with increasing distance from the coast and with elevation. In the upper third of the ice, temperatures decrease with depth, while below this level temperatures increase and in places reach the melting point at bedrock. The depth of frozen soil reaches 150 m in ice-free areas and 30–35 m at the sea bottom. The depth of seasonal thawing is 0.1–2.05 m.—From SIPRE 17976.

Shumskii, P. A. *See also* Avsiuk, G. A., 1956.

Shvetsov, P. F., 1937, Certain data on the characteristics of mineral hot springs of Chukotki [Nekotorye dannye k kharakteristike goriachikh mineral'nykh istochnikov Chukotki] : Voprosy kurortologii, no. 5.

Shvetsov, P. F., 1938, Permafrost and the engineering and geological conditions in the Anadyr region [Vechnaia merzlota i inzhenerno-geologicheskie usloviia Anadyrskogo raiona]: Leningrad, Glavsevmorput', 79 p.

Ground water is fresh above permafrost, but is mineralized within the upper part of the permafrost where it occurs at temperatures below 0°C. Fresh water occurs (1) in the active layer where it commonly is under hydrostatic pressure during the freezing season, (2) as subriverbed water in an 18- to 20-m-thick talik beneath the completely-frozen rivers, and (3) as water in a similar talik beneath lakes. The water in the thawed zones beneath lakes and rivers is confined on the sides by permafrost and on the top by lake or river ice. Chemical composition of the water beneath lakes differs from that beneath the rivers in its higher content of organic acids. These waters have a high capacity for oxidation.

Boreholes in the flood plain of the Lower Melku River encountered either fluid mud or water more salty than sea water at temperatures of —3.5°, —5.6°, and —6.9°C. Water of the upper part of permafrost is saline because this part of the valley was formerly tidal, and only recently has been elevated. Upstream, near Nizhnee Lake, the permafrost table is 20.5 m below the river, but is less than 1 m deep on the shores. On the lowest (first) terrace, permafrost temperature is —5.65°C at a depth of 16 m, the level of zero amplitude.

The thickness of permafrost in the Anadyr region must be at least 200 to 300 m. A borehole 300 km to the south established the presence of water and gas at a depth of 91.5 m, and thawed ground reportedly occurred at 100 m.—From unpublished condensation and emendation by I. V. Poiré, 1947.

1941, On the relationship between the temperature and permafrost thickness and geological and hydrogeological factors [K voprosu o sviazi temperatury i moshchnosti vechnoi merzloty s geologicheskimi i gidrogeologicheskimi faktorami]: Akad. Nauk SSSR Izv., Ser. geol., no. 1, p. 114–124.

Polovinkin (1922) attempted correlation between temperature of permafrost and mean annual air temperature, but Sumgin demonstrated that it is not only air temperature, but thickness of snow cover that is important in controlling the heat economy of permafrost. Shostakovich and, later, Grigor'ev devised special climatic coefficients characterizing areas of permafrost, but studies of 11 localities where ground temperatures are available show that there is no regular relationship between permafrost and climatic factors alone. Instead, it can be shown that differing geologic and hydrogeologic conditions result in various temperatures of frozen ground and depths of permafrost, irrespective of climatic differences.

Using climatic data alone, according to Grigor'ev's coefficient, permafrost temperatures should be low at Verkhoyansk, and relatively higher at Ust'-Port and in the Kozhevnikov Gulf region. However, at Verkhoyansk, because of the presence of relatively young igneous rocks and associated heavy discharge of fresh ground water in springs, the permafrost is relatively warm and not very thick. At Kozhevnikov Gulf, on the other hand, the rocks are only moderately deformed, and igneous rocks are absent; the mineralized ground water does not issue from springs. Permafrost in the Gulf area, therefore, is 620 m thick and has a temperature of —12°C. Conditions at Amderma are similar to those at Kozhevnikov Gulf. Fresh water from below permafrost circulates within permafrost and warms the ground at Vorkuta where permafrost thickness is only one-third that at Amderma, 260 km to the north.

At Yakutsk fresh ground water is present beneath permafrost, and at Igarka and Turukhansk a thick snow blanket, fresh ground water, and the Yenisey

River tend to warm the permafrost. Ground water is absent above and below permafrost at the mouths of the Yenisey and Anadyr Rivers, and natural springs are absent. In Spitzbergen salty ground water at temperatures below 0°C and fresh water at temperatures above 0°C are known. A thin layer of permafrost is affected by the underlying rocks and by circulating ground water to a greater extent than a thick layer. Ground water has a greater effect on permafrost temperatures if it is circulating especially within the permafrost body itself, than if it is static. Thus, the permafrost regions can be subdivided on the basis of geologic and hydrogeologic characteristics into (1) regions in which ground water is absent or lies deep beneath permafrost and where it does not circulate (Ust'-Port at mouth of Yenisey River and the mouth of Anadyr River); (2) regions where water beneath permafrost is in motion, and circulates through permafrost in ascending streams which form springs; these areas are generally in zones of intense folding and igneous rocks (Verkhoyansk, Yakutsk, Igarka, Skovorodino, Vorkuta River, east shore of Chukotsk Peninsula, the upper Indigirka and Kolyma Rivers, and the mouth of Utina River); and (3) regions that are parts of plateaus or old fold belts where igneous rocks are lacking and where ground water above or below permafrost is highly mineralized and motionless. The geothermal gradient differs in these three regions.

Thus, the temperature of permafrost is the historical result of the interaction of air temperatures below 0°C during a long period of time and other climatic factors with geological, hydrogeological, and geochemical conditions.—From author's English summary; condensation and emendation by I. V. Poiré.

1946a, Results and problems from studies of the giant naleds in Yakutia [Kratkie itogi i perspektivy izucheniia gigantskikh naledei IAkutii]: Merzlotovedenie, v. 1, p. 17–22.

Investigations since 1884 on the distribution and origin of naleds in Yakutia are briefly outlined, and problems for further studies in the fields of naleds and the hydrogeology of folded formations are discussed. Subterranean water forced to the surface through fissures in the bedrock should be considered as the main origin of the giant naleds in Yakutia. Water discharges measured in the naled region indicate the practically unlimited possibilities for using subterranean naled-forming water for water supply by new settlements in Northeast Yukutia.—From SIPRE 15882.

1946b, Role of permafrost and subpermafrost water in the hydrology of Indigirka and Yana Rivers [Rol' vechnoi merzloty i podmerzlotnykh vod v gidrologii basseinov rek Indigirki i IAny]: Akad. Nauk SSSR Izv., Ser. geol., no. 6, p. 137–152.

The hydrological regime of the Yana and Indigirka River basins which causes larger floods in summer than in spring is described. The snow melt runoff of the majority of rivers in the subarctic and the more southerly permafrost regions amounts to 50–75 percent and rain runoff is 15–35 percent. The snow melt runoff of the Yana and Indigirka Rivers is only 15–35 percent and rain runoff is 50–75 percent. This anomaly is explained by large subpermafrost water stores which produce gigantic "naleds." The total volume of ice in these icings reaches several hundred million cu m.—From SIPRE U–6167.

1947a, Subpermafrost waters and the gigantic icings of northeastern Yakutia [abs.]: Akad. Nauk SSSR, Referaty nauchn.-issled. rabot 1945, Otdel. geol. geog. nauk.

Gigantic icings occur in the Yana-Kolyma mountainous region, but not on plateaus or in older mountain systems. The ice fields attain an area of 150 km^2

and a volume of 500,000,000 m^3. Icings in the Tas-Khaiakhtakh and Verkhoyansk Ranges originate in springs that occur near the icings. These springs have a constant discharge of nearly 1,500 liters per sec throughout the year, a constant temperature, a low mineral content, and a large quantity of gas. Temperature is 0.4° to 0.5°C throughout the year. Similar nonfreezing springs occur near icings in the Momsk Range, in the Omolan River basin, and at the headwaters of the Kolyma River. Because of complete freezing or drying up of most small and medium-sized rivers in winter, deficiency of water in the alluvium under the riverbeds, and positions of the springs 1,000–2,000 m above sea level on upper slopes of mountains, they are classified as springs of subpermafrost waters. The existence of faults and fractures in sandstone, shale, and effusive rocks of Mesozoic age accounts for permeability of a permafrost layer that is 150–250 m thick.

Subpermafrost waters constitute the only water supply for many regions in northeastern Yakutia, as shown by test drilling at the headwaters of the Kolyma River. Factories and towns of this region obtain their water from subpermafrost springs.—From Minnesota Univ., 1950, p. 95–96.

Shvetsov, P. F., 1947b, New data on the influence of subpermafrost water on the Indigirka River run-off [Novye dannye o vliianii podmerzlotnykh vod na ob"em i rezhim stoka r. Indigirki]: Akad. Nauk SSSR (Doklady), v. 57, p. 711–714.

Extremely low winter temperatures cause the middle section of the river to freeze to the bottom with the consequent formation of naleds from subpermafrost water. The melting of these naleds is responsible for a hitherto unexplained amount of summer run-off increase. The thermal regime of the area is discussed and some data are given.—From SIPRE 9564.

1947c, The region of the Verkhoyansk and Kolyma Mountains as a separate permafrostological and hydrogeological province [Verkhoiansko-Kolymskaia gornaia strana kak osobaia merzlotnogidrogeologicheskaia provintsiia]: Vses. geog. obshch. Izv., v. 79, p. 427–438.

The formation of naleds in the region is analyzed. Hydrostatic pressure in rivers under a thick ice cover produces the usual river naleds. The freezing of ground water in the active soil layer causes the formation of ground naleds. Unusually large naleds (100 sq km or more in area) which continue to grow throughout the winter are observed in northeastern Yakutia, while the growth of ordinary river naleds is limited to the beginning of winter. Test borings have shown that these large naleds are caused by the upward penetration of subpermafrost water from depths of 100 m or more.—From SIPRE 8874.

1947d, Underground waters and ground ice in regions of Anadyr and Ugol'naia Bay [Podzemnye vody i iskopaemye l'dy raionov poselka Anadyr'i bukhty Ugol'n]: Nedra Arktiki, v. 2, p. 204–212.

In the Anadyr region frozen ground is universally distributed and is, on the average, about 120 m thick and its temperature is −5.6°C. The water is classified as follows: (1) Water of the annually thawing layer, as deep as 0.5–0.8 m; (2) water accumulating below lake and pond bottoms in depressions on top of permafrost; (3) strongly mineralized water which does not freeze at −6°C and which was formed by percolation of sea water through the soil; and (4) water of permafrost and the ground-ice lenses which are up to 5 m thick and are formed by burial of frozen lake ice. The salt content of the saline water is increased through processes of evaporation and freezing.

In the Ugol'naia Bay region permafrost is 60–120 m thick and its temperature is not lower than −3.2°C. Drill holes reached fresh water under artesian head beneath permafrost.—From author's English summary.

1951, Definitions of some terms in permafrostology [K opredeleniiu nekotorykh poniatii v merzlotovedenii]: Akad. Nauk SSSR Izv., Ser. geog. no. 5, p. 83–87.

Cryosphere is defined as the region of subfreezing temperatures on the earth's crust including glaciers, ice snow cover, and the upper layer of the atmosphere. Soils are rated as constituents of the cryosphere even if only a part of the water is present in the solid state. Definitions of freezing and of frozen and unfrozen ground by Soviet permafrostologists are discussed. Frozen ground is classified according to its time of existence, as eternal or permafrost (of three to many thousands of years' duration), of 1–2 yr duration, seasonal, and of short duration. Other terms for permafrost, frost zone of the lithosphere and continuous frost, are discussed. Permafrostology is viewed as a science of heat flow during cooling and freezing, heating and thawing of the upper layer of the lithosphere, together with accompanying mechanical actions of agents inside and on the surface of the earth's crust.—From SIPRE U–5992.

1955a, Introduction to geocryology [Vvodnye glavy k osnovam geokriologii]: Akad. Nauk SSSR, Inst. Merzlotovedeniia, Materialy k osnovam ucheniia o merzlykh zonakh zemnoi kory, v. 1, p. 1–110.

The development of permafrostology in the USSR and its basic problems are outlined, and existing Russian terminology for processes and phenomena associated with permafrost and ground freezing is reviewed critically. Required changes in terminology start with a basic term—permafrostology (literally "a science of perpetual congelation")—for the reason that congelation may be defined as action, process, or state, as well as the product of an alteration from a fluid to a solid state. At the same time congelation excludes the frost processes in rocks and in soils that contain only bound water. Geocryology is suggested as an accurate term to describe the processes associated with frost action in the earth. The term frozen ground is recommended for soil in which the change from water to ice occurs completely or in part. The term "frost soil" is suggested for rocks and soils containing only bound water below the freezing point.—From SIPRE 13708.

1955b, Effects of the interaction between gravity and temperature in water circulation in rock fissures [O znachenii vzaimodeistviia gravitatsionnogo i temperaturnogo polei v tsirkuliatsii treshchinnykh vod nekotorykh gornykh stran]: Voprosy Geologii Sibiri, v. 2, p. 596–600.

Water migration in fissures induced by temperature differences is mathematically analyzed. Formulas are given expressing the movement as a function of temperature differences and gravity. Intense water migration toward the freezing strata in sand and clay, both in permafrost zones and at times of seasonal soil freezing elsewhere, is also associated with thermodynamic factors.—From SIPRE 14311.

1956, Principles of classifying permafrost zones [O printsipakh raionirovaniia mnogoletnei kriolitozony]: Akad. Nauk SSSR, Inst. Merzlotoveniia, Materialy k osnovam ucheniia o merzlykh zonakh zemnoi kory, v. 3, p. 18–39.

The views of earlier workers on the problem of the division into regions of the occurrence of permafrost are reviewed. Shevetsov introduces the concept of a geocryologic formation. The quantitative and qualitative characteristics of such a formation directly reflect the geographic and geologic conditions of the given area. Geocryology should present a map of the occurrence of the particular geocryologic formations in the permafrost area. Secondly, a series of simple geocryologic facies should be distinguished. Every phenomenon occurring inside a particular formation is strictly connected with the exchange of heat between the lithosphere and the atmosphere. Loss of heat by the soil during the freezing period is of special importance in the permafrost zone; this phenomenon is called the cryogenic loss of warmth, whereas it was previously referred to as storage of cold. The lithologic character of the bedrock determines the cryogenic loss of heat. A numeral definition of the cryogenic loss of heat provides the soundest criterion for the distinction of geocryologic formations. Several tens of such formations have been distinguished within the USSR—that is, arctic lowlands, arctic volcanic areas, etc. Even though the formations are based on lithologic characteristics, their lithology is less important than their physiochemical properties.—From review by Olchowik-Kolasinska, Biul. Peryglacjalny, v. 5, p. 265–266, 197.

Shvetsov, P. F., 1958, Geocryology and its main problems in the USSR [O soderzhanii i osnovnykh problemakh geokriologii v SSSR]: Internat. Union Geodesy and Geophysics, Assoc. Sci. Hydrology, Gen. Assembly, Toronto 1957, v. 4, p. 394–396. [Russian, with English summary]; 1957, Akad. Nauk SSSR, Kom. geodezii i geofizike, Tezisy dokladov na khi gen. assamblee mezh dunarodnogo deodezicheskogo i geofizicheskogo soiuza, p. 86–87.

For the last 30 years (1927–56) a new branch of geologic-geographical and engineering-geophysical sciences—geocryology—has been considerably developed in the Soviet Union. It studies (a) laws of freezing and thawing of the earth's crust, formation development and propagation of frozen soil zones and rocks (cryolite zones) under various physico-geographical and geological conditions; (b) characteristics of composition, structure and physico-mechanical properties of freezing, frozen and thawing soils and rocks; (c) geophysical, physicogeological, geomorphological and hydrogeological phenomena associated with processes of freezing and thawing of soils and rocks; (d) a control of the effect of freezing, frozen, and thawing soils and rocks upon construction, agriculture, etc.

A perennial cryolite zone (permafrost) cannot be treated as a result of the climate only. Physicogeographical and geological conditions are of serious importance for the formation and development of permafrost.

The chief objective of geocryology is the study of processes of heat exchange between lithosphere, soil, and atmosphere, as well as between ground and buildings in order to work out the best types of firm constructions.

Besides these problems the Soviet geocryologists also study the following: (a) The distribution of frozen soils and rocks; (b) mechanical interaction between a building and freezing, frozen, and thawing ground and methods of controlling it; (c) physics of the cryogen process.—From author's English summary.

1959a, State, tasks, and developmental trends of geocryology [Sostoianie, zadachi, i napravleniia razvitiia geokriologii], *in* Materialy po obshchemu merzlotovedeniiu: Akad. Nauk SSSR, Inst. Merzlotovedeniia, p. 5–12.

Deficiencies in geocryological research have been an overestimation of theoretical achievements in the 1940's; a duplication of work because of a lack of knowledge of earlier investigations; an underestimation of the importance of theoretical analysis; a lag in working out proper construction methods in permafrost at temperatures above −1°C; deficient experimental studies on the physical and mechanical properties of frozen ground; the small numbers of experimental and theoretical investigations on the interaction between utility lines and permafrost; and the lag in the mathematical analysis of soil freezing and thawing. The main tasks facing geocryologists include the coordination of work conducted at the Institute of Permafrostology with similar work elsewhere; the solution of engineering problems; theoretical and experimental studies of heat and mass exchange in the natural environment; the study of soil thawing and compaction methods; the preservation of high-temperature permafrost under foundations; investigations on the stability of slopes in permafrost; regional permafrost investigations in industrial areas; the development of ultrasonic methods and apparatus for determining the limits of frozen and unfrozen ground; publishing the results of geocryological investigations; and compilation and dissemination of techniques for geocryological investigations.—From SIPRE 17928.

1959b, History of geocryological investigations up to 1917 [Istoriia geokriologicheskikh issledovanii do 1917 g.], pt. 1, chap. 2 *of* Osnovy geokriologii (merzlotovedeniia): Akad. Nauk SSSR, Inst. Merzlotovedeniia, p. 20–44.

An account is given of the development of geocryology from the first Russian manuscripts dating back to the 16th century. The first scientific approach to the problem was made in 1757 by Lomonosov when he attributed the existence of permafrost in Siberia to the severe climate and the balance between the cold entering the ground from above and the heat of the earth. More detailed and reliable data were obtained from 1820 to 1824 by F. P. Vrangel' and F. F. Matiuskhin in northeastern Asia and by an expedition of the Hydrographic Department to the Laptev Sea coast and the New Siberian Islands. Thermal measurements were made by Shershin in a well 116.4 m deep in the permafrost of Yakutia (1828) and at the same place by Middendoff (1842–45). The second stage in the development of geocryology was introduced in the 1860's with the studies of I. A. Lopatin in the northern Yenisey region. Important contributions were made during this period by V. A. Obruchev, L. A. IAchevskii, A. I. Voeikov, N. M. Koz'min, S. A. Pod'akonov, V. N. Sukachev, and others. This second period ended with the publication in 1916 of A. V. L'vov's book, which emphasized the importance of investigating discontinuities in permafrost and their causes.—From SIPRE 17912.

1959c, Fundamental concepts and definitions [Osnovnye poniatiia i opredeleniia], pt. 1, chap. 1 *of* Osnovy geokriologii (merzlotovedeniia): Akad. Nauk SSSR, Inst. Merzlotovedeniia, p. 7–9.

The cryosphere, its characteristics, and its geophysical significance are discussed, and associated phenomena and processes are defined. The history of the word "permafrost" is outlined. Definitions are given for the following recent terms: "cryolithosphere," "frozen ground" (containing ice); "ground frost" (with negative temperatures but no ice); "thawed ground"; the seasonally frozen or "thawing layer" (new term for the active layer); and the "vertically discontinuous cryolithosphere" (formerly stratified permafrost). Associated processes and phenomena, such as the thermal exchange between the soil and the atmosphere and in the ground-air-water system, freezing and thawing, and the "level of isothermal temperature exchange" (no longer the zero curtain) are also defined, and their characteristics are examined. The various aspects of geocryological studies are listed.—From SIPRE 17911.

Shvetsov, P. F., and Sedov, V. P., 1940, Origin of the extensive aufeis on the Tas-Khaiakhtakh Range: Akad. Nauk SSSR Comptes rendus (Doklady), new ser., v. 26, no. 4, p. 380–384. [English.]

Aufeis fields form on the Kyra River where it leaves the northwestern foothills of the Tas-Khaiakhtakh Range and enters the Selennyakh depression, splitting into channels. The total area of aufeis on the Kyra is 20.1 km^2, and its thickness reaches 5.5 m; smaller aufeis fields form on other streams. The Kyra River above the aufeis is dry in winter and has practically no ice cover; much of the alluvium of the Kyra Valley is believed to be thin and frozen and of only minor importance as a reservoir for storage of ground water. At the upper end of the aufeis field away from the river, an ice-free channel 200 m long leads from the slope of Atkhaia Mountain toward the aufeis. The water in this channel issues from a number of springs in the streambed and contains gas bubbles. Its temperature is 0.4°C and its discharge is 340 liter per sec; together with two other larger springs in the vicinity, the total spring discharge is 2,730 liter per sec. This flow is approximately 30 percent greater in winter than the volume of ice in the aufeis field, but the excess of flow can be accounted for by errors in calculation of volume and flow and by runoff beneath the aufeis. Springs at the head of the aufeis on Oyogordakh River flow at the rate of 1,400 liter per sec and are constant at 0.5°C.

Quality-of-water analyses show relatively low concentration of salts, 179 to 226.5 mg/1, chiefly Ca^{++}, Mg^{++} HCO_3^-, and $SO_4^=$. Silicic acid content is 6.5 to 10.5 mg per liter and the pH ranges from 6.4 on Oyogordakh River to 7.6 on Kyra River. Radioactivity at Oyogordakh Spring is -3.55×10^{-10}g Ra/l. Gas from the bottom of the funnels is mainly nitrogen.

The springs issue along the contact between the granordiorite and sedimentary-volcanic sequence consisting of effusive rocks and sandstone and shale of Mesozoic age and limestone and shale of Silurian age. The zone of springs follows the foot of the range for approximately 150 km; some springs are not connected to rivers. There must have been a major tectonic disturbance along the line which allows waters to rise through 200–300 m of permafrost to form springs. The constant temperature of the waters at all seasons, lack of morphologic or hydrographic features of karst terrain, increased radioactivity and flow of nitrogen-rich gas are cited as evidence for origin of the water at depth, not from shallow alluvial deposits or from karst sources.

1942, Gigantic icings and subterranean waters of the Tas-Khaiakhtakh Range [abs.] [Gigantskie naledi i podzemnye vody khrebta Tas-Khaiakhtakh]: Inf. biull. noveishei literatury geol. nauk., no. 1–6, p. 134. *See* annotation, Shvetsov, P. F., and Sedov, V. P., 1940.

Shvetsov, P. F. *See also* Meister, L. A., 1955; Sedov, V. P., 1940a–c.

Sidenko, P. D., 1955, On certain concepts of permafrostology [O nekotorykh poniatiiakh v merzlotovedenii]: Akad. Nauk SSSR, Inst. Merzlotovedeniia, Materialy k osnovam ucheniia o merzlykh zonakh zemnoi kory, no. 2, p. 57–58.

Sumgin's definition of permafrost as the soil strata beneath the surface in which a temperature below 0°C has existed continuously from two to tens of thousands of years is considered to be incomplete and inaccurate. Sumgin is criticized for neglecting the state of water aggregation in describing the general physical and mechanical properties of frozen ground. It is suggested that three zones be distinguished in permafrost; the active layer in which the annual freezing and thawing occurs, the frozen zone where soil particles remain locked in ice for several years, and the zone permanently below 0°C without a phase change in ground water.—From SIPRE 13733.

Sigafoos, R. S., 1951, Soil instability in tundra vegetation: Ohio Jour. Sci., v. 51, no. 6, p. 281–298.

Perennially frozen ground north of the Kigluaik, Bendeleben, and Darby Mountains on Seward Peninsula, Alaska, occurs nearly everywhere except under rivers and lakes. Larger areas of unfrozen ground occur in dissected uplands south of the mountains. In the coastal plain the deposits are perennially frozen from a depth of 1–10 ft to bedrock, but are not frozen beneath streams. Gravel tailings piles near Nome "have become perennially frozen in 7 yr from near the surface at least to bedrock at a depth of 60 ft" (p. 283).

Pingos occur in poorly drained areas 6 miles west of Nome in stream channels and in lakebeds near base of hills. The pingos are 15 ft high, oval in plan and 20–50 ft long, steep sided, and are formed by uparching of the surface through the growth of ground ice.

1958, Vegetation of northwestern North America, as an aid in interpretation of geologic data: U.S. Geol. Survey Bull. 1061–E, p. 165–185.

No correlation is shown between the distribution of vegetation and permafrost as mapped by Hopkins, Karlstrom, and others (1955).

Sigafoos, R. S., and **Hopkins, D. M.,** 1952, Soil instability on slopes in regions of perennially-frozen ground: Natl. Acad. Sci., Natl. Research Council Pub. 213; Highway Research Board Spec. Rept. 2, Frost action in soils, p. 176–192.

Soil terraces, lobate terraces, soil lobes, and tundra mudflows are the chief microrelief features on slopes of Seward Peninsula. In soil terraces the water table is generally controlled by perennially frozen ground at a depth of 3–6 ft and is generally close to the surface, emerging as seepage at the frontal escarpment. In the other forms, the top of perennially frozen ground lies below the top of bedrock; the water table moved downward with thaw of the frozen ground.

Sigafoos, R. S. *See also* Hopkins, D. M., 1951.

Silin-Bekchurin, A. I., 1931. The problem of genesis of carbonate-alkaline waters in the permafrost area of the Transbaikal, in the health resort region of the Darasun [Problema genezisa uglekislo-shchelochnykh vod v usloviakh vechnoi merzloty Zabaikal'ia v raione kurorta Darasun]: Vodnye bogatstva nedr zemli na sluzhbu, Sotsialisticheskomu stroitel'stvu, Pervyi gidrogeol. s"ezd, Sbornik 5, p. 57–67; Mineral'n. vody, Oblastnoe Nauchn.-Tekh. Izd. Leningrad-Moskow-Novosibirsk.

Investigations during 1929–31 indicated some specific pecularities of the dependence of the mineral water regime on permafrost. The permafrost layer in this region is discontinuous, which facilitates the penetration of precipitation to a significant depth. The thickness of permafrost in the region of mineral water is 1.5–3 m, but increases with distance from the mineral water sources to 22–30 m at a distance of 400 m. The irregularity of fresh water inflow and the structure variations of permafrost layer produced annual variations of the salt content in mineral waters. The largest percentage of mineral content was usually observed during December-March when the amount of water under the permafrost layer was lowest.—From SIPRE U–5040.

Silin-Bekchurin, A. I., 1939, Observations on the gas-bearing mineral waters of the wells at the Darasun and Arshan spas, Siberia [K voprosu intermittentsii burobykh skvazhin s gaziruiushchei mineral'noi vodo]: Akad. Nauk SSSR, Inst. geol. Trudy, v. 9, p. 161–169.

1951a, Survey of underground waters in permafrost regions [Razvedka podzemmykh vod v oblasti vechnoi merzloty], *in* Silin-Bekchurin, A. I., Spetnsial'naia gidrogeologiia: Moscow, Gosgeolizdat, p. 272–277.

The underground waters of permafrost are divided into suprapermafrost, intrapermafrost, and subpermafrost waters. The water above permafrost furnished a constant supply of water during spring, summer, and fall. The sources of suprapermafrost waters are the melt waters from snow, rain, and other types of surface waters. Maximum yield is obtained during the late summer when the active layer is thawed to the maximum depth. Intrapermafrost water is water within the permafrost occurring in thick alluvial deposits near rivers or old river channels. The subpermafrost waters are divided into shallow and deep-lying waters. Shallow subpermafrost water includes alluvial waters appearing in broad valleys of large rivers where the deposits are not completely frozen. It is suggested that large nonfreezing springs, icings, and hydrolaccoliths, usually fed by waters from considerable depths, be investigated during surveys for water supply.—From SIPRE U–2454.

1951b, Methods employed in studying underground waters in permafrost [Metodika izucheniia podzemnykh vod v oblasti vechnoi merzloty], *in* Spetsial'naia gidrogeologiia: Moscow, Gosgeolizdat, p. 277–280.

Methods for selecting and drilling for water supply in permafrost regions are described. Drilling for suprapermafrost water is similar to the methods used under nonpermafrost conditions. Test drilling for subpermafrost water in alluvial deposits should be placed near the river channel and extended into areas receiving maximum insolation. Drilling should be started wherever seepage of water from alluvial deposits occurs. Drill holes should be placed from 50 to 200 m and should be arranged in a checkerboard pattern. Test drills in stratified bedrock should be placed along and across the axis of the syncline depending on the structure of the bedrock. The deepest water vein should be tapped for relatively warm water whenever several veins are available.—From SIPRE U–2681.

Sills, A. N. *See* Waterhouse, R. W., 1952.

Simakov, A. S., 1959, Certain characteristics of the development of taryns in the northeastern USSR and the probable structure of the cryolithosphere [O nekotorye osobennostiiakh razvitiia tarynov na severo-vostoke SSSR i veroiatnom stroenii kriolitozony], *in* Materialy po obshchemu merzlotovedeniiu: Akad. Nauk SSSR, Inst. Merlotovedeniia, p. 210–214.

The distribution of taryns is discussed, and the relation between taryns and permafrost is examined. The greatest number of taryns is found in regions of young contrasting relief, especially in areas with bare faults and breaks, where large taryns may occur in series. The formation of taryns is related to the rise of ground water through tectonic fissures. Preliminary records indicate the existence of about 4,000 taryns in northeastern USSR, ranging from 100 m to 90–100 km in length, from a few meters to 3–5 km in width, and from 0.5 to 13 m in thickness. The small taryns near the Sea of Okhotsk form in February–March, while the large taryns form in October. The total volume of taryns in the northeast USSR is estimated at 25 billion cu m as against 24 billion cu m for glaciers.

Taryns are absent in areas of continuous permafrost 300–500 m thick. A new classification of taryns according to volume is proposed as being more precise than that suggested by Sumgin.—From SIPRE 17944.

Skrobov, A. A., 1937, Natural mineral waters of the Northern Region, Russia [Prirodnye mineral'nye vody Severnogo Krai]: Russia, Central Sci.-Inv. Geol.-Prosp. Inst., Pogrebov Jubilee volume, p. 94–103.

Skrobov, A. A. *See also* Tolstikhin, N. I., 1938.

Skvortsov, E. F., 1930, The coastal tundra of Yakutia [V pribrezhnykh tundrakh IAkutii]: Kom. Izuch. IAkut ASSR Trudy, v. 15, p. 1–244, 364–376.

The physiography of the area from Yakutsk to the Yana River delta and along the coast between the mouths of the Yana and Alazeya Rivers is described in detail on the basis of 9-month investigation in 1909. Permafrost, large deposits of fossil ice, and naleds are noted as typical features of this zone. Characteristics of permafrost and its effects on ground deformation and vegetation are given together with a description of the numerous pingos and naleds and their structure and distribution. Fossil ice was found everywhere, most frequently in clay ground, where layers reaching 0.3–0.7 m in thickness were usually found close to the surface and again under the clay strata. These clay layers sometimes reached 40 m in thickness. Islands of fossil ice were found in zones of intense ice melting. The structure and distribution of the ground ice and permafrost show the large variations in climatic conditions that have occurred. Water-filled pits in the fossil ice (called ice wells) associated with intense melting of the ground ice were often observed.—From SIPRE 15010.

Skvortsov, G. G., 1957, Permafrost and hydrogeological conditions in the southern part of the eastern Sayan in relation to the problem of mining [Merzlotno-gidrogeologicheskie usloviia iuzhnoi chasti vostochnykh Saian v sviazi s problemoi rudnichnogo stroitel'stva], *in* Materialy po podzemnym vodam Vostochnoi Sibiri: Irkutsk, Akad. Nauk SSSR, Vostochno-Sibirskii Filial, p. 164–171.

The physiography, climate, and geology of the region are outlined, and its permafrost and ground-water conditions are described on the basis of investigations from 1950 to 1954. The area is a tundra plateau at 1,800–2,200 m elevation with a mean winter temperature of −6°C and almost no snow. The permafrost is about 200 m thick, and its temperature reaches −5°C. The thickness of the active layer varies from 1 to 1.5 m in flat areas, reaches 2.5–3 m on south slopes, and decreases to 0.5–1.5 m on north slopes. Suprapermafrost water is found in glacial and alluvial deposits and freezes in winter. Subpermafrost water wells up to the surface in the form of permanent or seasonal springs and is found over extensive areas in fissured Cambrian and Silurian deposits, most frequently at a depth of 170–180 m. Several artesian basins of subpermafrost water were discovered in synclinal structures. Recharge of the water is believed to occur from surface water through taliks. Several lakes are fed by underground streams, and pressure from below causes the ice covers to sag.—From SIPRE 18016.

Slavianov, N. N., 1932, Instructions for recording mineral springs [Instruktsiia po registratsii mineral'nykh istochnikov]: Geolrazvedizdat.

Smith, P. S., 1908, Investigations of the mineral deposits of Seward Peninsula [Alaska]: U.S. Geol. Survey Bull. 345–E, p. 206–250.

At Nome, drilling of the Golden Gate well encountered 100 ft of schist at a depth of 40 ft, then penetrated quicksand below the schist. At the Daisy mine near Nome, a hole was sunk 22 ft to schist and 8 ft into the schist; 230 ft away a new hole was dug to pay streak at a depth of 97 ft, and a drift along the pay made until directly under the first hole, but 67 ft beneath the bottom of it. The schist beneath the first hole was interpreted as a slide. Shafts near Spruce Creek in the Solomon area show surficial deposits of blue clay with much ice. On Big Four Creek, Casadepaga drainage, operations have been hampered by inability to cope with seepage water in deep gravel.

Smith, P. S., 1909a, Recent developments in southern Seward Peninsula [Alaska]: U.S. Geol. Survey Bull. 379–F, p. 267–301.

Costs of pumping water from drift mines in thawed ground with circulating ground water has forced closure of one or more mines in buried ancient beaches.

Most of these difficulties with water are encountered in ground where there is no permanent frost. There are many such areas which do not show any definite or constant relations to the present topography. Clumps of willows are taken as surface indications of thawed ground, but the more sections exposed by prospecting the more irregular appears to be the distribution of the ground that is not permanently frozen. The presence of willows seems to serve little more than to point out the places where thawed ground is more likely to be encountered than elsewhere. They seldom grow on frozen ground, but on the other hand they are lacking in many places that are underlain by thawed material. Carefully drilled holes are probably the most effective and cheapest method of exploring an area to determine the physical character of the gravels in advance of actual developments.—Author's report, p. 271.

Shafts 65 and 69 ft deep in the inner submarine beach on a claim just west of Snake River and one-quarter of a mile from the present beach were dug in permanently frozen gravel. One hole on the valley slope a little above Rabbit Creek, tributary to Pine Creek, was sunk 45 ft without reaching bedrock; further digging was prevented by water in thawed ground. The other holes were generally to bedrock in frozen ground. Bench deposits, consisting of 12 ft of coarse rounded gravel 6–8 in. in diameter, are perennially frozen on Jerome Creek, tributary to Solomon River. Frozen muck containing ice occurs on Moran Gulch, Solomon River drainage. Low bench gravel deposits one-quarter of a mile above Solomon River on Shovel Creek are thawed for the first 100 ft back from Solomon River, but 150 ft from the river frozen ground was encountered. A shaft on a bench claim east of Solomon River between Quartz and Big Hurrah Creeks encountered frozen ground to bedrock.

To provide water for mining on Windy Creek, Kougarok drainage, a proposal was advanced to impound springs issuing from limestone at its contact with schist and to allow the springs to overflow at intervals during the winter in order to build up a thick body of ice which will supplement the spring discharge. The streambed above the contact is dry, and the water is carried underground in the limestone beds.

1909b, The Iron Creek region [Alaska]: U.S. Geol. Survey Bull. 379–F, p. 302–354.

Gravel beneath Iron Creek is unfrozen at depths of 5–6 ft and carries sufficient water to prevent sinking of prospect shafts. Bobs Creek, a tributary of Iron Creek, has placer ground that is entirely frozen. On Easy Creek, heading in a limestone ridge, is a spring which yields 100 miner's inches of water throughout the season (approx 2½ cu ft per sec). In Auburn Ravine, a tributary of American Creek, the creekbed across limestone beds is dry except after heavy rains; the water apparently seeps underground into the limestone.

Ditches along Willow Creek have encountered ground ice in frozen ground, which, when thawed by the water, forms cavities as deep as 20 ft. High water losses occurred in ditches across fissured limestone. A ditch on Moonlight Creek leads water from the springs to Casadepaga River.

1910, Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska: U.S. Geol. Survey Bull. 433, 234 p.

In the Solomon-Casadepaga area where limestone beds occur, water generally seeps underground. Frozen ground occurs along the Solomon River near Three Friends dredge, in Moran Gulch, and in bench gravel 150 ft back from the river above the mouth of Penny Creek. In Solomon River near the mouth of Big Hurrah Creek frozen ground occurs unusually near the river, but its distribution is irregular. On a bench claim along the east side of Solomon River, two-thirds of a mile below Big Hurrah Creek, the gravel is solidly frozen to bedrock. Flood-plain deposits above the mouth of Shovel Creek are frozen in many places. A hole on the divide between Manila and Jackson Creeks penetrated frozen ground in which not much ice occurred in the upper part of the section. Creek deposits near the mouth of West Creek are easily mined because of the absence of frozen ground and boulders.

Nearly a mile of Lost Creek is dry because of underground seepage of surface water into limestone. The bench deposits west of Butte Creek consist of 8 ft of frozen gravel. On the Casadepaga River near Fool Creek frozen gravel exposed in the riverbank is thawed by exposure to sun and air. Midway between Goose and Canyon Creeks a 30-ft shaft in frozen ground encountered quicksand in which seepage water entered the hole. Unfrozen fine gravel and interlaminated clay deposits half a mile from the mouth of Big Four Creek were difficult to prospect because of seepage. A hole on Penelope Creek, 1 mile above its confluence with the Casadepaga, passed through 57 ft of frozen gravel without reaching bedrock; another hole 150 ft from the creek passed through 40 ft of well-rounded creek wash, 24 ft of yellowish clay, 29 ft of washed gravel and slide, into bedrock at the base. A third hole, nearby, was sunk 86 ft without encountering bedrock. Water brought for sluicing on Quartz Creek disappears in the cavernous limestone crossed by the creek. On Rabbit Creek in the coastal plain rusty gold-bearing gravel deposits apparently have been coated with iron oxides brought by circulating ground water. West of this hole a shaft sunk 45 feet penetrated thawed ground before reaching bedrock, and ground water drove out the miners. Although most of the ground is frozen in the coastal plain placers, here and there are encountered zones of unfrozen ground.

Moonlight Creek, a tributary to Casadepaga River, heads in a series of large springs formed by emergence of water at the contact between schist and limestone.

1911, The Squirrel River placers [Alaska]: U.S. Geol. Survey Bull. 480–J, p. 306–319.

The physical condition of the stream gravels with respect to cementation by permanent frost has an important bearing on mining and prospecting, but the data available are not adequate for a thorough analysis of the problems. Practically all the shallow gravels are not permanently frozen. The thicker deposits, especially those in which there is a large amount of clay, and some of the bench gravels are probably frozen. * * *

The presence or absence of permanent frost seems to be in large measure determined by the effectiveness of subsurface drainage. Such drainage is best in well-rounded gravel deposits at an elevation above the streams and is poorest in those deposits containing a large percentage of clay or silt and lying below

the level of the ground-water table. The fact that the mean annual temperature * * * is less than 16°F * * * makes it possible to explain permanent frost in this region as due to existing climatic conditions.—Auther's report, p. 290.

Streambed gravels on Dahl Creek are unfrozen, but some of the low benches bordering the stream are reported to be permanently frozen. Placer ground in the bed of Shungnak River is unfrozen.

Smith, P. S., 1912, The Alatna-Noatak region [Alaska]: U.S. Geol. Survey Bull. 520–L, p. 315–338.

Of the marine deposits recognized along the Arctic coast and the lower Noatak, the recent beach deposits probably lack permanent frost, and the older marine gravels at some elevation above the sea probably are frozen.

1913, The Noatak-Kobuk region, Alaska: U.S. Geol. Survey Bull. 536, 160 p.

Above the point on the Kobuk River about 8 miles above the Squirrel River, the banks are composed of sand, gravel, and silt which includes ice masses as much as 20 ft thick. Ice in frozen silt deposits is seen along the Noatak River. On Dahl Creek, near Shungnak, the creek gravel deposits are unfrozen, but some of the bench deposits, as much as 15 ft thick, are reported to be perennially frozen. Placer deposits on Shungnak River are not perennially frozen. On Klery Creek, in the Squirrel River basin, the bench gravels probably are perennially frozen and covered with muck. In the Squirrel River flood plain the deep ground is frozen.

1933, Mineral industry of Alaska in 1930: U.S. Geol. Survey Bull. 836–A, p. 1–83.

The dredge on Little Creek in the Innoko district encountered frozen ground and was forced to close in midseason. In the Goodnews Bay area drilling was continued in the deep unfrozen alluvium of the Arolic Valley. Most of the 27 dredges operating in 1930 in Alaska were in areas where frozen ground is common; however, the cold-water thawing technique provides a means of eliminating the frost ahead of the dredge.

1934a, Mineral industry of Alaska in 1931: U.S. Geol. Survey Bull. 844–A, p. 1–82.

A face of gravel 25 to 30 ft high and 15 ft above Crow Creek, a tributary of Glacier Creek, Girdwood district, is frozen and is difficult to sluice with hydraulic equipment.

Frozen ground was encountered at the site of the McCarthy and Panos dredge, a short distance east of Nome on the second beach. The dredge on Spruce Creek, 6 miles east of Solomon, encountered sporadic patches of permanently frozen ground in alluvial deposits 11 ft thick.

1934b, Mineral industry of Alaska in 1933: U.S. Geol. Survey Bull. 864–A, p. 1–94.

Among new developments in placer mining in Alaska is the application of geophysical techniques to determine depth of muck and depth to bedrock. This experimental geophysical work produced results that were proved close to those obtained from drill holes and shafts, in either thawed or frozen ground.

1939a, Areal geology of Alaska: U.S. Geol. Survey Prof. Paper 192, 100 p.

Permanently frozen ground was once thought to be a relic of the ice age, and the clear ice masses were thought to be a remnant of the ice sheets of that time. However, ice masses and frozen ground lie far outside the limits of Pleistocene glaciation, and in many places occur in postglacial deposits. The

southern boundary nearly coincides with the 30°F isotherm of mean annual temperature; thus, it is reasonable to infer that little change in the climatic conditions of the present is required for formation and preservation of permafrost. A map (pl. 14 of the report) shows localities in which permafrost is reported.

1939b, Mineral industry of Alaska in 1938: U.S. Geol. Survey Bull. 917-A, p. 1-113.

The dredge of Deadwood Mining Co. on lower Deadwood Creek, Circle district, encountered frozen ground which caused lost time due to breakage. Preparatory work by the Nome Department of United States Smelting, Refining, & Mining Co. on the Nome coastal plain includes thawing of the frozen ground. Both dredges on Candle Creek, Seward Peninsula, were handicapped by frozen ground, on claims 4 and 5 below Discovery and claim 17, farther upstream. Dredge operations on Dese Creek, 6-8 miles east of Teller, were delayed by the need for thawing the ground. Frozen ground does not occur in the placer ground being mined in the Goodnews Bay area.

1942, Mineral industry of Alaska in 1940: U.S. Geol. Survey Bull. 933-A, p. 1-102.

Marvel Creek in the Tuluksak-Aniak district has placer ground that is naturally thawed.

Smith, P. S., and Eakin, H. M., 1910, Mineral resources of the Nulato-Council region [Alaska]: U.S. Geol. Survey Bull. 442-H, p. 316-352.

Bench deposits bordering Bonanza Creek, a tributary of Ungalik River, are reported frozen. In a shaft dug on Alameda Creek, a western tributary of the Koyuk River below the East Fork, considerable water was encountered at 192 ft, forcing abandonment of the hole before reaching bedrock.

1911, A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U.S. Geol. Survey Bull. 449, 146 p.

Owing to the high northern latitude, many of the deposits are permanently frozen, and as the presence or absence of frost in the ground has an important effect upon mining enterprises a general statement of the distribution of the ground ice may be made. Generally the older gravels are permanently frozen, and some of the bench deposits contain beds of clear ice in places a score or more feet thick. So far as is known, the presence or absence of trees on the gravels is no sure indication that the ground is thawed, for many instances are known of trees of large size growing on frozen ground. For instance, at Nulato, as Russell states, a well 25 ft deep went through clay and sand beds, which were frozen solid with the exception of certain dry sandy layers, and yet spruce was abundant in the neighborhood before it was cut off. Although most of the older deposits are frozen, those near the present streams are usually thawed. Whether this condition is due to the better drainage of the present stream gravels, which prevents the formation of ice, is not known. There is a strong suggestion, however, that the frozen condition is due to past climatic controls and is in a way an inheritance rather than a process now in progress. This possibility receives some support from the distribution of ground ice in the marine gravels. In the present beach deposits permanent frost is unknown, whereas in the older ones it is almost universally present.—Author's report (p. 82-83).

Bench deposits on Bonanza Valley, tributary to Ungalik River, are frozen. On Alameda Creek, tributary to Koyuk River, a shaft 192 ft deep encountered large quantities of water which prevented further digging.

Smith, P. S., and Mertie, J. B., Jr., 1930, Geology and mineral resources of northwestern Alaska: U.S. Geol. Survey Bull. 815, 351 p.

Aufeis or flood-plain icing formed by freezing of successive winter overflows attains a thickness of as much as 10 ft on the Killik River and other tributaries of the Colville, and on the Kivalina River. Their formation continues until the flow beneath the ice is reduced to that which can pass through the channels beneath the ice or that which can seep through the streambed gravel. Ice mounds as high at 10 ft are associated with the aufeis.

Smith, P. S. *See also* Collier, A. J., 1908.

Sochava, V. B., 1932, The tundra of the Penzhina River basin [Po tundram basseina Penzhinskoi guby]: Vses. geog. obshch. Izv., v. 64, p. 298–321.

Sofronov, G. P., 1944, Permafrost [Vechnaia merzlota]: Akad. Nauk SSSR, Inst. Merzlotovedeniia im. V. A. Obrucheva Trudy v. 6, p. 72–81.

In the Vorkuta River region permafrost is continuous and ranges from 84 to 132 m in thickness, depending on the depth to the permafrost table which has a complex configuration. Beneath the smaller streams permafrost is deep, and underground streams are reported. Permafrost has not been found in boreholes beneath the larger streams, but was encountered as thin remnants or pereletok beneath some sandbanks and shallow water. Subpermafrost water forms springs where the large streams cut bedrock, and evidence occurs that the Vorkuta region is fed by underground water through "talik cracks" under large rivers which are formed by warming from above by river water and from below by ground water. Permafrost temperatures are 0° to —1.5°, and the depth at which seasonal temperature fluctuations are absent is no deeper than 7–10 m.—From unpublished condensation and emendation by I. V. Poiré.

Sovetskii Sever, 1933, Conference on permafrost [Soveshchanie po vechnoi merzlote]: Sovetskii Sever, v. 4, no. 2, p. 111–112.

Biological analysis of frozen ground has shown the presence in deep permafrost strata of viable bacteria, including pathogenic types, such as those that cause typhoid fever and anthrax.—From SIPRE 10604.

Spofford, C. M., 1949, Low temperatures in inaccessible Arctic inflate construction costs: Civil Eng., v. 19, no. 1, p. 24–27.

In a section devoted to sanitary engineering is the statement that wells driven through the permafrost zone are practical and avoid the expensive aboveground storage structures which must be heated and which are subject to earthquake shock. A high iron and manganese content is common in water taken from wells driven through permafrost, and treatment for removal of these minerals as well as chlorination is necessary to provide water safe for domestic use. Generally, hardness is removed only for industrial use (laundries, steamplants, etc.) unless very high. During large fire demands, water is pumped directly from wells into the distribution system.

Stager, J. K., 1956, Progress report on the analysis of the characteristics and distribution of pingos east of the Mackenzie delta: Canadian Geographer, no. 7, p. 13–20.

The distribution and characteristics of pingos of 175.9 square miles in the area northeast of the Mackenzie delta to Liverpool Bay were studied from aerial photographs taken in 1954. The classification of pingos is based on size, shape, and location. Nearly all (98 percent) the 1,380 pingos identified occur

in lake basins; most (71 percent) have rounded outlines, are plug shaped, have smooth summits, and are either small (under 30 ft high) or medium (30–80 ft high). Large pingos, in the various combinations that occur, exhibit 168 distinct types of earth mounds, but a large number represent only a few types. The areas of greatest pingo concentration are along the East Channel of the Mackenzie (as many as 31 pingos per square mile), between Toke Point and Tuktuk (20 per 10 square miles), and along the west side of Richards Island (10 per 10 square miles). On the basis of the characteristics, of the pingos and the combination of the characteristics, it might be possible, after further work, to arrive at a significant basis for classification of these earth mounds.—From author's conclusions; SIPRE 15589.

Stall, J. B. *See* Abu-Lughod, J., 1957.

Stefansson, Vilhjalmur, 1910, Underground ice in northern Alaska: Am. Geog. Soc. Bull., v. 42, p. 337–345.

1950, Arctic Manual: New York, Macmillan Co., 556 p.

The theory that ground frost is a relic of the Ice Age no longer is tenable, for it has been shown that the ground exposed at the edge of retreating glaciers is unfrozen. Permanent frost was reported along the north shore of Lake Superior, and even more was encountered along the right of way of Canadian National Railway north of the lake. In Alaska there is permanent ground frost in all the land north of the Brooks Range and in much of the Yukon basin. South of the Alaska Range much land is unfrozen. Ground frost is reported from the Cook Inlet-Susitna basin where islands of frozen soil occur, especially where the moss is thick. At Montana and Willow Creeks ice is common within 3 ft of the surface, and in August ice was found within a foot of the surface along the banks of the Susitna River near Willow Creek.

The boundaries of ground frost in Siberia are those given by Cressey (1939). The absence of extensive ground frost in European Russia may be due to the extensive glaciation of that part of Europe during the Pleistocene Epoch. Arctic rivers and lakes can thaw ground frost for a considerable distance; the ocean may do the same. Along the north coast of Alaska the thaw will precede the invading ocean by 100–300 ft; in muck and ground ice, the thaw does not precede the attack of the waves.

Thawed ground near lakes may be suitable for water wells and mains. The best known example of river removal of ground frost is that of Snake River near Nome. Practically anywhere in that valley one can strike permanently thawed ground at a depth of 30 ft. Thawed ground is closest to the surface where willows grow, possibly because snow is caught in the branches.

It is good practice to maintain the insulating vegetation mat around wells and over water mains to protect them against deep frost penetration. Although one encounters warmer temperature with depth in permafrost, it is usually most economical to bury the utility mains near the surface and insulate them well and to keep the liquids moving when temperatures are low. Ground temperatures of 10° are reported in permafrost at Barrow and in the coal workings at Spitzbergen.

The water system at Nome consists of shallow uninsulated pipes fed by woodstave pipe from Moonlight Springs; the system operates in summer. The ground is frozen to bedrock at Nome. The fire system is a buried pipe in woodbox, and in winter it is kept drained and ready for use under pressure when needed.

"It is probable that under most or all of the big lakes that do not freeze to the bottom, the thaw goes indefinitely down—that there is no ground frost below them" (p. 353).

Stefansson, Vilhjalmur [undated] Glossary of snow, ice, and permafrost terms: Washington, U.S. Weather Bur., 121 p.

Steidtmann, Edward, and **Cathcart, S. H.,** 1922, Geology of the York tin deposits, Alaska: U.S. Geol. Survey Bull. 733, 130 p.

The unconsolidated materials (muck, gravel, etc.) underlying the tundra are frozen solid the year around and must be thawed before they can be mined. Such frozen masses may include 50 ft or more of material, as on the Nome flats, in the southern part of the peninsula. Again, a tundra-covered surface 50 ft from the bedrock may be underlain by 40 ft or more of ice with only a few feet of earth * * *. The stream gravels are frozen to a depth of several feet in winter, but are thawed by circulating waters in the open season (p. 5).

* * * * * * *

The checking of the underground water flow is most pronounced under low tundra-covered areas. In the rugged portions of the slate and limestone areas underground circulation penetrates to considerable depth, causing the perennial flow of springs and streams and the development of gossans 85 ft or more deep. It is more vigorous in limestone areas than in those underlain by slates. Slate areas are sufficiently impervious to make the transmission of water in open ditches along hillsides a success, but similar undertakings in the limestone areas of the York region failed because of the permeability of the rock.—Author's report, p. 5, 6.

Even the rugged areas have some deep frozen ground; for example, ice formed in summer at the end of adit 3, Cassiterite Creek, at a depth of 260 ft. This shows that the underground temperature is low enough to cause formation of ice wherever the circulation of water is not sufficiently vigorous to cause thawing.

Existence of deep-frozen ground in limestone terrane may be a cause for rapid rise in streams after even light showers. Ground water in the slate areas is more active chemically because of the peat and tundra through which it passes, but water of the limestone areas has a greater circulation and the limestone is more soluble than slate. Stream waters in the limestone belt are hard; those in slate areas are soft.

Stepanenko, E. V., 1916, Report on the problem of water supply of the middle part of the Amur railroad [Zapiska k voprosam vodosnabzheniia srednei chasti Amurskoi zheleznoi dorogi]: Blagoveshensk.

Stepanenko, E. V., and **Tregubov, V. V.,** 1915, Memoirs on the problems of water supply of the middle part of the Amur Railway: Blagoveshensk. [Russian.]

Stotsenko, A. V., and **Ignatenko, K. Z.,** 1957, The problem of the zero curtain [K voprosu of nulevoi zavese], *in* Sbornik materialov po voprosam sezonnoi merzloty: Vladivostok, Akad. Nauk SSSR, Dal'nevostochnyi filial, p. 21–26.

The "zero curtain" concept is explained, and pertinent long-period data from 60 stations in the far eastern USSR are examined. The "zero curtain," according to Sumgin, expresses the resistance to heat or cold penetration in soil due to latent heat liberated on freezing, which inhibits frost penetration to a degree depending on the moisture content of the soil. Soil-freezing data fail to reveal any retardation of temperatures near 0°C at any level for any length of time, except in areas where the amplitude of annual temperature variation is very small or in the presence of a deep snow cover when these temperatures represent the minimum. Analysis of soil thawing records reveal the presence of a zero

curtain (not Sumgin's) only after very snowy winters and only at depths from 10 to 40 cm. Sumgin's zero curtain occurs in a hidden form in finely dispersed soils outside of the permafrost region and is expressed by the higher frequency of certain temperatures near 0°C (from 0° to —0.5°C) than of all others.—From SIPRE 17392.

Strugov, A. S., 1955, Rupture of a hydrolaccolith [Vzryv gidrolakkolita]: Priroda, v. 44, no. 6, p. 117.

A case of hydrolaccolith rupture observed in July 1938 in the Byrtsa River valley (Siberia) is described. A sound like a gunshot was heard for about 7 km and masses of fossil ice and soil were lifted 8–12 m. The phenomenon occurred in permafrost 15–20 m deep as a result of increased hydrostatic pressure of ground water in a thawed space that had been reduced in size under the action of the surrounding frozen strata.—From SIPRE 11745.

Sturgis, S. D., Jr., 1953, Arctic engineering know-how gets acid test at Thule: Civil Eng., v. 23, no. 9, p. 585–589.

At Thule the ground is permanently frozen to a depth of more than 1,000 ft, and its active surface, periodically thawed, has an averaged thickness of 3 ft. Locally, free ice in lenses makes up as much as 50 percent of the subsoil. Ground water is not obtainable. At first Lake Eddy, located between the runway and a taxiway, was used as a source of water, the water being led 1½ miles to camp through a 6-in. invasion pipe and treated by an Army 50-gpm water-treatment set. As a supplement, salt-water distillation plants were established with a combined capacity of 129,600 gpd. Crescent Lake, 6 miles from the base, is deep enough to provide all-year water supply. Its level has been raised by an earth-filled dam, and under 8 ft of winter ice it has a storage capacity of 60,000,000 gal. In summer additional water can be made available by diverting a stream flowing from the ice cap. The water is to be treated and filtered at the lake and will be transported in heated trucks to indoor storage tanks in the camp buildings. Eventually a caisson to permit intake of water beneath the ice, a pumping system, and chlorination and storage facilities are to be installed.

Styrikovich, B. V., 1958, Certain special formations of ground water in Kamchatka [Nekotorye osobennosti formirovaniia gruntovykh vod Kamch'atka]: Inf. Biull. 1, 5-ogo Geol upr., no. 1, Leningrad.

Subitzky, Seymour. *See* Cederstrom, D. J., 1953.

Sumgin, M. I., 1927, Permafrost in the boundaries of the USSR [Vechnaia merzlota pochvy v predelakh SSSR]: Vladivostok, Far Eastern Geophys. Observatory, 372 p.; rev., 1937, with title, Permanently frozen ground in the boundaries of the USSR (Vechnaia merzlota pochvy v predelakh SSR): Moscow-Leningrad, Akad. Nauk SSSR, 379 p.

The revised edition published in 1937 is based on 9 yr of additional material, the work treats the science of permafrost, including definition, terminology, and classification, historical study, geographical distribution, and effect on economic life, temeprature, origin, degradation, and hydrological conditions in permafrost regions.—From SIPRE U–71.

1930, Present status of investigations of permafrost in the USSR and desirable future investigations [Sovremennoe polozhenie issledovaniia vechnoi merzloty v SSSR i zhelatel'naia postanovka etikh issledovanii v blizhaishem budushchem]: Akad. Nauk SSSR Materialy Kom. izuch. estestvennykh proizvoditel'nykh sil soiuza, no. 80, sbornik "vechnaia merzlota," p. 1–41.

Artificial icings were obtained by filling shallow cylinders with sand soil of 21–22 percent water content and freezing at —16° to —19°C. An icing begins to form with the appearance of a crack over the ice lens in the slightly convex top of the sample. Similar cracks formed in peat samples when ice lenses formed between two layers of peat. These experiments suggest that large peat mounds in tundra, 3–8 m high and 5–25 m wide are formed in a similar manner. Spotty tundra is formed by the action of hydrostatic forces in talik layers between the frozen surface and permafrost layers. A relationship is shown between formations such as surface icings and peat mounds in permafrost regions and landscape relief and stresses in the soil. The soil temperature in the Transbaikal Petrovsk valley averaged —0.6°C at a depth of 6 m and —0.4°C at 15 m in permafrost 21.2 and 49 m thick, respectively.—From SIPRE U-6420.

Sumgin, M. I., 1933a, Permafrost study in the years 1933–1937 [Ob issledovanii vechnoi merzloty vo vtoroi piatiletke 1933–1937] : Sovetskii Sever, v. 4, no. 1, p. 47–53.

Results of the study of permafrost up to 1933 are outlined; the chief organizations in the USSR engaged in the study of permafrost are listed; and problems for investigation during the next 5 yr are discussed. Collected data show that permafrost is a residual phenomenon of the glacial epoch and that degradation is taking place at present in the southern permafrost areas. Thermal conditions in permafrost, the hydrogeology and biology of frozen ground, and construction under permafrost conditions are listed as the principal problems in need of further investigation.—From SIPRE 10603.

1933b, The problems of permafrost [Problemy vechnoi merzloty] : Sotsialist. Rekonstruktsiia i Nauka, v. 3, no. 7, p. 36–35.

1935, The permafrost problem and its significance in engineering and farming in the Buriat'-Mongolian ASSR [Problema vechnoi merzloty i ee znachenie v promyshlennom stroitel'stve i sel'skom khoziaistve Buriat'-Mongol'skoi ASSR], *in* Pervyi konf. izuch. proizvoditel'nykh sil Buriat'-Mongol'skoi ASSR Trudy, v. 1, Problemy Buriat'-Mongol'skoi ASSR, p. 210–223 : Moscow-Leningrad, Izd. Akad. Nauk SSSR.

Permafrost is sporadic west of Lake Baikal and absent along the shoreline; talik and pseudotalik islands are present in continuous permafrost east of Lake Baikal. The thickness of the active layer varies from 0.5 to 5.3 m depending on soil type, moisture content, relief, slope inclination and orientation. Permafrost reaches a maximum thickness of 70 m with an average of 40 m east of Lake Baikal and a maximum thickness of 38 m west of the lake. Average monthly and annual temperature values under the natural and denuded soil surfaces in Irkutsk during 1887–1908 are tabulated for depths to 3.2 m and in Chita during 1900–1908 for depths to 1.6 m.—From SIPRE U-6606.

1938a, Construction under permafrost conditions [Stroitel'stvo v usloviiakh vechnoi merzloty] : Vestnik Inzhenerov i Tekhnikov, v. 24, p. 757–758.

Deformations of construction on permafrost are described and principal countermeasures are discussed. Foundation instability results from ground thawing, sliding of the subgrade soil over the lower frozen strata, hydrostatic pressure arising from ground-water freezing, and frost heaving caused by supersaturation of the surrounding ground. A thick layer of insulation between the foundation and the permafrost or trenches under the foundation which can be opened in winter for cooling the soil and drainage and replacement of fine-grained soils are effective countermeasures.—From SIPRE 11942.

1938b, Ice dams in the Soviet Far North [K voprosu o ledianykh plotinakh na Krainem severe SSSR]: Gidrotekhn. Stroitel'stvo, no. 10, p. 34–35.

Some difficulties in constructing ice dams as well as cost considerations are discussed. The presence of thick thawed layers under riverbeds and in some cases complete degradation of the permafrost makes freezing of the riverbed impossible without additional artificial cooling. The low heat conductivity of ice invalidates Romanov's 1938 considerations on the construction of high ice dams in one winter. The plastic properties of ice also require special construction measures because a structure 30–40 m high would be exposed to heavy water pressure. An accurate solution of the problem is possible only after construction of an experimental ice dam.—From SIPRE 11820.

1940a, On the formation of perennial ice mounds—Bulgunniakhs: Acad. sci. URSS Comptes rendus (Doklady), v. 28, no. 2, p. 156–157.

Some years ago the author suggested a mathematical formula for the formation of seasonal ice mounds that may serve also as a basis for an equation for the formation of a perennial ice mound or bulgunniakh. The formation of the seasonal mound is complete in a single year, but that of the bulgunniakh requires a long series of freezing cycles to increase its bulk in annual equidimensional increments. The summation of the annual increments produces the bulk of the hill, until it reaches the limit of its size. In symbols this may be expressed as follows:

n years is the time of formation of the bulgunniakh;
V_1 is the volume of the hillock during the first year;
V_2 is the volume during the second year;
V_3 is the volume during the the third year, etc.;
V_n is the increment of the hillock during the nth year.

Retaining in the left-hand part of the equation all designations assumed on page 302 of Sumgin's 1931 paper, we shall designate the constant value

a is 0.27g;
M is $(H'-H)$:
p_1 is the moisture content of the soil by weight percent during the first year of formation of the hillock;
R_1 is the range of feeding of the hillock;
M is the thickness of the layer of ground freezing during the winter;
p_2, R_2, M_2, etc., accordingly during the second year;
p_n, R_n, M_n, during the nth year.

Thus, the following mathematical expression is obtained for the whole process of formation of the bulgunniakh. During the first year the hillock is formed according to the equation

$$ap_1R_1^2M_1 = V_1;$$

during the second year the hillock is increased by the volume

$$ap_2R_2^2M_2 = V_2;$$

during the kth year the hillock is increased by

$$ap_kR_k^2M_k = V_k;$$

during the nth year the hillock is increased by

$$ap_nR_n^2M_n = V_n.$$

The bulk of the hillock formed during a period of n years as a total of many individual increments is

$$\sum_{k=n}^{k=n} ap_k R_k^2 M_k \sum_{k=1}^{k=n} = V_k$$

In the left-hand part of the equation a is constant, which may be put before Sigma; this part of the equation represents the since bulk [sic] of the bulgunniakh—the bulk is known value and can be measured. If the bulk is V_d we can write an equation as follows:

$$a \sum_{k=n}^{k=n} p_k R_k^2 M_k = V_d$$

This is the mathematical expression of both the growing process and the bulk of the bulgunniakh mounds. Considerations apply to 3 cases of mound formation: (a) mound formation is due to waters bedded between the lake bottom and the top of permafrost. Mounds of this kind are forming in the middle of lakes; (b) ice mounds are forming from waters bedding under the lower limit of permafrost and issuing in the middle of basins of former lakes; and (c) mound formation is due to waters overlying the top of permafrost and issuing on the surface in swampy localities.

The considerations are not to be applied to perennial mounds formed by hydraulic pressure of waters which are bedding [sic] under the permafrost.

Sumgin, M. I., 1940b, On the theory of formation of peat mounds of long duration at the base of icings and hydrolaccoliths in Yakutia [K teorii obrazovaniia mnogoletnykh nalednykh bugrov—bulgunniakov]: Akad. Nauk SSSR (Doklady), v. 28, no. 2. *See* annotation, Sumgin, M. I., 1940a.

1940c, The future of the study of permafrost in the Yakut Republic: Akad. Nauk SSSR, Kom. vechnoi merzlote Trudy, v. 9, p. 5–27.

In addition to zones of continuous permafrost, talik areas occur, but precise data on their distribution and size is lacking. Data on lower limits of permafrost also are lacking, and the total thickness is known in only a few areas. Features related to permafrost, such as icings and heavings, require further study. The results of a number of studies of separate aspects of permafrost, such as the work on frost mounds and fossil ice, and the history of temperature observations are cited. Permafrost is a relic of the ice age, rather than a product of the present cold climate. To further the work on permafrost in Yakutia, a special station should be established, regional studies should be tied in to large cities and agricultural areas, and fellowships for training of specialists should be established. Study is required of the dynamics of the freezing process to determine aggradation or degradation of permafrost and to investigate the possibility of lowering its upper surface for agricultural purposes. A study of the Kyra River icings as a means of determining the regime of the ground water in permafrost regions is suggested, and practical aspects of thawing of ground ice should also be considered. Studies of moisture migration during freezing and the influence of suprapermafrost waters on plants are suggested. All these investigations would be most efficiently conducted by a centrally located permafrost laboratory or station.—From abstract by E. A. Golomshtok for Stefansson Collection, Dartmouth College, Baker Library, Hanover, N.H.

1941, Icings and icing mounds [Naledi i nalednye bugry]: Priroda, v. 30, no. 1, p. 26–33.

An icing is considered a mass of surface ice formed by successive freezing of seepage from the ground, river, or spring. The landscape of a permafrost region may be grouped into microrelief and mezorelief features. Microrelief includes frost blisters, mounds, and spot medallions of varied duration. Icing mounds, formed on rivers and on the ground, and certain peat mounds, are considered mezorelief features. These terrain characteristics are described in detail, and a theory of origin is presented.—From SIPRE U-3013.

Sumgin, M. I., and Demchinskii, B. N., 1940, Region of permafrost [Oblast' vechnoi merzloty]: Leningrad-Moscow, Glavsevmorputi, 237 p.

This second edition of the book entitled "Zavoevanie severa v oblasti vechnoi merzloty," published in 1938, summarizes the geographic aspects of permafrost, with special emphasis on problems of agriculture, mining, housing, and transportation in the Arctic. Chapter 12 discusses knowledge of permafrost abroad in comparison to that in Russia. The warming of the Arctic during the last 50 yr as reflected in warming of soil temperatures and degradation of permafrost is also treated.

Pages 108–112 outline drilling difficulties and the effect of permafrost on mining. Special methods of drilling are used in permafrost areas. Permafrost is very hard, and drill rods twist, coupling boxes break, and drilling tools quickly get stuck. When the drilling tools get hot, permafrost begins to melt and the ground becomes sticky; but if drilling stops, the ground freezes again and the tools freeze in. Ground water and drilling fluid freeze and seal the drill hole. Use of salt water prevents the drill hole from freezing, but corrodes the metal. Landsliding due to permafrost may occur on hillslopes, and some of the slides in the Noginsk mining area (Lower Tunguska River area) were as much as 150 m long and 5 m wide. Generally speaking, permafrost is more of a help than a hindrance in mining because it lessens the need for timbering, reduces liberation of mine gases, and enables more effective control of ground water. Cases are known (notably Razdel'nyi Mine, Vaigach Island) where the inflow of salt sea water at a rate of as much as 150 cu m per hr suddenly flushed the ice from cracks in the rocks, even though the temperature was −3°C. At Amderma, the cracks were not filled with ice, and the flow of salt water was more constant. Bedrock in which the cracks are filled with ice tend to shear and settle more readily when the ice thaws than rocks in which the cracks are not so filled. To prevent thawing along shaft, mines may be closed during summer and used only in winter. Ponamarev has suggested lining the exposed rock faces with ice and water in order to form an impermeable sheath of freshwater ice to prevent flooding.—Meteorological Abstracts and Bibliography, v. 2, p. 222, 1951; SIPRE U-49; unpublished condensation and emendation of excerpt by I. V. Poiré.

Sumgin, M. I., Geniev, N. N., and Chekotillo, A. M., 1939, Water supply of railroads in permafrost regions [Vodosnabzhenie zheleznykh dorog v raionakh vechnoi merzloty]: Moscow, Transzheldorizdat, 251 p.

The book contains chapters on thermophysics, thermodynamics of the ground, permafrost, water sources, methods of investigating water sources, organization of water-source studies, water-intake structures, construction of water-conduit network, thermal technique for the water system, laying water pipe during winter, supplementary structures for water conduits, thermometry, experimental determination of heat loss in water lines and thermal regime of an operating water-supply system.

Outlets of subpermafrost water are found along the boundaries of different rock strata and along faults. Locating these narrow zones in the subsurface by drilling is difficult, and it is usually done by developing the surface seepages.

The best time to prospect for springs is February or March when they can be recognized by icings and icing mounds. The water outlet may be determined approximately by the direction of the flow of the water and by an increase in temperatures toward the source. Water source is usually located at the uphill edge of icings. Taliks are usually found by shallow drill holes; decreased thickness of seasonal frost and greater depth to permafrost may indicate the proximity of a spring. Discharge of the spring is concentrated in channels and measured, or is estimated from the volume of the icing divided by 100 days the time usually required to form ice up to early March in the region under study.

A more detailed study of the springs specifies the geologic conditions of the water outlets for correct construction of the spring capping, makes a more precise discharge measurement during various seasons, and determines the quality of water. During this stage further drilling and test-pitting are done to define the contours of the talik in which the spring occurs.—From SIPRE Translation 28 (excerpts), chap. 5, secs. 35, 38, Methods of investigating water sources. Full translation available, Library Congress Sci. Translation Center, RT 3377, 66 p.

Sumgin, M. I., and others, 1940, General permafrostology [Obshchee merzlotovedenie] : Moscow-Leningrad, Akad. Nauk SSSR, 340 p.

Twelve chapters written by M. I. Sumgin, S. P. Kachurin, V. F. Tumel', and N. I. Tolstikhin describe terminology of permafrost and the concept of permafrost as a temperature phenomenon, its physicomechanical processes, seasonal freezing and thawing, distribution and thickness, thermal regime of ground, physical properties of frozen ground, its origin, its degradation, regime of ground and surface waters in the permafrost region (*see* Tolstikhin, N. I., 1940, for detailed summary), relief and microrelief of the permafrost region, effect on man's economic activity, and instructions for study of permafrost. This work is a summary of Russian work on frozen ground through 1940, but chiefly that of the Commission for the study of permafrost (1930–36) and the Committee on permafrost (1936–39) of the Academy of Sciences of the USSR.

Suslov, S. P., 1947, Physical geography of the USSR: Western Siberia, Eastern Siberia, Far East, and Central Asia [Fizicheskaia geografiia SSSR; Zapadnaia Sibir, Vostochnaia Sibir, Dalnii Vostok, Sredniaia Aziia] : Leningrad-Moscow, Gos. pedagogicheskoe izd. ministerstva narodnogo prosveshcheniia RSFSR, 544 p. [College textbook.]

Permafrost is an important geographical factor in Eastern Siberia. Water-supply problems, causes of building destruction, and ground and river-icing problems are mentioned.—From SIPRE U–849.

Svetozarov, I. M., 1934, The hydrogeology of permafrost based on investigation In the Yakutsk region [Gidrogeologiia vechnoi merzloty po materialam issledovanii v raione IAkutskaia] : Problemy Sovetskoi geologiia, v. 4, no. 10, p. 119–131.

A hydrogeological survey was made in the area of Yakutsk in order to locate an adequate source of water supply. The region has a rugged climate with average annual air temperatures about —10.7°C and limited winter precipitation. The following three types of water sources were found: Suprapermafrost water, talik water flowing beneath the Lena riverbed, and subpermafrost water. The suprapermafrost waters of the Yakutsk region are turbid, easily contaminated, and usually unreliable as to the yield and sanitary conditions. Free talik water was found below the riverbed of the Lena and near the edge of the stream.

Drilling revealed a water-bearing horizon, 10 m thick and 700 m wide, which could be effectively utilized. The water was highly mineralized, but was considered suitable for use after purification.—From SIPRE U-1636.

Taber, Stephen, 1916, The growth of crystals under external pressure: Am. Jour. Sci., v. 41, p. 544–545.

1918a, Ice forming in clay soils will lift surface weights: Eng. News-Rec., v. 80, p. 262–263.

1918b, Surface heaving caused by segregation of water forming ice crystals: Eng. News-Rec., v. 80, p. 683–684.

1926, Discussion of metasomatism and the pressure of growing crystals: Econ. Geology, v. 7, p. 717.

1929, Frost heaving: Jour. Geology, v. 37, p. 418–461.

1930a, Freezing and thawing of soils as factors in the destruction of road pavements: Public Roads, v. 11, no. 6, p. 113–132.

1930b, The mechanics of frost heaving: Jour. Geology, v. 38, p. 303–317.

1943a, Some problems of road construction and maintenance in Alaska: Public Roads, v. 23, no. 9, p. 247–251.

Except for the coastal zone in southern and southeastern Alaska, the ground is perennially frozen to depths as great as 300 ft. In many places perennially frozen ground contains ice in almost horizontal layers and lenses as much as 12 ft thick and in wedge-shaped veins as much as 8 ft wide. Since formation of frozen ground took place in early Pleistocene time a part of the ground has been deeply thawed and refrozen at least once; most of it has remained continuously frozen to the present. Evidence is available to show that during the last few thousand years the climate has become warmer, and the area of perennially frozen ground has been decreasing.

Springs and seepages of ground water in winter form large deposits of ice, locally called glaciers, which may cover an area of thousands of square yards and attain a thickness of 25 ft.

The Alaska Highway does not pass over perennially frozen ground in British Columbia, where, as in Alberta, the frozen ground is only local and occurs at high altitudes. Perennially frozen ground occurs in Yukon Territory.

A map shows the southern boundary of permafrost in eastern Alaska along the northern and central Chugach Mountains.

1943b, Perennially frozen ground in Alaska; its origin and history: Geol. Soc. America Bull., v. 54, p. 1433–1548.

In areas of perennially frozen ground, rock disintegration caused by growth of ice crystals is the dominant form of weathering. In Tertiary time large areas of Alaska were subjected to peneplanation and deep rock decomposition in a climate more moderate than the present one.

In early Pleistocene time, creek-valley gravel deposits were formed during a cool arid climate. The change from gravel to silt deposition was due chiefly to the change to a more humid climate. The silt originated by disintegration of the schist bedrock by frost action; it was moved down the valley slopes by soil creep and slope wash and distributed over the valley floors by floods. During its retransportation the silt became mixed with organic material. During deposition of the silt, the climate became colder, but not cold enough in central Alaska and on Seward Peninsula for formation of perennially frozen ground.

After deposition of the silt, the climate became colder, and perennial frost extended slowly downward from the surface. In fine-grained soils the freezing was accompanied by the segregation of water to form relatively pure ground ice, much of the water being fed up from the underlying gravel deposits. Deep freezing of the ground, which probably coincided with the maximum cold of the first glacial stage, occurred long after the beginning of the Pleistocene in Alaska.

The ground later thawed to a considerable depth. Thawing was accompanied by erosion of the silt as deep as 200 ft in some valleys. Marine transgression occurred along the coasts. Evidence of only one period of deep thaw is preserved, and this period is correlated with the warmest part of the Yarmouth interglacial. The period of erosion and thawing was followed by a colder climate in which the deeply thawed ground and the retransported silt was frozen. Some ground ice formed during the second period of freezing. Temperature profiles and the distribution of thawed and frozen ground show that the temperature has been rising in Recent time.—From author's conclusions, p. 1541–1543.

Tambovtseva, O. S. *See* Tolstikhin, N. I., 1938.

Taylor, L. D. *See* Barnes, D. F., 1958.

Teis, R. V., 1939, Isotopic composition of water from some rivers and lakes of the USSR: Akad. Nauk SSSR Comptes rendus, v. 24, no. 8, p. 779–782.

Density values were determined for water samples from six rivers, six lakes, Moscow tap-water, and two subpermafrost waters. The results indicate that lake water is on the average denser than the standard. Subpermafrost waters and water from lakes and rivers fed with melting snow and ice have lower density values than the standard.—From SIPRE U–3744.

Terzaghi, Karl, 1952, Permafrost: Boston Soc. Civil Engineers Jour., v. 39, no. 1, p. 1–50.

Knowledge of the physical aspects of permafrost is still expanding, but little is known concerning the effect of relative density and degree of saturation on the thermal conductivity of coarse-grained sediments, the effect of freezing temperatures on the strength of saturated clay in an undisturbed state, the relation between stress, strain, and time for pure ice, and other fundamental relations. Heat conductivity of frozen and unfrozen ground depends not only on porosity and water content but also on the average mineral composition of the grains, and on other factors. Real conductivity values may deviate by ±25 percent from the average values, which are accurate enough for most purposes.

Geographic distribution of permafrost is determined by present climatic conditions. The time lag between a change in mean annual temperature and the corresponding displacement of the southern boundary of the permafrost area is measured in decades or centuries and not in thousands of years.

If the voids of a coarse-grained soil are completely filled with ice, the upper boundary of permafrost can be determined by rail penetration tests. However, if the permafrost contains layers and lenses of porous or spongy material, it is difficult to determine the upper surface and the rate of degradation beneath heated structures. Layers and lenses of porous or spongy material are common along the margin of the permafrost area in Alaska. Methods for distinguishing between compact unfrozen and porous frozen soil are still unsatisfactory.

Lenses of layers of clear ice are formed during the freezing of fine-grained soils only. Coarse-grained sediments may conceivably contain bodies of clear ice which were formed or deposited on the surface and subsequently buried, but so far no such relics have been encountered.

The upper limiting value of the settlement of the surface due to thawing of frozen coarse-grained sediments with a porosity n is 0.1 n per unit depth of thawing. The few data indicate that the real value of the shrinkage due to melting decreases from the upper limiting value close to the ground surface to almost zero at a depth of a few tens of feet. The settlement of the surface is by no means negligible.

Theis, C. V., 1944, Thermal processes related to the formation of permafrost: U.S. Geol. Survey open-file report, 36 p.

Permafrost is a result of present climatic conditions and is not necessarily a relic of past colder climates. Permafrost has formed to a depth of 28 ft beneath piles of gravel tailings on Pedro Creek since 1910. In Alaska the permafrost zone lies north of the 30°F isotherm. Sources of soil heat are solar radiation and back radiation, internal heat of the earth, conduction and radiation to and from the air, and ground water. The role commonly ascribed to ground water in preventing formation of permafrost seems misapplied, because ground water moves at such a slow rate in most cases that it can not travel far between frozen beds without freezing. Some of the phenomena ascribed to movement of the water are probably effects of the lateral movement of heat by conduction from an abnormally warm area, such as a riverbed. In porous unfrozen ground where the water table is deep, percolating water from rains may carry heat downward faster than it could be carried by conduction, and, thus, may warm the material at depth.

Mathematical consideration is given the soil temperature under temperate and arctic conditions, with a discussion of the effect of surficial insulation on soil temperatures, and also the effect of snow, surface-water bodies, and frozen and wet soils.

Most of the water from precipitation is retained in near-surface relatively impermeable materials that lie above permafrost. During the freezeup this moisture is placed under hydrostatic head because of unequal penetration of seasonal frost. The pressure forces water to form icings or "glaciers," and in some cases the water escapes with explosive violence.

Thomas, B. I., 1957, Tin-bearing placer deposits near Tofty, Hot Springs district, central Alaska: U.S. Bur. Mines Rept. Inv. 5373, 56 p.

The alluvial deposits are permanently frozen, except along some stream courses and in areas that have already been mined. Seasonal frost generally penetrates to permafrost in winter. The shallow deposits consist of 3–10 ft of gravel overlain by 10 to 20 ft of silt or muck; the deeper deposits contain 5–45 ft of gravel overlain by 10–120 ft of muck. Along lower Woodchopper Creek bedrock is more than 200 ft deep. The frozen silt or muck that covers the gravel deposits consists of silt with minor amounts of ice, as veins and lenses, frozen plant and animal remains, and considerable sand and gravel.

Drilling of the placers was done by a portable-type modified 6-inch churn drill, using thin placer bits, forged to 5⅝ in. Heavy special 6-in. drivepipe with 7½-in. shoe was used in testing thawed ground. Drilling showed that permafrost is thicker than 115 ft in some places.

The Larsen shaft, 119 ft deep to bedrock, was the only drift mine still in operation in the district. This mine, on Deep Creek, has permafrost throughout, and the base of the frozen ground lies at an unknown depth in phyllite bedrock.

Thomas, J. F. J., 1956, Interim report—Hardness of major Canadian water supplies: Canada Dept. Mines and Tech. Surveys, Mines Branch, Memo. Ser. 132.

Report includes data on Dawson, Yukon River, Whitehorse, Aklavik, and other places in the permafrost zone.—Arctic Bibliography 48370.

Thomas, M. K., 1953, Climatological atlas of Canada: Canada, Dept. Transport, Meteorol. Div., and Natl. Research Council, Div. Bldg. Research No. 41 (NRC 3151), p. 192–193.

A map of the southern limit of perennially frozen ground (as of 1952) shows that the boundary passes through southern and central Yukon, north of Great Slave Lake to the south shore of Hudson Bay south of Churchill, and encloses interior Ungava Peninsula of northern Quebec.

Thompson, R. F., 1952, Water treament—Ladd Air Force Base: Science in Alaska, Alaskan Sci. Conf., 3d, Mount McKinley Park 1952, Proc., p. 64–67.

A large-capacity water-treatment plant was designed to handle the needs of a distribution system comparable in size to that of a city of 10,000 persons. The water was typical of most of the subpermafrost water from the alluvium of the Chena, Tanana, and Yukon Valleys, and was characteristically high in hardness, iron, and manganese. Water temperature was 35°F. The most economical treatment was a breakpoint chlorination dosage followed by rapid mixing, sedimentation, and filtration.

The principal factors concerning design of a water-treatment plant in the arctic are (1) ground water from below permafrost exceeds acceptable limits for both iron and manganese; (2) ground-water temperature is only a few degrees above freezing; (3) winter temperature reaches —60°F; (4) the necessity of enclosing all treatment facilities in heated buildings; (5) heated buildings enclosing exposed water surfaces need ventilation; (6) construction is hindered by permafrost and the short season.

Thompson, S. F., 1953, Construction in permafrost: Western Construction, v. 28, no. 10, p. 63–65.

Ladd Air Force Base and Eielson Air Force Base, near Fairbanks in the interior of Alaska, are situated in the zone of sporadic permafrost. The soils area to the south is unfrozen, whereas the area to the north is almost entirely frozen. At Fairbanks are areas of both unfrozen and frozen ground. The temperature of permafrost at Ladd and Eielson was never below 31°F, and a slight change in surface conditions greatly and rapidly affects underlying frozen soil. The silt that mantles alluvium is generally 10–15 ft thick, seldom more than 20 or 30 ft. Birch Creek schist lies at a depth of 200–400 ft near these bases. Permanently frozen silt overburden is removed before construction by (1) rippers dragged by tractors, (2) blasting, or (3) thawing artificially or naturally.

In 1952 a deposit of gravel embedded in ice was noted. Although not common, such gravel deposits in which the particles are separated by ice can produce appreciable settlement upon thawing. Neither auger nor drill holes indicate the presence of this ice, and it can be detected only by inspection. This peculiar occurrence is always associated with loose, openwork gravel in the alluvial deposits.

Permafrost in silt is generally the greatest problem in construction; where not too thick, as at Ladd and Eielson, it may be excavated and backfilled with gravel, but where very thick, construction practices should seek to preserve it and utilize its strength by artificial refrigeration, insulation, or other means. Tests in some of the frozen silt at Ladd AFB showed that it averaged 90 percent shrinkage on drying.

Thorne, R. L. *See* Rutledge, F. A., 1953.

Tibbitts, G. C., 1954, Jet drilling in Fairbanks [abs.]: Alaskan Sci. Conf., 5th Anchorage 1954, Proc., p. 60

The first jet drilling experiments of their kind were made by the Geological Survey at Fairbanks in 1954. The equipment is so simple that it could be used in many areas by homesteaders to drill their own wells. It readily penetrates thawed and frozen silt and soft or weathered schistose bedrock. Glacial till (hardpan), coarse gravel, and harder bedrock are unsuitable for jet drilling.

Tikhomirov, B. A., 1948, On the geographic distribution of pingos (baidzharakh) in northern Eurasia (O geograficheskom rasprostranenii bugrov-baidzharakhov na severe Evrazii): Priroda, no. 1, p. 51–53.

Deals with the geographic range of the pingos, previously recorded from coasts of Laptev and East Siberian Seas; also found on Dikson Island, northern Yakutia, on Taymyr Peninsula.—Arctic Bibliography 32472.

Tikhonov, A. N., 1939, The thermal regime of a deep well at the Skovorodino frost station [O termicheskom rezhime glubokoi skvazhiny Skovorodinskoi merzlotnoi stantsii]: Akad. Nauk SSSR Izv., Ser. geog. i geofiz, no. 1, p. 35–52.

The thermal properties of a well 28 m deep and dug in permafrost were studied to test the heat conductivity equation. Daily temperature readings of the layer located 10–28 m below the surface were taken for 7 yr. The data of the first 2 yr agreed closely with the calculated results. The data of the next 5 yr showed that the readings were consistently above the values obtained from the heat conductivity equation. It is concluded that the latent heat of the well disrupted the thermal regime of the permafrost event though precautions were taken to maintain the deeper layers.—From SIPRE U–1573.

Tiutiunov, I. A., 1945, Ground ice and the subterranean waters of the Anadyr region [abs.] [Iskopaemye l'dy i podzemnye vody Anadryskogo raiona]: Akad. Nauk SSSR, Referaty nauch.-issled. rabot 1944 Moskova, Otdel. geol.-geog. nauk, p. 129.

The ground ice of the Anadyr region is a remnant of the continuous ice sheet of the last glacial period. The ice layer is a few meters thick and covers a large area. The ice layer is not continuous, because of erosion and new types of ice formations. Three small artesion basins were found in the area.—From SIPRE U–1442.

Tkachuk, V. G. *See* Presniakov, E. A., 1957.

Tokarev, N. S., 1936, Hydrogeological regions of the East Siberian district [Gidrogeologicheskoe raionirovanie Vostochnosibirskogo kraia]: Irkutsk, Vostochnosibirskoe Kraevoe Izd. 37. p.

The physiography and hydrogeology of the area and the effects of permafrost on ground-water distribution are described. Low temperatures and a thin snow cover over much of the province have resulted in soil freezing to depths of 7 m and permafrost in several parts of the area. A snow cover of 5–10 cm is observed in the Ekhirit-Gulagat region, where permafrost thickness ranges from 10 to 50 m. Snow cover on the steppe averages from 40 to 60 cm, and permafrost occurs as islands. Frost fissures, polygonal structures, solidly

frozen rivers, naleds (both ground and river types), and pingos are common.—From SIPRE 14329.

Tolmachev, I. P., 1903, Ground ice from the Berezovka River terraces, northeastern Siberia [Bodeneis vom Fluss Beresovka, nordöst. Sibiriens]: Zap. Imperatorskogo St. Petersburgkogo Mineralog. Obshch., ser. 2, v. 40, p. 415–452.

Tolstikhin, N. I., 1931, Mineral springs of the Transbaikal [Mineral'nye istochnik Zabaikal'ia]: Vodnye bogatstva nedr zemli na sluzhbu, Sotsialisticheskomu stroitel'stvu, Pervyi gidrogeol. s"ezd, Sbornik 5, p. 23–57.

The regime of mineral springs depends largely on climatic factors and especially on permafrost, which is observed everywhere in Transbaikal. The temperature of this water is usually near 0°C, and was frequently observed from 0.1°C to −0.6°C. This fact suggested the possibility of a circulation of water saturated by CO_2 in the permafrost layer. Gas expanding at the spring causes intense cooling. Ice formations are normal phenomena even in summer.—From SIPRE U–5039.

1932, Subterranean waters and their hydrolaccoliths of the Transbaikal [Podzemnye vody Zabaikal'ia i ikh gidrolakkolity]: Akad. Nauk SSSR, Kom. izuch. vechnoi merzloty Trudy, v. 1, p. 29–50.

The ground waters of the Transbaikal are located above, within, and under the permafrost, and may be classified according to the solid or liquid phase with more detailed subdivisions. Ground water affects the formation of ground ice and may erupt as springs, icing, and hydrolaccoliths (pingos). The hydrolaccoliths of the region were as high as 15 m and extended over areas as much as 60,000 m². There are several theories on the origin of hydrolaccoliths; according to one, they are formed by progressive downward freezing of water or semifluid mud. The Aleniu laccolith consists of a 0.6-m top layer of peat and two 0.35-m layers of ice separated by a 0.28-m layer of claylike sand. The hydrolaccolith was superimposed on a body of pressurized water.—From SIPRE U–1726.

1933, Ground water in the Quaternary formations of permafrost regions [Podzemnye vody v chetvertichnykh otlozheniiakh raionov vechnoi merzloty]: Mezhdunarodnoi kon. assotsiatsii po izuch. chetvertichnogo perioda Evropy 2d, Leningrad 1933, Trudy, v. 2.

The location and movement of ground water in permafrost regions are described and effects on construction are analyzed. Suprapermafrost ground water is characteristic of Yakutia and other parts of northern Siberia where permafrost reaches more than 150 m in thickness. Intrapermafrost and subpermafrost water is associated with a thin layer of permafrost where water penetration through thawed spaces in the permafrost is possible. Fissures in the frozen layer and Quaternary formations permit water exchange between the suprapermafrost and subpermafrost layers and thus promote permafrost degradation. The freezing of suprapermafrost water and of water which has welled up through fissures causes frost heaving and the formation of icings, frost mounds, and similar phenomena.—From SIPRE 9506.

1934, Subterranean waters in permafrost regions [Podzemnye vody v raionakh vechnoi merzloty]: Vses. gidrolog s"ezd, 1st, Leningrad 1931, Vodnye bogatstva nedr zemli na sluzhbu, Sotsialist. stroitel'stvu Sbornik, v. 4, p. 177–179.

Suprapermafrost, intrapermafrost, and subpermafrost subterrannean waters are defined and discussed. Intrapermafrost waters frequently exist under pres-

sure in multilayer lenses or in veins. Icings are a product of the regime of subterranean and surficial waters under the influence of long and severe frosts. The main classes of icings are river and subterranean water icings.—From SIPRE U-4909.

1935a, Ground water of Buriat'-Mongolian ASSR [Podzemnye vody Buriat'-Mongol'skoi ASSR], *in* Pervyi konf. izuch. proizvoditel'nykh sil Buriat'-Mongol'skoi ASSR Trudy, v. 1, Problemy Buriat'-Mongol'skoi ASSR, p. 224–250: Moscow-Leningrad, Izd. Akad. Nauk SSSR.

The physical and chemical properties of ground water in permafrost are discussed. The supply of suprapermafrost water depends largely on the temperature regime of the active layer. The asymmetry of northern and southern slopes of the Buriat'-Mongolian region is explained by the speed of thawing of suprapermafrost water. Intrapermafrost water is present in taliks and is consequently unevenly distributed. Subpermafrost water is usually under pressure, highly mineralized, contains the least O and bacteria and the most CO_2 and N. Various methods of utilizing ground water in permafrost regions are described.—From SIPRE 6607.

1935b, Mineral springs of the Buriat'-Mongolian ASSR [Arshany Buriat'-Mongol'skoi ASSR], *in* Pervyi konf. izuch. proizvoditel'nykh sil Buriat'-Mongol'skoi ASSR Trudy, v. 1, Problemy Buriat'-Mongol'skoi ASSR: Moscow-Leningrad, Izd. Akad. Nauk SSSR.

Mineral springs of the Buriat'-Mongolian ASSR as related to geologic structure, chemical composition, and permafrost are discusssed. The occurrence and temperature regime of these springs is influenced by the presence of permafrost and deep frost penetration.—From SIPRE U-6608.

1936, Hydrogeological conditions of water supply in permafrost regions [Gidrogeologicheskie usloviia vodosnabzheniia v raionakh merzloi zony litosfery; vechnoi merzloty]: Pervyi geol.-razved. konf. Glavsevmorputi, Leningrad 1935, Trudy, v. 3, Geologiia i poleznye iskopaemye severa SSSR, p. 102–127.

The water supply of permafrost areas may be of surface, suprapermafrost, intrapermafrost, or subpermafrost origin. The water may be classified according to the solid or liquid phase with further subdivisions and subgroups. The presence of water at various ground levels is determined by the geologic and geomorphologic characteristics of the terrain and by the tectonic structure. Water sources are classified as atmospheric, ground and surface ice, surface water—such as rivers and lakes—and subsurface waters.—From SIPRE U-2914.

1937a, On the classification and numeration of the natural waters [O klassifikatsii i numeratsii prirodnykh vod]: Russia, Central Sci.-Inv. Geol.-Prosp. Inst. Gen. ser., colln. 2, p. 62–68.

1937b, Numeration of natural waters: Problemy Sovetskoi geologii, v. 7, no. 8, p. 730–733.

A scheme for labeling any given water supply with a number indicative of its salt content.—Geol. Soc. America, Bibliography and Index of Geology Exclusive of North America, v. 5, 1937, p. 308, 1938.

1938a, The mineral water provinces of the USSR: Problemy Sovetskoi geologii, v. 8, no. 3, p. 240–243. [Russian.]

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Tolstkhin, N. I., 1938b, Mineral waters of the frozen zone of the lithosphere [Mineral'nye vody merzloi zony litosfery]: Akad. Nauk SSSR, Kom. vechnoi merzlote Trudy, v. 6, p. 63–78.

The extent of mineralization of subpermafrost waters was investigated for industrial development and water-supply sources. The permafrost zone of the USSR is divided into three regions. The subpermafrost water in the area east of the Lena River has a high hydrogen potential; the water in the area west of the Lena has high salinity; and the water in Zabaikal area is predominantly alkaline. The waters are highly mineralized because permafrost tends to retain them under the surface. The temperature of subpermafrost water ranges from 7° to −2.0°C. Waters with high salt content have the lower temperatures. More extensive investigation of mineralization is suggested.—From SIPRE U-1784.

1938c, Instructions for survey for water supply in the permafrost region [Instruktsiia po izyskaniiam tseliakh vodosnabzheniia v raionakh merzloi zony (vechnoi merzlote)]: Akad. Nauk SSSR, Kom. vechnoi merzlote, Sbornik instruksii i programmnykh ukazanii po izuch. merzlykh gruntov i vechnoi merzloty, p. 193–212.

Prospecting for water supply in permafrost regions is initiated by a reconnaissance or a detailed survey of existing water sources. A reconnaissance survey is a compilation of data on rivers, lakes, and springs. A hydrogeologic survey is made to determine the presence of water below the permafrost. Each of these surveys considers all aspects of water sources in relation to the demand. Such a survey lasts a year with emphasis on the period of lowest water yield. Samples of water in excess of 2 liters are tested quantitatively biannually, before the melting season and during the period of maximum runoff. Water sources are classified as atmospheric (precipitation), ground and surface ice, surface ice, surface water—such as rivers and lakes—and subsurface water. Subsurface waters may be spring, suprapermafrost, intrapermafrost, and subpermafrost waters.—From SIPRE U-1991.

1938d, Ground water [Podzemnye vody]: Akad. Nauk SSSR, Kom. vechnoi merzlote, Sbornik instruktsii i programmnykh ukasanii po izuch. merzlykh gruntov i vechnoi merzloty, p. 41–71.

Subterranean waters in a permafrost region may be investigated by reconnaissance and by special and stationary surveys. In a reconnaissance survey information is gathered on all sources of water, and the presence of water below the surface is determined by the geologic and geomorphic characteristics of the terrain and the tectonic structure. Special and stationary surveys are limited to a specific area selected by reconnaissance surveys, and the presence or absence of waters is determined by geologic and hydrogeologic investigations without resorting to drill tests. The preparatory work in all subterranean-water surveys consists in obtaining and compiling pertinent meteorological data for the area in question. Field investigations should be carried out with geomorphologic, hydrogeologic, lithologic, and geologic maps as a source of basic data, and as a means of plotting current data. Chemical properties and physical characteristics of water should be indicated. The relationship between the permafrost thickness, the depth of winter freezing, and the water balance should be ascertained.—From SIPRE U-2005.

1938e, Instructions for the study of icings [Instruktsiia po izucheniiu naledi]: Akad. Nauk SSSR, Kom. vechnoi merzlote, Sbornik instruktsii i programmnykh ukazanii po izuch. merzlykh gruntov i vechnoi merzloty, p. 73–84.

Icings or naledi are sheets of ice formed by the freezing of river water or ground water that is poured out over the surface of river ice, the ground, or formed within the active layer. The water pours out when the surface-water channel or ground water freezes. Icings are classified in 3 categories: (1) those produced by river water, (2) those produced by ground water, and (3) a combination of the two. Those formed from ground water may be classified as those originating from suprapermafrost waters and those originating from subpermafrost waters. For ground-water icings data should be collected on the origin of the water and stratification of the water-bearing layers. Study of river icings requires data on profile, volume, velocity, character of the riverbed, and hydrologic regime of the river.—From SIPRE U–1993; unpublished condensation by I. V. Poiré, 1947.

1939, A contribution to the problem of provinces of mineral waters in the USSR [K voprosu o provintsiiakh mineral'nykh vod SSSR]: Leningrad, gornyi inst. Zap., v. 12, no. 2, p. 99–113.

Author maps the zones of distribution of the main types of mineral waters in the USSR: hydrocarbonate and alkaline earth waters, in fissures of medium depth; sodium waters, in fissures of great depth; and saline, strongly mineralized waters, in shallow fissures.—Geol. Soc. America, Bibliography and Index of Geology Exclusive of North America, v. 8, 1940, p. 243, 1941.

1940, The regime of ground and surface waters in the region of permafrost distribution, chap. 9 *in* Sumgin, M. I., and others, General permafrostology (Obshchee merzlotovedenie): Moscow, Akad. Nauk SSSR, 340 p.

A general summary of the principles of occurrence of ground water in permafrost regions and a classification of the occurrences of suprapermafrost, intrapermafrost, and subpermafrost waters.

Suprapermafrost waters lie above the permafrost layer, which serves as an impermeable substratum; they occur in hollows and valleys and to a lesser degree on slopes, especially those with northern exposure, and are found mainly in Quaternary deposits. Suprapermafrost waters are divided into three types: (1) water that freezes seasonally and lies within limits of the active layer ("verkhovodka"); (2) water that freezes to about half its depth and has upper portions within the active layer; and (3) water that remains frozen throughout the year and has upper surfaces beneath the active layer. In some cases, however, all three types may be formed from the same suprapermafrost zone under differing degrees of seasonal frost penetration.

Depth of thaw and thickness of the suprapermafrost layer increase southward; the waters of this zone are fed by precipitation, surface water, and subpermafrost water locally and by thawing of buried ice. Water levels are high in summer, but generally supplies diminish in winter as freezing progresses, and during the critical water period supplies of type 1 are absent. In many instances downward seasonal freezing traps the suprapermafrost water which increases in volume on freezing; the freezing creates pressure which arches the ground to form a mound from which compressed air and water may escape. Freezing temperatures are 0° to −0.5°C, owing to slight mineralization, but in some cases supercooling takes place. Waters that occur both within and below the active layer (type 2) and those that lie beneath the active layer (type 3) occur in permeable materials in which percolation of warm water depresses the permafrost table below the active layer, occurs beneath rivers and lakes, near apexes of alluvial fans and cones, and near points of emergence of subpermafrost waters. The "river-bed-streams" beneath the Lena and Yenisei Rivers in the north probably connect with subpermafrost waters, as do the thawed zones beneath both large and small streams in the southern part of the permafrost region.

Estimates of maximum flow of suprapermafrost waters are made in the fall during the period of deepest seasonal thaw; minimum flow is measured during the critical water period in March or April. Studies of maximum and minimum flow of suprapermafrost waters require trenches down to permafrost across the direction of flow, study of naledi and other evidence of winter ground-water emergence, and pumping tests of at least 10–15 days' duration from large-diameter pits at two or more depths. Observations of water level, composition, temperature, and winter freezing are important; investigations of quality should include bacterial studies, since suprapermafrost water is easily polluted. Temporary supplies come from wells partly within or below the active layer but above permafrost. Suprapermafrost waters are commonly a detriment to engineering projects, such as construction of roads and buildings.

Intrapermafrost waters include both buried (fossil) ice and water in its liquid phase, which circulates within the limits of the layer of permafrost. Two types of fossil ice are recognized: (1) "syngenetic ice" formed simultaneously with the ice formed as naledi, lake, and river, and glacier ice that is buried in Quaternary deposits; and (2) "epigenetic ice" which includes veins and other forms of ice that were created after deposition of modern, Quaternary, and even older deposits. Melting of fossil ice is a source for nourishment of ground and surface waters, for discharge of rivers is reportedly increased as they cross areas of fossil ice. Thawing of fossil ice gives rise to numerous springs and feeds thermokarst lakes. The liquid-water phase of intrapermafrost waters is apparently stable with the solid phase, and changes take place over long periods, possibly in relation to alternating cold and warm climatic cycles. During the warming trends some of the water in dead-reserve as ice is melted and is added in its liquid form to the hydrologic cycle. The parts of the permafrost zone occupied by intrapermafrost waters serve as passageways for waters passing from the suprapermafrost to the subpermafrost zone and serve as lateral passageways for near-horizontal water movement. Intrapermafrost water may occur in especially permeable layers within perennially frozen alluvial deposits and may represent an old underriver-bed thawed zone or may be connected to the modern one. Intrapermafrost water may occur as veins or natural pipes in sandy formations or in fissured rocks. These waters may or may not be under pressure, and they may resemble in quality either suprapermafrost or subpermafrost waters, according to their source.

Subpermafrost water lies beneath permafrost, which forms a confining layer. No water occurs in the solid state, and the temperature near the permafrost layer is 0°C but is higher at depth. Subpermafrost water occurs in five types: (1) alluvial, (2) layer, (3) layer crevice, (4) crevice vein, and (5) crevice. All except the alluvial type are deep waters, and the alluvial type occurs only when the thickness of the permafrost is less than that of the alluvial deposits. Four environments of the alluvial type in the Trans-Baikal region are: case 1, asymmetrical permafrost of about the same thickness on slopes and in north-south-trending valleys; case 2, asymmetrical permafrost of trending valleys in which permafrost is thicker beneath north-facing slopes and the south margin of the valley; case 3, permafrost along margins of valleys, wedging out at the center; and case 4, when permafrost is absent or in island form in center of valley, but thick on divides and on higher terraces. Alluvial water is fed by seepage of atmospheric water through thawed zones in the alluvium, by inflow of ground water from bedrock, by inflow from rivers, and by condensation. The water in the alluvial environment is commonly under pressure in cases 1 and 2 and may be under pressure in case 3 if it is underlain by a frozen lens. Temperatures of alluvial-type waters range from 0° to 2°C, but exceed 2°C, only when alluvial waters are fed by waters from deep sources. The waters have less oxygen and fewer organic compounds and are more sterile than suprapermafrost waters; they commonly reflect the composition of bedrock, or of the river, whichever is their source.

Of the four types of deep subpermafrost waters, the layer type is obtained in various Mesozoic and Cenozoic sedimentary rocks, commonly under pressure; in areas of continuous permafrost, recharge of depleted aquifers is not always possible, but to the south in areas of discontinuous or island permafrost, recharge is generally possible. The layer-crevice type of water comes from crevices in rock layers or from pores of still older rocks (pre-Mesozoic) and is transitional between the layer and crevice types. The crevice type of water occurs in fissures, faults, and cracks in rock. Permafrost in the upper, highly fissured part of bedrock (upper 50 m) tends to restrict circulation and recharge from above ground water below permafrost. Crevice-karst waters, a special type of crevice waters, are those associated with carbonate or other easily water-soluble rocks. Contemporary karst activity has been shown to occur in permafrost regions. It is supposed that in permafrost regions the regime of karst waters fluctuates more sharply and is somewhat restricted; however, these are the largest sources of water and have large springs and naled'; no work has been done on the problem of karst in permafrost.

Suprapermafrost waters are generally located by pits and probes and wells used only for exploitation; subpermafrost waters, however, lie so deep that drilled wells must be used for exploration as well as exploitation. Wells are flushed or thawed by salt solutions, hot water, or steam.

Springs are formed where suprapermafrost waters are located above the local erosion base and where subpermafrost waters ascend to the surface. Suprapermafrost springs are either seasonal (summer-fall only) or perennial; the discharge of the suprapermafrost springs is not constant and is closely related to the freezing and thawing of the active layer and to the amount of precipitation. Some springs fed by thawing buried ice have a diurnal fluctuation with maximum discharge in afternoon. Permafrost affects springs of subpermafrost water as follows: (1) the number of springs, or number per unit area, in permafrost regions is less than in regions without permafrost; (2) distribution of springs is uneven—greater numbers occur in mountains than in plains, just as in regions without permafrost; (3) in southern regions of permafrost, asymmetrical distribution of springs depends on orientation of slopes and springs are more numerous on southern exposures than on northern; (4) a number of springs occur at the break in slopes where the frozen Quaternary diluvial deposits thin out and the older rocks are close to the surface; and (5) permafrost aggradation decreases the number and flow of springs conversely, degradation of permafrost increases the number and flow.

Constant springs have stable temperature, discharge, composition, and point of emergence; are commonly located at points where Quaternary deposits are thin; and are fed by subpermafrost waters in layers and crevices. Springs with fluctuating discharge occur in places where the outlet of water from bedrock is covered by a well-filtrating layer of Quaternary deposits; in summer the water flows above the permafrost into the Quaternary deposits and emerges as many small springs, but in winter, under the influence of seasonal frost, the flow is concentrated in a single large spring. Seasonal springs do not flow during part of the year—freezing springs discharge in winter and thawing springs discharge only in summer. Changing springs have one outlet for winter and another for summer. Periodically disappearing springs discharge, then disappear for a period of years before reappearing. Subaquatic springs occur beneath lakes and rivers and may be detected in winter by polyn'ia, by unfrozen places in the ice, or by naled'.

The regime of a spring depends not only on the resources of the aquifer, but on freezing and thawing of passageways leading to the surface. Thus, seasonal frost and permafrost studies, as well as studies of the aquifer, are required. In some cases diminution or cessation of spring discharge does not mean drying of the source, as in nonpermafrost regions, but may mean that the outlets have become frozen. Composition of the spring waters also varies, especially of those fed by suprapermafrost water, or of those fed simultaneously by suprapermafrost and subpermafrost waters. Spring outlets are funnel shaped and are bordered by a funnel-shaped zone of thawed ground. Spring outlets are commonly on mounds on which frost mounds and marshes may occur.

Rivers in the permafrost zone occupy the same position in the hydrologic cycle as elsewhere, but their module of outflow (discharge) in liters per second per sq km is 2–3 times that of rivers outside the permafrost region. One reason for the excess discharge from permafrost regions is the lower moisture loss to evaporation. Permafrost acting as a cold screen functions as a moisture condenser, at its upper boundary in summer and part of the winter, at its lower surface throughout the year; the amount of condensation in the suprapermafrost layer may amount to more than 60 to 100 mm per yr. The third reason for the higher discharge per unit area, especially the higher ground-water discharge, in the permafrost region is apparently the process of permafrost degradation which releases water stored in fossil ice. The discharge in the 3–4 months of summer and spring ranges from 74.7 to 89.7 percent of that of the entire year; the winter discharge is only 10–25 percent. Discharge due to rivers fed in winter by underground waters amounts to only 4–10.5 percent of the yearly amount.

Polyn'yas, areas of river channel that remain unfrozen, are commonly an indicator of ascending ground water. Naled' (icing) is another phenomenon common on rivers in winter. Both are found beyond the limits of the permafrost region. In winter rapid freezing of the river in shallows forms ice which is interbedded with air, and a thick accumulation of ice forms over much of the river. The river water in deeper reaches beneath the ice cover is cut off from circulation and becomes stagnant.

The relationship of river water to ground water in permafrost regions is expressed in (1) feeding of river water by suprapermafrost and subpermafrost waters, which predetermines the winter regime of sections of the river; (2) feeding of ground water by the river temporarily and at certain seasons; (3) connection between "under-the-bed" ground water and river water; (4) permafrost aggradation increasing accumulation of ice in the ground, and decreasing module of discharge; and (5) permafrost degradation liberating water from ice in the ground and increasing module of discharge.

Lakes are of many types, chief among which are the "proval'noe" (sunken) lakes formed by thawing of ground ice and ice-bearing formations. Lakes shallower than 2 m commonly freeze to the bottom and some have frozen beds; the deeper lakes have thawed zones beneath them. However, mineral lakes even in summer may have temperatures below 0°C, and conditions may be suitable at these temperatures for preservation of underlying permafrost. Lakes fed by ground waters are more numerous and better sources of water than those lakes from which water filters into the ground. A number of "buried or fossil" lakes are reported, which consist of buried ice in depressions.

Naled' is the result of the complex physical mechanical processes in which water migrates, ground or water freezes, forms mounds, cracks, water emerges, and freezes. It is, according to Tolstikhin and others, "the body of ice which is either a product of freezing of the natural surface or ground waters which emerge on the surface of ice, snow, or ground, or within limits of the active layer." Naledi of several types are recognized: (1) those formed by river water; (2) those formed by underground water; and (3) those formed by a combination of river and ground water. Most naledi are seasonal; only a few last more than a year. Naledi are systematically classified as to size, and their thickness is generally 1–4 m.

The naled' cycle starts in infancy when the area is small and the ice thin, progresses to a stage of rapid growth in areal extent and thickness at which the mounds are beginning to develop, and next, to the mature stage at which it is at full areal growth though it continues to thicken. At this time the mounds begin to split, and some rupture explosively. Thawing of the naledi in the spring accompanies cessation of growth and collapse of the mounds. The theory of naled' formation first detailed by Pod'iakonov (1903) is with advent of freezing weather the river and its "under-the-bed" stream begin to freeze from the surface downward. The cross section of the river narrows so much that it cannot accommodate the entire flow of water. As a result, pressure is created and causes a part of the river water to penetrate alluvial deposits of the valley. In conjunction, both surface and ground waters in the alluvial deposits rise. In weak places in the river valley the riverbed water breaks through to the surface or through the river ice to form river naled'. This outflow continues as long as further freezing of riverbed and "under-the-bed" stream takes place. When the river is frozen to the bottom, the "under-the-bed" stream continues and while it freezes, water continues to emerge. Only when the "under-the-riverbed" stream has frozen will growth of naled' stop.

Permafrost plays only a passive role in formation of naledi by serving as a watertight base to which seasonal frost penetrates. Naled' of ground waters is of two types: that formed by ground waters, and that formed by springs.

Hydrolaccoliths or bulgunniakh are mounds of many years' duration, 10–30 m high, and 80 m or more in diameter. Smaller seasonal mounds (underground naledi) are formed within the active layer and these disappear each season. The large hydrolaccoliths commonly have cracks on their summit and slopes; on many the summit is occupied by a pond. Hydrolaccoliths are generally formed by either the ascending subpermafrost water or the supramafrost or intrapermafrost waters circulating in horizontal layers or belts.

1941, Ground water of the frozen zone of the lithosphere [Podzemnye vody merzloi zony litosfery]: Moscow-Leningrad, Gosgeolizdat, 201 p.

In this book-length treatise on the relationship of ground water to permafrost in the USSR, waters are divided into suprapermafrost, intrapermafrost, and subpermafrost waters. They may be classified also according to the solid or liquid phase with further subdivisions and subgroups. Ground waters affect formation of ground ice and may emerge at the earth's surface in the form of springs, icings, and hydrolaccoliths.—From SIPRE U–757.

Tolstkhin, N. I., 1947a, Relief and the distribution of ground water [Rel'ef i raspredelenie podzemnykh vod]: Vses. geog. obshch Izv., v. 79, p. 515–522.

The effects of relief and the physical properties on the distribution of ground water are analyzed. The geographical and vertical distribution of ground water in Siberia depends on permafrost, and the seven hydrogeological zones currently recognized are based on permafrost distribution. Permafrost from 100 m to 600 m thick is found in the Yakutian and Khatanga hydrogeological basins. Permafrost in the Tunguska basin is about 500 m thick in the north and has many thawed spaces in the south. Thawed spaces characterize the permafrost in the upper Lena basin, where it averages about 100 m in thickness. Islands of permafrost are observed in the Kansk and Irkutsk basins. Permafrost in the north of western Siberia reaches 400 m in thickness, but the south is permafrost-free.—From SIPRE 8875.

1947b, The artesian waters of the frozen part of the earth in the territory of the USSR [Artezianskie vody merzloi geozony v predelakh SSSR]: Akad. Nauk SSSR, Merzlotovedenie, v. 2, no. 1, p. 31–35.

A distinction is made between the open and closed types of artesian basins. The open-type basin is referred to as "oceanic"; the closed basins are considered as "lakes." The lake-type artesian basin contains fresh water; the open-type basins contain salt water with superimposed films of fresh water of varying thicknesses. Fresh water is not found in the open-type basin when the depth of permafrost is considerable or when there is little or no circulation of water in the basin. In Yakutsk, however, fresh water was found at a depth of 450 m. In addition, the report describes occurrence of these basins in and outside of the permafrost region, and presents observations on the character of permafrost as a factor in determining the hydrogeological conditions of artesian water.—From Arctic Bibliography 17865, SIPRE U–818.

1956a, Basic principles for a classification of ground water in the frozen zone of the lithosphere [Osnovnye printsipy klassifikatsii i raionirovaniia podzemnykh vod zony litosfery], *in* Tezisy i plany dokladov * * * k soveshchaniiu 1956 po merzlotovedeniia: Akad. Nauk SSSR, Inst. Merzlotovedeniia, no. 2.

A hydrogeological classification of ground water in permafrost regions is discussed. Water is classified according to vertical distribution (surface water, ground water, and a zone of hot vapor); geologically (water of sedimentary strata and volcanic formations, that of solid crystalline, metamorphic rock); and according to the space in which it is contained (pore and fissure water). The types of water found in permafrost regions include surface water of the active layer; suprapermafrost, intrapermafrost, and subpermafrost ground water; artesian water of sedimentary layers between or below permafrost layers; fissure and vein water in frozen extrusive and metamorphic rock; and thermokarst water. The characteristics of ground water outside the frozen regions, in areas of island permafrost, in regions with an extended or a limited active layer, and in regions having both permafrost and unfrozen areas are outlined.—From SIPRE 17044.

1956b, Hydrochemical zones of the artesian basins [Gidrokhimicheskaia zonalnost artezianskikh basseinov v poriadke obsuzhdeniia]: Leningrad. Gornyi inst. Zap., v. 32, no. 2, p. 3–9.

Author distinguishes three hydrochemical zones in the artesian basins of the USSR—an upper zone whose waters are generally fresh and usually contain hydrocarbonates; a central zone, with moderately mineralized waters; and a lower saline zone. The interrelationship between hydrochemical and artesian zones depends on the geologic structure and the hydrogeologic history of the artesian basins.—Geol. Soc. America, Bibliography and Index of Geology Exclusive of North America, v. 21, 1956, p. 600, 1958.

Tolstikhin, N. I., Dzens-Litovskii, A. I., and **Skrobov, A. A.,** 1938, The hydrogeologic provinces of the natural mineral waters of the USSR: Russian Geol. Soc. Izv., v. 70, no. 6, p. 673–687.

Tolstikhin, N. I., and **Ernshtedt, A. V.,** 1938, Mineral springs of the Yakut ASSR [Ob IAkustskikh mineral'nykh istochnikakh]: Razvedka Nedr, no. 7, p. 30–31.

Of the 32 known mineral springs of Yakutia, only three have had their geographical coordinates determined and seven have analyses made of their waters.—Arctic Bibliography 32508.

Tolstikhin, N. I., Ernshtedt, A. V., and **Popov, A. I.,** 1937, Mineral springs of the granite massifs of the USSR [Mineral'nye istochniki granitnykh massivov SSSR]: Russia, Central Sci.-Inv. Geol.-Prosp. Inst., Pogrebov Jubilee volume, p. 82–93.

Tolstikhin, N. I., and **Leiboshits, N. A.,** 1955, The work of V. A. Obruchev on the studies of mineral waters of USSR [Trudy V. A. Obrucheva v oblasti izucheniia mineralnykh vod SSSR]: Akad. Nauk SSSR, Voprosy geologii Azii, v. 2, p. 629–632.

A map of the mineral waters in the USSR has been compiled, largely from data collected by V. A. Obruchev.—From Geol. Soc. America, Bibliography and Index of Geology Exclusive of North America, v. 21, 1956, p. 600, 1958.

Tolstikhin, N. I., and **Obidin, N. I.,** 1936, Icings of the eastern Transbaikal [Naledi Vostochnogo Zabaikal'ia]: Gos. geog. obshch. Izv., v. 68, no. 6, p. 844–877.

Icing mounds are formed by the freezing of successive layers of water seeping from underground sources. The geographical location of ground water sources, its direction of flow, and its relation to the surface affects the formation of ground ice and the eruption of springs, icings, and hydrolaccoliths. The icings are usually annual in character, forming in the winter and melting during the spring and summer. Icings occur rarely in southern Transbaikal but increase toward the north.—From SIPRE U–3062.

1937, Icings of eastern Transbaikal (Naledi Vostochnogo Zabaikalia): Vses. geog. obshch. Izv., v. 66, no. 6.

Tolstikhin, N. I., and **Osipova, E. E.,** 1934, Hydrogeology of eastern Siberia [Gidrogeologiia Vostochnoi Sibiri]: Vses. gidrogeol. s"ezd, 1st, Leningrad 1931, Sbornik 4.

The hydrogeologic classification of the area and brief descriptions of particular regions are presented. All of Eastern Siberia with the exception of the western part is located in zones of permafrost or deep winter soil freezing. The scarcity and low temperature (below 1°C) of ground water in the regions of thick permafrost is noted. Underground waters of the neighboring regions have higher temperatures. The thick permafrost (probably more than 100 m) of the north results in large deposits of fossil ice. The eastern and southern parts of the Far East Province are permafrost-free.—From SIPRE 8640.

Tolstikhin, N. I., and Tambovtseva, O. S., 1938, Mineral springs of the Far Eastern District [Mineral'nye istochniki Dal'nevostochnyi Krai]: Razvedka Nedr, nos. 8–9, p. 30–34.

Includes some data on mineral springs of the Chukotsk (5) and Kamchatka (26) Peninsulas. Names of springs and analyses of their waters are given.—Arctic Bibliography 32507.

Tolstikhin, N. I. *See also* Dzens-Litovskii, A. I., 1936a, b, 1937, 1948; Kamenskii, G. N., 1959; Maksimov, V. M., 1940; Mikhailova, M. P., 1946; Loparev, N. G., 1939; Obruchev, S. V., 1941; Ponomarev, V. M., 1959.

Tolstikhin, O. N., 1957, Basic problems of the formations of ground water in southeastern Kamchatka and the Kuril Islands [Osnovnye voprosy formirovaniia podzemnykh vod iugo-vostochnoi Kamchatka i Kuril'skikh ostrovov]: Leningrad, Avtoreferat dissert.

Tolstikhina, M. M. *See* Kamenskii, G. N., 1959.

Trainer, F. W., 1953a, Preliminary report on the geology and ground-water resources of the Matanuska Valley agricultural area, Alaska: U.S. Geol. Survey Circ. 268, 43 p.

Perennially frozen ground was found in bogs 2½ miles southeast of Wasilla and 2¼ and 2¾ miles west of the experiment station; it was reported also from a bog three-quarters of a mile south of Palmer. These thin bodies of permafrost are of postglacial age and probably postdate the loess that overlies the glacial deposits. There is no evidence to suggest that post glacial permafrost has been of widespread extent.

1953b, Water supply at six localities on the Alaska Railroad: U.S. Geol. Survey open-file report, 15 p.

Near Dunbar, permafrost occurs in the valley of Goldstream Creek and some distance up adjacent hillsides. Thickness of permafrost is not known, but a shaft dug near Standard, 7 miles east-northeast, penetrated 180 ft of frozen gravel before entering frozen rock. The present source of water at Dunbar is a spring modified by a well that is 13.25 ft deep. Static water level is about 5 ft below the top of the well cover, or 9 ft above the level of Goldstream Creek; this level is maintained throughout the year. The well was pumped at a rate of 93 gpm with a drawdown of 5 ft for 40 minutes, and 45 minutes after pumping the water level was within 7 in. of static level. The water, at 35°F, probably comes from fissures in bedrock.

Mount McKinley Park Hotel is situated on a gravel terrace which is bordered on the west and northwest by mountain slopes. Permafrost occurs in valleys near the park and on some of the mountain slopes. Present supplies of water are provided by an impounded stream. Reports of a well drilled about 200 ft without reaching water are not confirmed; other reports say that permafrost was encountered. If the present supply system is retained, it would be well to add steam to the pipeline leading from the reservoir to the hotel to keep the enclosing ground from freezing.

Tregubov, V. V. *See* Stepanenko, E. V., 1915.

Troll, Carl, 1944, Structure soils, solifluction, and frost climate of the earth [Strukturboden, Solifluktion und Frostklimate der Erde]: Geol. Rundschau, v. 34, p. 545–694.

TSytovich, N. A., 1957, The fundamentals of frozen ground mechanics (new investigations): Internat. Conf. Soil Mechanics and Found. Eng., 4th, London 1957, Proc., v. 1, p. 116–119.

At a given negative temperature every soil is characterized by a definite content of unfrozen water. The quantity of unfrozen water in frozen soils is not constant, but changes with the variations of external influences and remains in dynamic balance with these influences. Part of the water in frozen soils remains unfrozen because of its interaction with the active surface of mineral particles. Frozen soils increase their strength with decrease in temperature because mobility of the hydrogen atoms in the ice lattice decreases. The elasticity modulus of the frozen soils decreases with increase in external pressure.

Migration of water in finely dispersed freezing and frozen soils is a direct function of the gradients of temperature and water content. The film-crystallization mechanism of moisture movement plays the main role in migration of water to the freezing front, the latter depending on the relation between the velocity of freezing and the velocity of water movement. It is thus possible to determine the limiting value of permeability at which migration of water to the freezing front is replaced by squeezing of the water from the freezing layer. The squeezing of water takes place only in sands having a permeability of 0.1 m per day. Migration of water accompanied by its freezing produces heaving of soils, the total volume of which consists of the volume increase on freezing plus the volume increase of water sucked up in the process.

The three types of frozen soil structure are (1) "massive," formed as a result of quick freezing; (2) "cellular," formed during intermediate freezing and (3) "laminated," formed during slow freezing and upward migration of water from deeper layers of soil. The more ice inclusions are present in the frozen soil, the greater is its instantaneous and the smaller its continuous shearing strength. An increase in the ice content has the same effect. The strength of a frozen soil is a function of both its composition and its temperature and, on account of the relaxation of stresses, strength also depends on the interval of time during which the load is applied. For example, the instantaneous strength of a frozen sand at —1°C is 62 kg per cm^2, but continuous application of load decreases the strength to 9 kg per cm^2. Such a decrease in strength may be caused by (1) viscous flow of films of unfrozen water, which is particularly intense in the interval of considerable phase alterations, and (2) plastic properties of ice, which depend on the mobility of hydrogen atoms in its lattice and are represented in recrystallization of ice inclusions—therefore, the limit of the continuous strength of ice approaches zero. An external load produces great pressures at the contacts between hard particles, causing partial thawing of ice in interstices and squeezing out of the film water into lower stressed zones.

Thawing of frozen clays and silty clays is accompanied by a considerable settling, which is approximately equal to the thickness of ice inclusions. An alteration of the structural bonds takes place in both thawing soils and soils which undergo freezing and thawing cycles. The strength of thawed soils depends on their structure in the frozen state, decreasing, generally, in the cellular and laminated ice structures by several times compared to the strength of unfrozen soils that have never been frozen. Soils with massive ice structures showed on thawing an increase of textural bonds.

TSytovich, N. A., 1958, Unfrozen water in frozen soil: Internat. Conf. Soil Mechanics and Found. Eng., 4th, London 1957, Proc., v. 3, p. 92–93.

Experiments in the USSR showing that there is always a certain amount of unfrozen water, depending on temperature and pressure, in frozen soil, are discussed. The lack of freezing is due to electromolecular attraction between mineral particles and water molecules which increases as the layer of pore water decreases; ionic attraction of water molecules in the diffusion layer, which occurs only at low temperatures up to —0.5°C; and capillary effects at temperatures near the freezing point. When the equilibrium between unfrozen soil water and external factors is disturbed, excess pressures develop which cause water movement. One cause of this excess pressure is the temperature gradient governing the movement of unfrozen water to the freezing line, where the films of water become thinner and have a greater force of attraction. If the gradient (temperature, pressure, or electroosmosis) is less than the initial gradient, there is no water movement. The velocity of the water movement is very small, the coefficient of water penetration or filtration being of the order of 10^{-2} cm per sec.—From SIPRE 16690.

TSytovich, N. A., and Sumgin, M. I., 1937, Principles of mechanics of frozen ground [Osnovaniia mekhaniki merzlykh gruntov]: Moscow-Leningrad, Akad. Nauk SSSR, 423 p.

Among the important properties of frozen ground are its moisture content, porosity, permeability, and capillarity. Few experimental data are available on these properties. Even when the ice content of frozen ground is considered as a mineral constituent, the porosity may range from 0.01 to 0.15. For all practical purposes permafrost is regarded as impermeable to water. Movement of water within permafrost takes place along unfrozen passages, with rare exceptions in the cases of mineralized waters with temperatures below 0°C. Capillary phenomena in permafrost are probably absent. Development of ideas concerning the processes of evaporation and condensation in permafrost require further study and experimentation.

Formerly, scientists doubted that liquid ground water could exist in the presence of permafrost, but numerous observations and theoretical discussions show that such water does exist, though in smaller amounts than in nonpermafrost areas. The ground water is classified into suprapermafrost, intrapermafrost, and subpermafrost waters, following Tolstikhin, and each type is illustrated. A classification of ice contained in permafrost includes buried glacial ice, snow, icings, frozen lakes, river ice, and sea ice, and ice formed in the ground itself, chiefly ice formed in underground icings (icing mounds), ice formed by freezing of suprapermafrost water or intrapermafrost water, ice interlayers formed during ground freezing, and ice formed from water vapor. Ground-water icings are widespread in the permafrost area, but are less common in the extreme north where ground water is generally below thick permafrost or is absent. A typical ground-water icing has one or several round or elongated mounds 3–4 m high and 30–50 m in diameter at the base. Cracks radiate from the summit, and water is emitted through the cracks. The section through the mound, from the surface downward, consists of ice as much as 2 m thick, soil layers, and an ice core. The surface ice extends beyond the base of the mound to form an icing.

Tuck, Ralph, 1940, Origin of the muck-silt deposits at Fairbanks, Alaska: Geol. Soc. America Bull., v. 51, p. 1295–1310.

Permanent frost in the creek gravel commonly extends to bedrock, as much as 200 ft deep. The muck that overlies creek gravel is frozen. The muck includes ice in pore spaces, sills a few inches to 10 ft thick, and ice dikes formed as tension fractures that became filled with either ground or surface water, which subsequently froze. The frozen subsoil serves as an impervious layer, so that much of the ground water is under considerable head. Among the topographic irregularities of the large creek valleys are irregular depressions caused by subsurface thawing of frozen ground by circulating ground water and consequent subsidence of the surface. Elliptical and circular depressions are surrounded by a muck ridge 5–20 ft high, which is broken at one end; the depressions probably have been caused by hydrostatic pressure doming up the frozen layer, which collapsed on release of pressure, leaving a ridge around the depression that was breached at one end by outflowing water.

Unfrozen silt as much as 300 ft thick mantles lower hillslopes and hilltops. The gravel and bedrock that underlie the silt also are unfrozen. The conformity of the area of perpetually frozen ground with the unglaciated area may be more than concidence; in the glaciated area the ground was insulated by its mantle of ice, but elsewhere, in the absence of insulating ice, the alluvium and bedrock were frozen to depths of a few feet to 300 ft.

Tumel', V. F., 1939, The sixth All-Union Conference on Permafrostology [VI Vsesoiuznaia konferentsiia po merzlotovedeniiu] : Akad. Nauk SSSR Vestnik, v. 9, p. 65–70.

In a summary of progress in the field of permafrostology in 3 yr between 1936 and 1939, the author enumerates the current investigations, including Koloskov's report on temperature conditions of the vertical movement of water in the vapor state under permafrost conditions, Tumel' on classification of talik formed as a result of interaction of water-bearing and permafrost layers, and Efimov on filtration of mineral water in permafrost at Arderma.—From abstract by E. A. Golomshtok.

1945, Permafrost researches of the Academy of Sciences [Merzlotovedenie i raboty Akademii Nauk po vechnoi merzlote], *in* Obruchev, V. A., ed., Ocherki po istorii Akademiia nauk, Geologo-geograficheskie nauki : Moscow, Akad. Nauk SSSR Izd., p. 96–103.

The development of permafrost study in Russia associated chiefly with researches of the Academy of Sciences is outlined, including the principal problems and names of associated scientists. The first information on permafrost in Russia was obtained from Yakutsk in 1640–43. The first expedition in Siberia for permafrost study was made under the direction of A. F. Middendorf in the mid-19th century. The construction of the Trans-Siberian Railroad and the general economic expansion into Siberia resulted in a systematic study of permafrost after 1873. The establishment of the Permafrostological Commission in 1930, its reorganization into a Committee in 1936, and into the Institute of Permafrostology in 1939, characterize a new period of Academy activity in permafrost investigations.—From SIPRE 14197.

1946a, A map of permafrost distribution in the USSR [Karta rasprostraneniia vechnoi merzloty v SSSR] : Merzlotovedenie, v. 1, p. 5–11.

The principles and data used to compile a new map of permafrost distribution are outlined, and characteristics of 12 regions distinguished on the map are presented. About 2,000 cross sections were used to determine boundaries between these areas. The map, completed in 1945, shows areas of island permafrost and also regions where thickness of the strata reaches 35, 60, 120, 250, 500, and 500 m. The northern limits of permafrost temperatures not lower than –10°, –5°, –3°, and –1°C at a depth of 10 m are also plotted.—From SIPRE 15880.

Tumel', V. F., 1946b, A contribution to the history of permafrost in the USSR [K istorii vechnoi merzloty v SSSR]: Akad. Nauk SSSR Inst. geografii Trudy, v. 37, p. 124–131.

In the Quaternary period, permafrost covered, either completely or in islands, nearly all the present-day Soviet territory with the exception of a narrow segment between the Black Sea and the Asiatic mountains. Permafrost existed only a short time in Europe and Western Siberia and has not increased in area during the last 2,000–3,000 yr. The degradation of permafrost in southern Siberia coincided with this period. Man has contributed extensively to the acceleration of degradation in recent centuries. The history of permafrost is of interest, but it is also important in predicting the occurrence of water-bearing strata and natural gases and oil fields.—From SIPRE U–1183.

1946c, Some geographical results of Soviet permafrostology [Nekotorye geograficheskie itogi sovetskogo merzlotovedeniia]: Akad. Nauk SSSR Izv., Ser. geog. i geofiz., v. 10, no. 2, p. 205–212.

The intensive development of the economy of permafrost regions in the northeastern half of the USSR in the last 15 yr has made necessary frozen-ground studies of a geographical nature. Greater accuracy was achieved in delimiting the areal boundaries of permafrost, and additional data on its depth were obtained, particularly in the north where it extends 300–500 m; the depth at Nordvik was recorded to be as much as 600 m. Hydrogeological investigations showed that not even a 200-m layer of permafrost can stop formation of springs by ground water emerging from beneath the permafrost. During the winter these springs form icings, the volume of which reaches tens and hundreds of millions of cubic meters in the Indigirka basin. In addition to the icings, large areas of buried ice were studied and found to belong to the glacial age. The permafrost is being degraded at a number of places, as first suggested by Sumgin.

The concept of the active layer and its dynamics during freezing and thawing have been worked out in addition to study of the relationships of the active layer to eternal frost. Heat exchange at the earth's surface and in the active layer is reflected by the character of the permafrost, and thus regional investigations of permafrost provide material for study of the characteristics of the heat balance of these regions. Sumgin introduced the division of permafrost areas into three zones according to temperatures at 10–15 m: the northern zone, below −5°C; the middle zone, −5° to −1.5°C; and the southern zone, warmer than −1.5°C.—From author's English summary, p. 212; abstract by E. A. Golomshtok.

1947, Permafrost conditions in Manchuria [abs.] [Merzlotnye usloviia v Man'chzhurii]: Akad. Nauk SSSR, Referaty nauch.-issled. rabot 1945 Moskva, Otdel. geol.-geog. nauk, p. 169.

Limited and inadequate data were used in preparing a 1:2,500,000 scale chart showing the permafrost distribution throughout Manchuria. Supplementary material on winter freezing and summer thawing of soils, and maximum thicknesses of permafrost layers is appended.—From SIPRE U–1549.

Tumel', V. F. *See also* Dementiev, A. I., 1946; Sumgin, M. I., and others, 1940.

Tyrrell, J. B., 1903, A peculiar artesian well in the Klondike: Eng. Mining Jour., v. 75, p. 188.

Eldorado Creek is a 7-mile-long tributary of Bonanza Creek which joins the Klondike River a mile above its confluence with the Yukon. In the bottom of the

valley of Eldorado Creek, at an elevation of about 550 ft above the Yukon, two miners sank a shaft 221 ft deep. When visited by the author, the shaft was 205 ft deep, timbered to 199 ft, but exposed at its bottom a frozen breccia consisting of irregular fragments of mica schist in fine material. At 205 ft the surface frozen layer had not yet been penetrated. Digging continued after the author's visit, and on November 23, at a depth of 221 ft, water began to rise rapidly to the surface. The discharge from the shaft was 100 miner's inches, or 1,000 imperial gallons per minute, of clear potable water and showed no sign of decrease.

The frozen superficial layer forms a cover through which water normally cannot flow, and this layer covers the valley slopes and bottoms as well as hill summits. In the valley bottoms the water is prevented from escaping upward; so it is retained under a pressure varying according to the head and resistance of underlying rock. Any large fissure, if open at all, and especially if at a low level as in Eldorado Valley, would serve as a main channel of flowage into which the water would seep from all surrounding rocks.

1904, Crystosphenes or buried sheets of ice in the tundra of northern America: Jour. Geology, v. 12, p. 232–236.

A theory of origin for the sheets or layers of clear ice that occur in alluvial deposits or in sphagnum swamps of the Arctic is based on observations in the Klondike district, Yukon. The surface deposits and bedrock are nearly every where permanently frozen to 40 or 50 ft on the higher uncovered parts of the hills and to 200 ft in the moss-covered valley bottoms. Locally are unfrozen channels through which springs issue from hillsides, carrying water from the deeper, saturated and unfrozen ground through the frozen layer to the surface. Most springs issue from the rock above the level of the alluvial deposits in the valley bottoms, but some have been exposed in mine workings below the surface levels. They all discharge some water throughout the year, without appreciable effect imposed by weather conditions. In summer most springs discharge into brooks, but in winter the water freezes to form masses of ice (or "glaciers") many feet thick near the spring. In addition to these surface masses of ice, others form beneath the surface in positions protected from summer thaw; these may increase in size each year. The underground ice masses formed in this manner also are called "glaciers" locally, but the name "crystosphene" (from the Greek for ice wedge) is proposed for the masses or sheets of ice developed by a wedging growth between beds of other material. The name "crystocrene" (from the Greek for fountain) is suggested for the surface masses of ice formed each winter by overflow of springs.

Crystosphenes are formed by springs which issue from the rock under alluvial deposits; they are generally horizontal sheets of clear ice 6 in to 3 ft thick, or more, lying between layers of muck. Most are 2–4 ft below the surface. One near Daly Lake (west of Hudson Bay) occupied about a square mile; those in the Klondike were 100–1,000 ft long and 50–200 ft wide. The ice sheets are generally of even and regular thickness, and they closely approximate the slope of the surface under which they lie. The city of Dawson is built on an alluvial bottom land sloping from the base of a steep hill to the riverbank and is underlain by a crystosphene of about the same slope.

Crystosphenes are also, locally, veins or dikes of ice that rise through the rock into overlying gravel. Two such veins were seen in the underground workings of claim 39 below Discovery on Hunker Creek; they represent the former course of a spring that has changed its point of discharge. Vertical masses of ice in the gravels indicate positions of former water channels from the rock toward the surface.

In some places where there are no springs apparent at the base of hills, yet where gravel has been removed and rock exposed, springs have been found.

The process of forming underground sheets of ice is as follows: Water issuing from the rock beneath a layer of alluvium rises through the alluvium and in summer spreads out on the surface, tending to keep it wet. In winter, if the flow is large and the surface consists of incoherent gravel, the water rises to form a mound of ice at the surface. If the flow is not large and the ground is covered with coherent vegetable material, the spring water, already at 32°F, rises until it comes under the influence of cold air temperatures and freezes; the process continues with the ice forming downward as the cold of winter increases, until a few feet below the surface a plane of weakness in the frozen vegetable or alluvial deposit is reached. Then, with outlet to the surface blocked, the water is forced along the plane of weakness where it freezes and thus begins the horizontal extension of the sheet of ice. The thickness of the ice sheet is increased by additions from beneath until its bottom surface is beyond the reach of low air temperatures, after which it continues to increase in extent but not in thickness. In summer, growth ceases, but the cold spring water has little power to melt the ice, and its cover of moss and muck is excellent insulation. Thus, the crystosphene is preserved for still more growth the following winter.

Tyrrell, J. B., 1917, Frozen muck in the Klondike District, Yukon Territory, Canada: Royal Soc. Canada Trans., ser. 3, v. 2, sec. 4, p. 39–46.

Muck, an organic silty material, forms a frozen overburden that covers the gold-bearing gravel of the Klondike District. The moisture content of muck is about 44 percent. The deposit contains layers of clear ice which have been formed by spring water rising from beneath and freezing before it reached the surface. In one instance the water derived from this ice was found to be very hard from the presence of salts of lime. The formation of muck began after the freezing of rock and gravel prevented good drainage and cut off the supply of ordinary alluvial materials; the muck started forming during a period of great cold in early glacial times and continued to the present.

Urvantsev, N. N., 1934, Permafrost [Vechnaia merzlota]: *in* Klimat i usloviia raboty v riaone Noril'skogo kamenno-ugol'nogo i polimetallicheskogo mestorozhdeniia: Poliarnoi Kom. Trudy, no. 14, p. 41–47.

Continuous permafrost in the Noril'sk region extends over 60 m in depth at an average temperature of about —6°C at the 5-m level. Summer thawing reaches a maximum of 0.8–1.0 m in August. Frost mounds, icings, and hydrolaccoliths are found throughout the area.—From SIPRE U–3842.

U.S. Air Force, Arctic, Desert, Tropic Information Center, 1955, Glossary of Arctic and Subarctic terms: Arctic, Desert, Tropic Inf. Center Pub. A–105, 90 p.

U.S. Army, Corps of Engineers, Arctic Construction and Frost Effects Laboratory, 1954, Ground-water studies, Fairbanks Research area: U.S. Army, Corps of Engineers.

The fluctuations in ground-water level during the freezing of the active zone above permafrost are investigated and utilized to explain the phenomena of ice segregation and frost heave.—Am. Geophys. Union Annotated Bibliography on Hydrology and Sedimentation, 1955.

U.S. Army, Corps of Engineers, St. Paul District, 1956, Engineering problems and construction in permafrost regions *in* The Dynamic North: Tech. Asst. to Chief of Naval Operations for Polar Projects (Op–03A3) Rept., U.S. Navy, Book 2, 3 tables, 53 p.

A review article describing the occurrence of ground water in permafrost regions, developing ground water by wells and collection galleries, treatment methods, and precautions needed to prevent freezing of wells in permafrost. Includes discussion of methods of water treatment and sewage disposal. The origin of icings and their effect on structures and highways are explained.

U.S. Army, Corps of Engineers and Canadian Army Engineers, 1949, Digest of current information on permafrost: Pamph. reproduced by U.S. Air Force, Alaskan Air Command, Deputy for Installations, 57 p.

In the permafrost region which abounds in surface water in summer in innumerable lakes, swamps, and rivers, the problem of adequate water supply is a difficult one. In winter many of the surface-water sources are deeply frozen, and springs and shallow wells may freeze or dry up. Deep wells, therefore, are the most dependable sources of supply. Drilling wells presents many mechanical difficulties, and because of the great depth of permafrost in some areas, deep wells are not always practicable, especially in coastal areas where the water is not always palatable. Distribution lines must not be allowed to freeze yet must not be allowed to transfer heat to the ground and disturb the thermal regime, which would create unstable foundation conditions.

Under certain conditions, ground water, trapped under hydrostatic pressure between the seasonal frost and permafrost may escape to the surface through the thawed zone beneath heated buildings and may form icings in or around the building. Air circulation beneath heated buildings permits freezing beneath the building and prevents escape of the water. Elsewhere, icings are formed where ground water is present in the active layer, when low temperature of the air with a thin snow cover occurs during early winter, where the permafrost table is near the ground surface, and when a thick snow cover exists during the latter part of winter.

U.S. Navy, Civil Engineering Corps, 1948, Cold-weather engineering, chaps. 1 to 5 *of* Bur. Yards and Docks, NAVDOCKS P–17: 109 p.

U.S. Senate, Select Committee on National Water Resources, 1960, Water resources activities in the United States; Water resources of Alaska: 86th Cong., 2d sess., Senate Select Comm. Natl. Water Resources Print 19, 21 p.

Permafrost in Alaska is the product of both present climate and cold climates that prevailed intermittently during the last 100,000 yr.

"The transition from the permafrost-free terrain of southern Alaska to the continuous permafrost of northern Alaska reflects the present and past variation of climate. Locally, permafrost varies in thickness, depending on subsurface drainage and surface insulation.

"Permafrost limits supplies of ground water in central and northern Alaska. North of the Brooks Range the prevalence of permafrost makes the development of wells improbable except in the alluvium of major rivers, such as the Colville, in material beneath deep wide lakes, and in proximity to hot springs. Between the Alaska Range and the Brooks Range ground water may be developed in the flood plains of major rivers, in unfrozen channels within permafrost, in unfrozen sediments overlain by permafrost, and in areas entirely free of permafrost.

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Distribution of water through pipes and collection of sewage is difficult and costly in permafrost regions. Water mains and sewers cannot be protected from freezing by entrenching them, but must be placed in enclosing insulated conduits on top of the ground to protect from freezing."—Author's report, p. 3.

U.S.S.R., 1938, Hydrogeology of the rivers of the Soviet Arctic [Gidrogeologiia rek Sovetskoi Arktiki] : Leningrad, v. 2.

Uzemblo, V. V. *See* Vel'mina, N. A., 1959.

Vasilevskii, M. M., 1936, Definition of terms for subsurface waters: Internat. Union of Geodesy and Geophysics, Assoc. Sci. Hydrology, Bull. 22, p. 332–354.

1937, Russian and foreign hydrogeological terminology (O russkoi i inostrannoi gidrogeologicheskoi terminologii) : Russia, Central Sci. Inv. Geol.-Prosp. Inst., Pogrebov Jubilee volume, p. 46–54.

1938, Definitions of terms for different types of subsurface waters: Russia, Central Sci. Inv. Geol.-Prosp. Inst., Materialy, gen. ser., v. 3, p. 95–108.

Vasilevskii, M. M., and others, 1939, Arrangement of the principal hydrogeological regional divisions of the Asiatic part of the USSR [Skhema osnovnogo gidrogeologicheskogo raionirovaniia Aziatskoi chasti SSSR] : Sovetskaia geologiia, v. 9, no. 7, p. 21–36.

Vel'mina, N. A., 1959, Problems of the interaction between ground water and permafrost in the Aldan crystalline massif [Voprosy vzaimodeistviia podzemnykh vod i mnogoletnemerzlykh porod v predelakh Aldanskogo kristallicheskogo massiva], *in* Materialy po obshchemu merzlotovedeniiu: Akad. Nauk SSSR, Inst. Merzlotovedeniia, p. 138–141.

Factors determining the aggradation and degradation of permafrost are examined on the basis of borehole studies in 1947 and 1950. The thickness of permafrost in watersheds is generally 15–30 m, reaching up to 100 m in some areas, and varies from 100–150 m in valleys. Permafrost temperatures in watersheds do not drop below −1.0° to −1.5°C and are often higher. In valleys, conditions are more severe and sometimes even favorable for the development of permafrost. Two main types of taliks are distinguished according to relief: watershed taliks and valley taliks which comprise both perforating and nonperforating taliks. Perforating watershed taliks may be 1 km or more long and serve as a source of supply to ground water. There are also smaller (0.2–0.4 sq km) perforating taliks through which ground water rises to the surface, primarily at the bottom of valleys and along rivers. Deep borehole studies also indicate that ground water may contribute to the degradation of permafrost from below.—From SIPRE 17939.

Vel'mina, N. A., and **Uzemblo, V. V.**, 1959, Hydrogeology of the central part of southern Yakutia [Gidrogeologiia tsentral'noi chasti iuzhnoi IAkutii] : Moscow, Akad. Nauk SSSR Izd., 178 p.

The physiography and hydrogeological characteristics of the Aldan crystalline massif, which is a permafrost area, are discussed on the basis of laboratory and field studies from 1951 to 1955, emphasizing ground water. A short history of the investigations is given in chapter 1, and the orography, climate, and hydrology of the area are described in chapter 2. Chapter 3 is devoted to the geological structure of the area. The interrelationship between ground water and permafrost is discussed in chapter 4, including permafrost aggradation, degradation, seasonal freezing and thawing of soils, the moisture content of permafrost and thawed soils, taliks, geological phenomena associated with permafrost—

such as soil fissuring, heaving, peat mounds, naleds, and icing mounds—ground ice, and solifluction processes and thermokarst. A hydrogeological classification of permafrost areas is included. Ground water in various geological strata is examined in detail in the final chapter and classified.—From SIPRE 17538.

Vittenburg, P. V., 1939, The thermal regime and underground waters in the permafrost of Vaigach Island and Amderma [Termicheskii rezhim i rudnichnye vody v zone vechnoi merzloty ostrova Vaigacha i Amdermy]: Problemy Arktiki, no. 9, p. 5–29.

Summer thawing extends to 1.4 m, and the active layer lies between 1.4 and 1.7 m; means annual temperature is −6.4°C, and snow cover is thin. Permafrost in the vicinity of the mines is more than 500 m thick, but since mine workings extended under the sea, drilling was necessary to determine whether permafrost extended beneath the sea floor in order to calculate the danger of flooding by salt water. Temperatures in the mine shafts beneath the land and the sea were below 0°C, but no frozen ground was found 200 m from shore because of high salinity of the ground waer. In the Rasdelmaia mine the saline waters within permafrost had a higher salt content than sea water, and seepage at the rate of 147–150 cu m per hr was attended by a decline in salt content, showing that sea water was seeping into the mine.

The ground water is subject to pressure from sea water. The presence of Glauber salt (mirabilite) in the ice within permafrost and the nature of the ice are evidence for the antiquity of the water from which it was formed, especially as the freezing of the mine walls reduced the flow of water, and that if temperatures were kept below −2.8°C in the Rasdelmaia mine and −3.2°C in the Amderma mine and if 115–120 m of permafrost were preserved above the upper water-bearing horizon (which occurred in permafrost 104–145 m), seepage could be minimized.—From English abstract by E. A. Golomshtok for Stefansson Collection, Dartmouth College, Baker Library, Hanover, N.H. SIPRE U–2127.

Voiekov, A. I., 1889, On the frozen ground in Siberia along the proposed railroad line [O merzlote v Sibiri po liniiam predpolagaemykh zheleznykh dorog]: Min. Putei soobshch. Zhur., no. 13.

1895, The distribution of ground ice and geothermal observations in Siberia (Zur Frage der Erstreckung des Eisbodens und geothermische Beobachtungen in Sibirien): Meteorol. Zhur., v. 12, p. 212–214.

1904, Heat circulation in the shell of the earth's sphere: Sbornik statei po fizikie posviashchennii pamiati F. F. Petrushevskii, St. Petersburg [Collection of articles on physics, devoted to the memory of F. F. Petrushevskii, in Russian].

Vonder Ahe, K. L., 1953, Operating problems in oil exploration in the Arctic: Petroleum Engineer, v. 25, no. 2, p. B12–B18.

The experience of Arctic Contractors in Naval Petroleum Reserve No. 4 is used in discussing the chief difficulties in exploring in the Arctic: (1) transportation problems caused by thawed ground in summer and fall; (2) thawing of foundation footings due to heat transfer from drilling mud circulated in deep wells; (3) retardation of setting time and refusal of cement to set around casing within permafrost; (4) collapse of casing caused by expansion of ice upon freezing of water or mud in the annulus; (5) blocking of oil production by ice in shallow oil sands; and (6) formation of hydrates in casing and tubing of high-pressure gas wells, shutting off flow of gas. Permafrost extends as deep as 1,150 ft and has a temperature of 32°F at the base, with a minimum of 14°F at a depth of 100 ft, just below the zone of seasonal temperature fluctuations.

In the Arctic coastal plain, the upper 30–50 ft contains so much water that it loses bearing strength when thawed. Circulation of warm drilling mud during the long periods of drilling required for the deeper holes thaws the surrounding ground; the conductor pipe is set at a depth of 100 ft or more with the upper 60 ft jacketed with a larger size pipe. In this way an insulating air space is left in the annulus to prevent thawing next to the casing. Wells only 4,000–5,000 ft deep can be put down without these special measures before significant thawing occurs.

Some oil-bearing sands have been found at depths corresponding to parts of the permafrost. If the connate water is highly saline, it will probably not be frozen, but any addition to fresh water from drilling fluid might reduce the salinity and permit ice formation at higher temperatures than was previously possible. One well drilled with a rotary rig and water-based mud in 1947 cored oil sand, but could not be made to produce. Later a cable-tool rig placed a hole less than 100 ft away and produced more than 350 bbl per day of high-gravity crude oil; the cable-tool hole was drilled with only a small amount of brine in the bottom. Another well drilled on this structure with cable tools and brine flowed 500 bbl per day; but after 2 hr ice formed inside the tubing and shut off the flow. When thawed with hot brine, the well resumed its 500-bbl flow. Similarly, gas from a shallow source passing through permafrost tends to deposit hydrates on the inside of the pipe, and sometimes the flow of gas becomes shut off. This condition could be overcome by installing a resistance heater on future wells.

von Baer, K. E., 1838. On the ground ice or frozen soil of Siberia: Royal Geog. Soc. [London] Jour., v. 8, p. 210–212.

von Ditmar, C., 1855. Ice fields in eastern Siberia [Ueber die Eismulden im ostlichen Sibirien]: Akad. Nauk SSSR, Otdel. fiz. mat. nauk, v. 11, p. 305–312; discussion by A. Th. von Middendorf, p. 312–316.

The characteristics and origin of taryns, i. e., icefields which do not melt in summer, are described on the basis of observations made in 1851. The distinguishing feature of the taryns is that they generally form in circular hollows in valleys and are surrounded by rock debris. The ice is usually clear, hard, free of air, and only occasionally mixed with debris of varying sizes from sand to boulders. The temperature of the ice in one taryn was —1°R at a depth of 1 ft while the air temperature was 8°R. The depth of the ice in the center of this taryn was 10 ft at the end of summer. The largest such icefield encountered was 80 fathoms long and 35 fathoms wide. Conditions necessary for the formation of this ice are the existence of a trough in a valley or a flat valley floor, the presence of a spring which does not freeze in winter, and cold winters rich in snow. The growth of the taryns is due to the freezing of overflowing water. Middendorf comments that the phenomenon is associated with permafrost, which keeps soil temperature below the freezing point throughout the year, and is comparable in appearance and origin to naleds.—From SIPRE 14129.

von Kotzebue, Otto, 1821, A voyage of discovery into the south sea and Beering's Straits in the years 1815–18: London, v. 1 *of* English translation in 3 v.

von Middendorf, A. Th., 1848, Geothermal observations [Geothermische Beobachtungen], *in* Reise in den äussersten Norden und Osten Sibiriens: K. Akad. Wiss., St. Petersburg, v. 1, pt. 1, p. 83–184.

1867, Natural history survey of northern and eastern Siberia [Übersicht der Natur Nord- und Ost Sibiriens], *in* Reise in den äussersten Norden and Osten Sibiriens: K. Akad. Wiss., St. Petersburg, v. 4, pt. 1, 783 p.

Vturin, B. I., 1956, On several geomorphological terms in permafrostology [O nekotorykh geomorfologicheskikh terminakh v geokriologii]: Akad. Nauk SSSR, Inst. Merzlotovedeniia, Materialy k osnovam ucheniia o merzylkh zonakh zemnoi kory, v. 3, p. 126–134.

Waanenen, A. O., 1952, The hydrology of Alaska, *in* Science in Alaska, Alaskan Sci. Conf. of the Natl. Acad. Sci.—Natl. Research Council, Washington, 1950, Arctic Inst. North America Spec. Pub. 1, p. 151–162.

Permafrost, along with climatic and topographic variations and effects of glaciers, makes the hydrology of Alaska highly complex. The permafrost in interior and northern Alaska usually acts as an impervious layer, but there are opportunities for storage or release of water from the active layer between the ground surface and the permafrost. Changes in permafrost may be accompanied by changes in local water regimen. In northern Alaska, little information is available on ground water. Eskimos sometimes obtain summer water from small wells dug into permafrost; these wells accumulate water from melting permafrost and ground ice. Exploratory test drilling has been done at Fairbanks and Kotzebue. At Kotzebue a test hole 325 ft deep produced only salt water and showed permafrost to be present to 238 ft.

There is reason to believe that extensive ground-water supplies are available in many areas and that they would provide a more dependable and economical supply of water than remote surface sources. A close relationship exists between the occurrence of permafrost and ground water, and the studies of permafrost being undertaken by the Geological Survey and Department of the Army could be adapted by the hydrologist to narrow the scope of his inquiry. Future research in Alaska should include studies of the effects of permafrost on streamflow and the recovery of ground water.

Wahrhaftig, Clyde, 1958, Quaternary geology of the Nenana River valley and adjacent parts of the Alaska Range: U.S. Geol. Survey Prof. Paper 293–A, p. 1–68.

Permafrost is common throughout the Alaska Range and has been encountered wherever deep excavations have been made. It may be absent in some of the very well drained terraces which have springs issuing from their bases and which are formed of coarse gravel. On bare slopes of rock and gravel, perennially frozen ground is more than 20 ft below the surface and may be relict; it is reported to occur in the Suntrana coal mines, excavated beneath a south-facing rocky slope.

In bedrock, permafrost occurs as ice that fills or partly fills joints and cracks; in gravel, it occurs as ice cementing the particles, or may be dry permafrost in which the sediment lacks ice but is below 32°F. In silt, sand, and clay, permafrost may occur as lenses and veins of ice, as well as interstitial ice. Permafrost was exposed in the Diamond coal mine pit in 1948 and in clay at the railroad bridge at mile 351.4 in 1948 and at Moody in 1949.

Wahrhaftig, Clyde, and Black, R. F., 1958, Engineering geology along part of the Alaska Railroad: U.S. Geol. Survey Prof. Paper 293–B, p. 69–119.

Permafrost is discontinuous throughout the central part of the Alaska Range, and therefore is absent under large rivers and lakes and may be absent or of limited extent beneath terraces of coarse-grained well-drained gravel. All excavations to depths of several tens of feet have penetrated permafrost, except those in bare gravel. Permafrost in bedrock consists of ice fillings in the joints and fissures; in gravel, ice may or may not fill the voids, or locally the gravel may be supersaturated with ice. In near-surface fine-grained deposits most of the frozen material is supersaturated with ice and contains veins and lenses of ice.

Permafrost is in delicate equilibrium with its environment. Wherever disturbed by burning or stripping of vegetation, erosion by the river, or alteration by man, the permafrost is thawing. On the other hand, some fills in shaded areas along the tracks have become perennially frozen within the last 20 yr. Where the movement of ground and surface water is altered, the resulting disequilibrium may thaw permafrost. The water released by thawing of permafrost plays an important part in lubricating landslides and slumps.

The bridge near mile 351.4 is the site of several borings. At the south end, permafrost in clay and gravel is 10–15 ft deep; at the north end, permafrost in clay is 6 ft deep. West of the track and south of the bridge, 15–20 ft of frozen blue clay overlies unfrozen yellow clay. A hole churn drilled south of the bridge passed through unfrozen clay at 32–45 ft. A hole just north of the bridge was drilled in frozen clay and gravel to 100 ft and in unfrozen gravel containing flowing ground water between 100 and 110 ft. This 100 ft of permafrost is the thickest encountered in the area.

Wahrhaftig, Clyde, and Cox, Allan, 1959, Rock glaciers in the Alaska Range: Geol. Soc. America Bull., v. 70, p. 383–436.

Permafrost is common throughout the Alaska Range. It has been found in mines in the Nenana coal field and in most excavations for railroads and roads across the Alaska Range down to the lowest altitudes in the range. The depth to permafrost in these excavations ranged from 2 to 20 ft. Permafrost-free areas, if present, lie only beneath southward-facing slopes. However, even mines beneath southward-facing slopes have penetrated permafrost. Permafrost is in areas that were glaciated as recently as late Wisconsin time and in areas that were never glaciated. As has been indicated, the average annual temperature in lowland valleys in the Alaska Range is 5°F below freezing; permafrost is therefore probably in equilibrium with the climate under most conditions. Conditions would be even more favorable to permafrost at high altitudes, where the climate is colder, and in northward-facing valley heads and northward-facing walls of valleys, the sites of most rock glaciers. The cold springs emerging at the toes of many rock glaciers show that the rock glaciers contain water, but most of the water in them must be in the form of ice.—Author's report, p. 413.

Wahrhaftig, Clyde. *See also* Cederstrom, D. J., 1950.

Wallace, R. E., 1946, Terrain analysis in the vicinity of Northway, Alaska, with special reference to permafrost: U.S. Geol. Survey, Permafrost Program, Prog. Rept. 3, 34, p., pub. by Engineer Intelligence Div., Office, Chief of Engineers, U.S. Army.

The Northway area is divided into the following terrain subdivisions: Flood plains, sand dunes, lake-sediment terraces, alluvial fans, bedrock hills, and lakes.

In the flood plains, the area immediately adjacent to flowing water is free of permafrost. In abandoned channels, permafrost is distributed in irregular fashion. The channels that are longest abandoned have permafrost that contains lenses of ice, but those more recently abandoned are less likely to have permafrost. In interchannel areas the permafrost table is commonly at a depth of 1–2 ft, and in many such areas permafrost contains lenses of ice a fraction of an inch to several feet thick. Permafrost is more irregularly distributed in natural levees.

Permafrost occurs in most of the sand-dune areas, but generally lacks ice lenses and masses that cause subsidence upon thawing. Permafrost occurs in some of the exposures of lake sediments beneath the dune deposits. No permafrost was encountered to depth of 6 ft on alluvial fans, but no information is available on the presence or absence of permafrost at greater depth. No specific tests were made for permafrost in bedrock areas, but it probably is present. Many of the lakes in the area originate from thawing of permafrost.

1948, Cave-in lakes in Nabesna, Chisana, and Tanana River valleys, eastern Alaska: Jour. Geology, v. 56, p. 171–181. *See* annotation, Wallace, R. E., 1946.

Waller, R. M., 1957a, Ground water and permafrost at Bethel, Alaska: Juneau, Alaska Dept. Health, Sanitation and Eng. Sec., Water Hydrologic Data Rept. 2, 11 p. 1957.

The Kuskokwim River has thawed the permafrost, wholly or in part, on the east side of the river. Permafrost is present to a depth of about 350 ft below sea level on the west side of the river. The river is thawing the permafrost below the riverbed, but the migration of the river is proceeding at a faster rate than the thawing.

Ground water is present at different places above, within, and below the permafrost. Near the village, the zone above the permafrost is of little consequence. Although the intrapermafrost zones (talik) are more extensive than the surficial zone, they do not appear to be very promising. Ample ground water is present east of the river where the subsurface material is saturated and largely unfrozen. The major aquifer west of the river lies beneath the permafrost and is a nonflowing artesian aquifer. The iron content of water from this aquifer is high, and removal of iron is required for domestic use.

There is a possibility of a hydraulic connection between the river and the deeper water-bearing zones.—Author's summary, p. 7.

1957b, Riverbank erosion and ground-water conditions at Beaver, Alaska: U.S. Geol. Survey open-file report, 6 p.

The thickness of permafrost at Beaver is unknown. Near the Yukon River the ground is thawed by river water, in some places as much as 100 ft from the bank. Back from the riverbank several shallow pits have been dug to frozen ground at a depth of about 5 ft. The riverbank upstream from the village is frozen. Water probably can be obtained from well points driven along the riverbank below the level of low water. Installation of driven well points is inexpensive, and they are not ruined by flooding.

1957c, Ground-water reconnaissance of six Eskimo villages in the Kobuk-Noatak area, Alaska: Juneau, Alaska Dept. Health, Sanitation and Eng. Sec., Water Hydrologic Data Rept, 4, 8 p., 1958.

Possibilities for developing adequate water supplies for the northwestern Alaska villages of Kiana, Noatak, Noorvik, Point Hope, Selawik, and Shungnak are suggested as a means of eliminating dependence on and need for hauling surface-water supplies. At Kiana, situated in a draw between bluffs, possible shallow suprapermafrost water might be obtained from a well dug at the upper end of the draw, where the axial stream may have formed a thawed zone in permafrost and where the creekbed crosses more permeable material. Such a location would be upstream from possible sources of contamination.

At Noatak, situated on a low terrace, a shallow well beneath the terrace to intercept the coarse terrace gravel may prove a satisfactory source of water, provided the gravel is not frozen. Alternately, the creek that joins the Noatak River north of the river could be dammed and used as a water supply, with the possibility of gravity feed in surface pipelines for summer use.

Noorvik, on the Kobuk delta, is on a hill about 200 ft above the river. The site is underlain by perennially frozen silt and very fine sand in which huge ice lenses occur. Ground water may be obtainable from fine-grained deposits in the 20-ft terrace bordering the river, provided the materials are unfrozen. A large pond south of the village, and about 50 ft lower, offers the possibility of unfrozen zones beneath the east and north shores, where contamination would be least.

Point Hope is on a spit of well-sorted sand and fine gravel which extends into the Chukchi Sea opposite the mouth of Kukpuk River. The spit consists of perennially frozen ground, but a well dug 4 ft to the top of permafrost southeast of the village provides a summer water supply that reportedly can be pumped all day. No suggestions for alternate sources of water are offered, other than to deepen the existing well and lower the pump intake in order to continue the progressive enlargement of the reservoir of suprapermafrost water.

Selawik, on the delta of the Selawik River, near Selawik Lake, is situated on fine gray perennially frozen sand. Exploration for ground water would be best attempted by the jetting method along the banks of the river or near the deeper ponds on the island, beneath which there may exist unfrozen zones.

Shungnak is on a narrow 20-ft terrace along the Kobuk River; the terrace deposits consist of sand, gravel, and cobbles which do not appear to be frozen either where exposed or in the 20-ft dug well at the north end of town. The 20-ft well was abandoned because the water was dirty, but apparently it had a hydraulic connection with the river, and if developed properly, using the sand-pack technique, might provide adequate water.

Waller, R. M., 1958, Ground-water reconnaissance in five Eskimo villages in the lower Kuskokwim-Yukon River area, Alaska: Juneau, Alaska Dept. Health, Sanitation and Eng. Sec., Water Hydrologic Data Rept. 5, 11 p.

Ground-water possibilities for the villages of Kwethluk, Hooper Bay, Chevak, Tununak, and Kwigillingok are estimated on the basis of surficial geology and topography, in the absence of ground-water developments.

At Kwethluk, near Bethel, permafrost is 1–8 ft deep; its thickness is unknown. Recent meandering of the Kuskokwim and its tributaries may have thawed the original permafrost, but it is not possible to tell how much new permafrost has developed since the river channel shifted elsewhere. A driven point or jetted well is suggested for a site east of the school.

Hooper Bay on the Bering Sea coast is situated on dunes near a tidal stream and brackish lakes. Permafrost is present everywhere and probably is deep. Saline water is a possibility beneath permafrost; a possible shallow water supply may occur in unfrozen ground near the edge of the only fresh-water lake.

At Chevak, on the Ninglikuk River, permafrost is present at shallow depth everywhere in the two terraces, which are, respectively, 9 and 29 ft above the river. A fresh-water lake on the upper terrace constitutes the village water supply. Exploration by drive point or jet could be made to search for coarse permeable unfrozen deposits on the lower terrace, but caution should be exercised not to allow contamination of the well by refuse and sewage dumped from the village on the terrace above. On the upper terrace a location between the school and church is best, but it offers little chance of shallow water; there is a chance for shallow ground water near the shores of the lake that is used as village supply.

Tununak, on the west shore of Nelson Island, is on the landward end of a spit that separates the sea from a river. No permafrost is reported in the spit gravel, and the school well, 14 ft deep, has fresh water at 11½ ft. A spring on the mountainside empties into the river 200 yd above the village and is the village supply. Wells to be located on the spit should be away from the sea and near the river to avoid salt water. A good well site is between the school and the store, where there is recharge by water percolating down the mountain slope.

Kwigillingok near the north shore of Kuskokwim Bay is built on silt and clay deposited by the Kuskokwim River; the materials are perennially frozen, probably to great depth. Present water supplies are from a fresh-water lake; some lakes are brackish. Prospects for ground water are poor and are limited to potential thawed zones bordering the stream; if no water is available near the stream, a deep well to penetrate the permafrost is necessary.

1959a, Water-resources reconnaissance of Gambell and Savoonga villages, St. Lawrence Island, Alaska: Juneau, Alaska Dept. Health, Sanitation and Eng. Sec., Water Hydrologic Data Rept. 6, 14 p.

Gambell is on a gravel spit which encloses Troutman Lake, the local water supply fed by streams from Sevuokuk Mountain. The thickness of permafrost is unknown, and its distribution is believed to be discontinuous. Permafrost may form an impermeable barrier to ground-water discharge of Troutman Lake to the west, allowing the ground-water discharge to move toward the north.

Savoonga is on a lowland underlain by clay and stones, which lies between two lava headlands. Some fresh-water seepages are reported along the shoreline, notably in the lava headlands. Depth to rock is unknown beneath the village, but a possibility exists of coarse unconsolidated deposits in which thawed zones may occur along the contact with bedrock.

1959b, Ground-water reconnaissance of Koyuk and Shaktolik villages, Alaska: Juneau, Alaska Dept. Health, Sanitation and Eng. Sec., Water Hydrologic Data Rept. 7, 10 p.

Permafrost is present near Koyuk, but ground-water seepages and springs within and near town suggest that ground water may be available at shallow depths. A dug, jetted, or driven well might be placed in soil and loose rocks near the surface, upstream from the main seepage and near the foot of the upper-terrace escarpment. Drilling in the bedrock would require a drilling machine; tunneling in the slope above the seepage area may be feasible to develop a supply of water.

Shaktolik is situated on gray sand and gravel which are unfrozen and at least 10 ft thick; permafrost probably occurs at depth. The stream is 10 ft above sea level, and ground water should occur under water-table conditions at shallow depth. The old school well, 19 ft deep, originally reported to have encountered salty water, is producing potable water except for periods when storm winds back up tidewater in the stream. A new well dug 8 ft and driven still deeper is not used. Combinations of dug and driven well points are suggested; also suggested is the possibility of a trench at the water table and several individual points driven below the water table and hooked to a single pipe; the best site is at the upstream end of the village near the stream.

Care should be taken not to penetrate too deeply into the fresh-water aquifer; the well should be pumped carefully to avoid intrusion of salt water.

Waller, R. M., 1960a, Ground-water conditions in the vicinity of Project Chariot, Ogotoruk Creek, northwestern Alaska, *in* Kachadoorian, Reuben, and others, 1960, Geologic investigations in support of Project Chariot in the vicinity of Cape Thompson, northwestern Alaska—Preliminary report: U.S. Geol. Survey open-file report (TEI-753), p. 72-78.

Shallow aquifers just beneath or adjacent to surface-water sources and deep aquifers in permeable bedrock both occur in the Ogotoruk Creek area. The flood-plain deposits permit infiltration of water which thaws the seasonal frost each year. If an unfrozen zone exists between the bottom of seasonal frost and the permafrost table, it will remain unfrozen as long as recharge from the creek is adequate to maintain the underflow. Occurrence of winter icings on the flood plain is an indication of such an unfrozen zone.

Deep aquifers are indicated by springs; Covroeruk Springs near Cape Seppings flow at 20 cfs at 37° to 38°F from the base of a mountain composed of sandstone and limestone. In the Ogotoruk Creek area borings as much as 1,172 ft deep encountered frozen mudstone. Recharge of the sandstone and limestone aquifers that lie beneath permafrost probably originates in streams that cross the outcrop belt of these rocks at some distance from the Ogotoruk Creek area.

1960b, Winter ground water investigations in the vicinity of Cape Thompson, Alaska, *in* Kachdoorian, Reuben, and others, 1960, Supplemental report on geologic investigations in support of phase II, Project Chariot in the vicinity of Cape Thompson, Northwestern Alaska, p. 29-30: U.S. Geol. Survey open-file report (TEI-764), 30 p.

After freezeup, until some time probably in December, when the creekbed froze, Ogotoruk Creek maintained a flow beneath the ice cover. Source of the water in the creek was the adjacent creekbed and flood-plain deposits.

Covroeruk Springs, near Cape Seppings, flowed throughout the winter. Temperature measured in September 1959 and April 1960 was about 38°F; between these dates discharge decreased from 22.7 to 6.17 cfs. Decrease in discharge coincident with similar declines in streamflow suggests that the springs obtain their water from a surface stream of considerable flow.

Springs occur in the Igichuk Hills, 100 miles southeast of Ogotoruk Creek. A sulfur odor was noticeable half a mile downstream from the springs; water temperature in April 1960 was 38°F.

The springs indicate that ground water is present in the permafrost region of this part of Alaska the year around.

1961, Summary of ground-water conditions in Alaska as they affect private water supplies: Juneau, Alaska Dept. Health, Sanitation and Eng. Sec., Water Hydrologic Data Rept. 11, 2 p.

In the narrow to broad intermontane valleys that make up interior and western Alaska, the most serious obstacle to ground-water development is permafrost, which is a few to several hundred feet deep beneath most of the area. Only coarse sediments containing fast-moving or saline ground water remain unfrozen. To obtain water it is necessary to drill through permafrost or to locate an unfrozen zone within permafrost. The thick impervious silt mantle and below-freezing temperatures induce formation of permafrost. Where permafrost extends into bedrock, the chances for obtaining ground water are slight.

Shallow thawed zones are present beneath the larger streams or lakes, and such zones generally yield water to wells, but only if the well is deep enough to allow for the winter "decline" of the water table. Permafrost presents a problem to obtaining a successful well because the water, commonly under artesian head, rises in the well and is subject to freezing where in contact with permafrost; the well should be pumped daily to prevent freezing. Iron content as high as 10 ppm and, in some areas, high salt content are chemical problems of the permafrost region of interior and western Alaska.

In northern Alaska conditions are similar to those of the interior, but permafrost is thicker to the north, reaching a depth of about 1,300 ft. Ground-water development is feasible only near lakes deeper than 7 ft and larger in diameter than one-half a mile, and beneath large streams where thawed zones occur.

Waring, G. A., 1917, Mineral springs of Alaska, with a chapter on the chemical character of some surface waters of Alaska, by R. B. Dole and A. A. Chambers: U.S. Geol. Survey Water-Supply Paper 418, 114 p.

In his preface, A. H. Brooks describes the 1914 studies by H. M. Eakin on the effect of erosion and ground-water conditions on the quality of surface waters of the subpolar region of northern Alaska; sufficient data were not collected from which to draw meaningful conclusions. Two conditions affecting quality of the water are (1) paucity of erosion, due to the mat of vegetation and to light rainfall, and (2) permanently frozen subsoil, which prevents circulation of ground water. In the Klondike the alluvium is frozen to a depth of about 200 ft; at Fairbanks permanent ground frost occurs in many places to a depth of more than 200 ft, and the deepest shaft penetrated 318 ft of frozen alluvium. On Seward Peninsula many holes in permanently frozen alluvium are more than 75 ft deep, and one is nearly 200 ft deep; these shafts are all on flood plains. Some ground is unfrozen, and in some mines underground flows of water have interfered with operations. The ground frost appears to be a survival of a climate colder than the present and is preserved by the non-conducting mat of moss and vegetation. This colder climate probably brought on the last glaciation.

Sunken areas 6–8 miles west of Glacier, in the upper Kantishna basin, in a plain of glacial gravel and clay are 50 ft or more deep and are lined with dead-standing trees; these areas are occupied by water which remains open all winter. Twenty miles north of Glacier, the Toklat and Moose Rivers sink into the ground for a mile or two and reappear apparently warmed, for the rivers remain unfrozen for short distances downstream throughout the winter.

Mineral springs are classed as hot springs, warm springs, cool carbonate springs, sulfur springs, iron springs. In most descriptions no mention is made of permafrost, but in some descriptions of hot springs the surrounding ground is described as unfrozen.

Waterhouse, R. W., and Sills, A. N., 1952, Thaw-blast method prepares permafrost foundation for Alaska power plant: Civil Eng., v. 22 p. 126–129.

The West Powerplant at Ladd AFB (Fort Wainwright), near Fairbanks, was constructed on gravel capped with 12 ft of sandy silt and sand. Porosity of the gravel was 25 percent, and its silt content 6 percent. Probing with a section of 70-lb rail and drilling with a 4-in. churn drill revealed that permafrost underlay the area from a depth of 17 ft to a depth of as much as 60 ft. Tests of the gravel showed that it would consolidate under load when thawed, and that the foundation would settle nearly 1 in. from 19 ft of

thawing, but that thawing deeper than 30 ft would not increase the settlement. An attempt was made to pump water from a test pit, but the water level could not be lowered because the pit was apparently obtaining water under head through or beneath the permafrost from a nearby gravel pit.

Three 6-in. temperature wells were drilled to 36 ft; a 1-in. thermocouple was installed, and the wells backfilled with sand after the casing was removed. While the steam points were being jetted down, water flowed from adjacent casings which projected 5 ft above land surface. This indicated that the ground was not frozen to the full depth of the steam point, but was stratified with lenses of unfrozen material.

Wayland, R. G., 1943, Gold deposits near Nabesna, *in* Moffitt, F. H., Geology of the Nutzotin Mountains: U.S. Geol. Survey Bull. 933–B, p. 175–199.

Oxidation of the ores in the mine of Nabesna Mining Corp. at White Mountain may have occurred (1) during the period of erosion after intrusion of the diorite but before deposition of overlying lava or (2) during the period following extrusion of the lava, perhaps during some of the longer and warmer enterglacials of the Pleistocene. However, no oxidation can occur under present climatic conditions because rock temperatures in the mine are 1°–2° below freezing, and surface waters freeze on entering mine openings and rock fractures. It is questionable that rock temperatures were above freezing during the interglacials for a sufficiently long period to account for oxidation, and it is probable that the oxidation took place before deposition of the Quaternary lavas.

Weller, J. M., chm., 1960, Supplement to the glossary of geology and related sciences: Washington, Am. Geol. Inst., 72 p.

Werenskiold, W., 1922, Frozen earth in Spitsbergen: Geofys. Publikationer, v. 2, no. 10, 10 p.

In regions of sufficiently low mean annual temperature and low snowfall, the subsoil is constantly frozen. In Spitsbergen the mean annual air temperature is about −8°C, and the snow is blown clear and deposited in hollows and on the fjord ice. In the Swedish Coal Mine (Sveagruvan) in Lowe Sound a temperature of 0°C was found at a depth of 320 m below the surface and 430 m from the mouth of the adit in dry rock. The frozen soil continues under the sea bottom, but its upper surface slopes down at a greater rate than the beach and disappears farther out under the sea. At the pier of the Swedish Mine ice was found to stretch under the sea bottom 100 m from shore. Theoretical speculations are made to explain this peculiar distribution of frozen soil and the distribution of frozen ground beneath a shallow fjord bordered by low ground. It was found that the fjord must be broader than 400 m if the bottom is not to be frozen from shore to shore under the conditions existing in Spitsbergen.

The existence of frozen ground beneath glaciers is considered. Beneath an active glacier the temperature is practically at the ice-melting point and water is streaming forth, even in winter. If a glacier (in Spitsbergen) is wider than 400 m, the frozen soil cannot reach beneath the ice from one margin to the other, for along the central parts of large glaciers water may soak down into the ground and pass below the water-tight layer of frozen ground. In this way it is possible to account for the ground water that gives rise to numerous springs in the floor of some of the broad flat valleys in the central parts of West Spitsbergen. The temperature of these springs may be only

a little above 0°C, as contrasted to that of the springs of late volcanic origin, which is as much as 28°C. The water of all the springs seems slightly saline. The cold springs are surrounded by accumulations of ice and sod and look like mud volcanoes. The water in these springs, if not of juvenile origin, must come from a source such as surface water that is able to pass through the 1000-ft-thick crust of frozen ground.

1953, The extent of frozen ground under the sea bottom and glacier beds: Jour. Glaciology, v. 2, no. 13, p. 197–200.

The ground in Spitsbergen is frozen to a depth of about 320 m, as can be seen from observations in the collieries. At a mean surface temperature of —8°C this corresponds to a geothermal gradient of 1° per 40 m. The temperature of the sea water is almost 0°C. Along the coast the land lies very little above the sea level, and here the sea is shallow. One assumes that the land as well as the sea bed is horizontal. Thus the temperature on the land is —8°C, in the sea, 0°C. On the coast the temperature must suddenly change. One must also take into account the fact that the temperature rises with depth. A simple calculation leads to the conclusion that the frozen ground below the sea bed must extend about 100 m from the coast. Investigations near a Swedish colliery have shown this to be the case.

This result also applies to the conditions underneath a glacier. On the same assumptions one can conclude that if the glacier is less than 400 m wide the frozen ground underneath forms one coherent layer, and that this is not the case if the glacier is wider. The same applies to a shallow fjord.—Author's abstract.

Wernecke, Livingston, 1932, Glaciation, depth of frost, and ice veins of Keno Hill and vicinity, Yukon Territory: Eng. Mining Jour., v. 133, no. 1, p. 38–43.

Keno Hill, the site of a silver mine, is on the Yukon Plateau 100 miles east of Dawson at an elevation of 4,500–5,600 ft. Permafrost thickness in clay, gravel, and bedrock varies with the elevation, hillside exposure, depth of overburden, and proximity to running water. Near the summit, shafts sunk 360 and 400 ft into solid rock did not reach the botton of the frozen zone. At the Sadie shaft the ground is unfrozen from the surface down because water runs down the gulch and sinks into the broken rock on the surface. This break in frozen ground permits ground water to come to the surface.

Temperature of the frozen ground is $-2\frac{1}{4}$°C at 100 ft, $-1\frac{1}{2}$°C at 200 ft, and $-\frac{3}{4}$°C at 300 ft in the Lucky Queen shaft. Thermometry is used to predict proximity of water-bearing thawed ground to the workings. Ground water under pressure occurs wherever the frozen zone is penetrated; in some places a flow of as much as 100 gpm has been noted. Mine water contains 178 ppm dissolved solids, mostly as $CaCO_3$.

Springs occur on slopes along veins or faults that extend through the frozen zone. The alinement of springs is of special interest to prospectors seeking ore-bearing veins or faults.

Ice veins as much as 6 in. wide in frozen bedrock exerted pressure between 360 and 700 lb per in^2 and locally contain wires of supergene silver. Calcium carbonate on the walls of the fractures was precipitated during freezing of the water.

Westfall, H. C., 1958, Battling permafrost, subarctic weather and tough soil to give Fairbanks water: Water Works Eng., v. 111, no. 1, p. 128–131, 153–154.

Extremely low temperatures and light snowfall permit winter frost penetration to depths as great as 10 ft, and in many places the seasonal frost reaches permafrost. The newly constructed municipal water system is a single-main recirculating system. Heat was added to the system through water-to-water heat exchangers utilizing heat of condenser cooling water from the city steam-electric generating plant. Optimum water-main depth was calculated at 6 ft, where the minimum ground temperature is 15°F and the winter average is 27°F. Much of the permafrost in the area is in saturated silty clay, which forms unstable mud when thawed; this system should be designated to prevent excessive thaw of permafrost as well as to keep mains from freezing. Where permafrost was encountered, the trench was dug 2 ft below grade and backfilled with washed gravel to insulate permafrost. The dual service pipes were tied together and covered with at least a 2-in. layer of asphalt-impregnated vermiculite. The most desirable water velocity was 3 fps at 40–90 psi, and a flow balance was also made for 2 fps velocity. The mains are sloped between hydrants at a gradient of 1:1,000, and hydrants serve as points of access for pumping and venting.

Three fire wells, each of 1,500-gpm capacity, are located in the system; each has an automatic chlorinating unit to protect the system when wells are in use. Mains are 6- to 14-in. wood-stave pipe. Construction began July 1953, but delays and unexpected areas of permafrost were encountered. Permafrost was dug with ¾-yd track-mounted backhoe. The history of construction and the operation of the several parts of the system are described. This is the first single-main recirculating system in use.

Whetstone, G. W., 1952, General character of surface waters of Alaska: Science in Alaska 1952, Alaskan Sci. Conf., 3d, Mount McKinley Park 1952, Proc., p. 172–175.

Water analyses for the Copper River and its tributaries show that the water is of the calcium carbonate type. Significant quantities of chloride occur in a few of the western tributaries. Several salt springs are known.

Whittaker, E. J., 1922, Mackenzie River district between Great Slave Lake and Simpson: Canada Geol. Survey Summ. Rept., 1921, pt. B, p. 45–55.

Several small sulfur springs occur on Sulphur Creek, a tributary of Horn River; one is accompanied by a strong flow of hydrogen sulfide. Waters of streams heading in Horn Mountains are impregnated with iron. The springs emerge from Devonian shale; the streams head in Cretaceous shale.

Wild, G., 1882, The air temperatures in the Russian Empire: St. Petersburg.

Cited by Sumgin (1927) and Nikiforoff (1928) as the first climatic hypothesis proposed for the origin of permafrost.

Wilkerson, A. S., 1932, Some frozen deposits in the goldfields of Interior Alaska: Am. Mus. Nat. History Novitates 525, 22 p.

Williams, G. A., 1943, Winter maintenance problems on the Alaska Highway: Roads and Bridges, v. 81, no. 11, p. 27–30, 58–59.

Springs that flow all winter, cold weather, and rivers that freeze from the bottom up are the major maintenance problems not the snowfall. Between Watson Lake, Yukon Territory, and the Alaska boundary, 250 icings are troublesome. In some side hill cuts several feet of earth and gravel overlie 3–6 ft of ice, beneath which occurs more gravel. Springs flow from ice deposits in summer and continue to flow in the coldest weather. In some places permafrost is reportedly within inches of the surface. Streams in which ice forms on the sides and bottoms become higher and higher, and may form

considerable thicknesses of ice; one case of 50 ft of stream ice was reported to the author.

Williams, J. R., 1953a, Observations on river-ice conditions near highway bridges in Alaska, winter 1949–1950: U.S. Geol. Survey in cooperation with Engineer Intelligence Div., Office, Chief of Engineers, U.S. Army, Eng. Notes 30, 40 p., 26 figs.

This report describes ice cover and channel cross sections that existed on several streams in the Matanuska, Copper, Tanana, and Yukon Valleys during February 1950. Shallow supplies of ground water are available beneath gravel bars or in gravel banks along these streams.

1953b, Icings in Alaska, 1949–50: U.S. Geol. Survey in cooperation with Engineer Intelligence Div., Office, Chief of Engineers, U.S. Army, Eng. Notes 32, 23 p., 12 figs.

Icings along the Glenn Highway between Palmer and Tok Junction are classified as river icings, ground icings, or icings of mixed origin. The river icings and those ground icings formed at intermittent and perennial springs and seepages are not necessarily related to permafrost. The ground icings formed behind frost dams are caused by emergence at the surface of ground water trapped between deep seasonal frost and an impermeable layer, such as permafrost.

1955, Preliminary geologic evaluation of the Chena area, Alaska: U.S. Geol. Survey open-file rept. 198, 5 p.

The Chena area occupies 127 square miles of the Chena and Little Chena Valleys and part of the Yukon-Tanana Upland near Fairbanks. Of this area, 42 percent is underlain by alluvial-fan and creek-valley silt deposits which are rich in small to large ground-ice masses; ground water is probably available from thawed gravel beneath the frozen silt at depths of 10–150 ft in the upland creek valleys and as much as 175 ft in the alluvial fans bordering the major valleys. The rest of the area is composed of (1) flood-plain deposits in which water is available from gravelly alluvium beneath permafrost; (2) low terrace deposits in which water is probably available beneath permafrost at depths of 50–150 ft; (3) sand terrace deposits in which ground-water conditions are unknown, owing to lack of subsurface data; and (4) unfrozen upland silt and underlying bedrock in which small ground-water supplies are uncertain, even at a depth of 100 ft.

1960, Cenozoic sediments beneath the central Yukon Flats, Alaska: U.S. Geol. Survey Prof. Paper 400–B, p. B329.

An unproductive water well drilled by Corps of Engineers, U.S. Army, Aug. 7 to Oct. 1, 1954, near Fort Yukon, penetrated 148 ft of sand and gravel and 292 ft of silt and silty sand. Permafrost was logged from 8 to 320 ft, and ice lenses were noted between 320 and 390 ft.

Williams, J. R., Péwé, T. L., and Paige, R. A., 1959, Geology of the Fairbanks (D–1) quadrangle, Alaska: U.S. Geol. Survey Geol. Quad. Map GQ–124.

Permafrost in the Fairbanks (D–1) quadrangle is as much as 317 ft thick. It is nearly continuous on lower hillsides and in creek bottoms of the Yukon-Tanana Upland and in the alluvial fans which border the Chena and Little Chena Valleys; these deposits of silt include small veins, lenses, and stringers of ground ice, and locally contain large wedges and irregular masses of ice. The permafrost ranges in thickness from 1 to 20 ft at the upslope edge of frozen zone to 50–317 ft in creek valleys and alluvial fans. Permafrost in the alluvial deposits of the major valleys is discontinuous laterally and vertically; it is as much as 265 ft thick beneath some of the older alluvial surfaces and is probably absent beneath the streambeds, some abandoned channels, and lakes. All the deep wells are listed among selected subsurface data.

Williams, M. Y., 1922, Exploration east of Mackenzie River, between Simpson and Wrigley: Canada Geol. Survey Summ. Rept., 1921, pt. B, p. 56–66.

The soil is generally frozen in the area. Mineral springs occur near Old Fort Wrigley where water issues from the surface of the smaller island 15 ft above river level and leaves a deposit of lime. Lime deposits also occur on the mainland across the river. Mineral springs occur also at Roche-qui-trempe-à-l'Eau, where warm waters emerging from a travertine cone about 50 ft above the river have deposited calcareous material; the springs are related to a fault.

Wilson, J. D., 1949, Arctic construction: Mil. Engineer, v. 41, p. 258–260.

Permafrost underlies much of the Arctic from depths of a few feet to as much as 700 ft. Permafrost can exist where mean air temperature is only a degree or two below freezing. Ground water may exist above, within or below permafrost. Practically all destructive effects of freezing and thawing are related to ground water. Heat is conveyed by ground water to thaw permafrost. Ground water may be present, at all seasons, between the permafrost table and the base of seasonal frost.

Wilson, W. K., Jr., 1948a, The permafrost investigation in Arctic and Subarctic regions: Internat. Conf. Soil Mech. and Found. Eng., 2d, Rotterdam, Proc., v. 1, p. 330–335.

Ground water is one of the important factors which influence permafrost. In road construction, especially in cut sections, one of the byproducts of permafrost was filling of the ditches with ice during the winter season; in many places the icing would overflow the roadway to considerable depth, interfering with normal highway use. The icings were caused principally by seasonal freezing downward from the surface of the ground under the ditch to the permafrost table; this forced the ground water in the hillside to break out slightly upslope from the ditch. This difficulty can be overcome to some extent by clearing the natural insulating material from a strip of land uphill from the road and installing a ditch and dike, perpendicular to the direction of ground-water movement, to intercept and convey surface and ground water away from the road.

Observations are in progress at Northway airfield, Alaska where churn borings or core drilling in permafrost was done to 30–75 ft for installation of temperature-recording equipment. Ground-water wells were established throughout the Northway area, and vertical-movement observation points were set up to study ground settling. At the Fairbanks Permafrost Experiment Station ground-water wells were included in the research facilities. Fifteen Alaskan weather stations were equipped with ground-temperature measuring equipment installed in 20-ft holes.

The report is a general summary of the 1945–48 studies of the St. Paul District, Corps of Engineers, U.S. Army.

1948b, The problem of permafrost: Mil. Engineer, v. 40, p. 162–164. *See* annotation, Wilson, W. K., Jr., 1948a.

Wimmler, N. L., 1927, Placer-mining methods and costs in Alaska: U.S. Dept. Commerce, Bur. Mines Bull. 259, 236 p.

No permanently frozen ground is found along the Pacific littoral. In Southwestern Alaska, back from the coast, permanent frost is seldom met except in a few isolated areas of deep ground mantled with moss and thick overburden. East and north of the Alaska Range in the Yukon and Kuskokwim Basins and on the Seward Peninsula, most of the deposits are permanently frozen, especially where covered with moss and muck. The ground may be solidly frozen to bedrock, and some places are known where this condition extends to depths of 400 or more feet. The shallower creek deposits up to 10 ft or so deep, especially those which are mostly gravel and have no covering of moss and muck, are usually free of permanent frost. The beds of the larger watercourses are generally unfrozen, although there may be irregular frozen patches; but the ground in the flats adjacent to such streams is in many places solidly frozen. The gravel benches along the valley walls and the deep creek placers often develop, through drainage, thawed areas which may form more or less defined streaks or channels or may be irregular. Such drainage may be natural, or, as on some of the creeks, subsequent mining has created drainage resulting in the thawing of much gravel. It is not uncommon to find thawed gravel overlain by frozen muck or overburden. Although the rule is not infallible, thawed areas are generally found underlying heavy growth of willows, particularly on the Seward Peninsula.—Author's report, p. 63.

Under the average conditions muck contains 25–40 percent organic matter, fine silt, sand, and 60–75 percent ice. The average frozen gravel contains 10–20 percent ice, although some may contain more ice, and some may contain less than 5 percent where the material is fine or tightly packed. In places where the voids are only partly filled, the material is called dry frost.

Yehle, L. A. *See* Nichols, D. R., 1959.

Zaikov, B. D., 1934, Run-off in Yakutia [Stok na territorii IAkutskoi ASSR]: Leningrad. Gos. gidrolog. inst. Zap., v. 12, p. 35–61.

Physiographical conditions of the area are described, and their influence on annual runoff is analyzed. Data on the average maximum depth of snow cover and of seasonal variations in runoff are tabulated. The location of Yakutia in the permafrost zone tends to keep the runoff ratio of snow melt close to 1. The thin quickly saturated active layer causes a heavy runoff of rainwater. Average maximum depth of snow cover varies from 15 to 64 cm. Naleds are formed in areas of light snow cover where rivers often freeze solid. Permafrost thickness up to 50–114 m and more causes low runoff of ground water. The highest rate of ground-water runoff was observed in the Aldan River, where many thawed spaces occur within the permafrost. The lowest runoff of ground water was measured in the Vilyui and Yana Rivers, where maximum thickness of permafrost occurs.—From SIPRE 8623.

Zaitsev, I. K., 1958, Some constant features of distribution and formation of underground brines in the territory of the USSR [Nekotorye zakonomernosti rasprostraneniia i formirovaniia podzemnykh rassolov na territorii SSSR]: Vses. geol. inst. Biull. 1, p. 123–136.

Includes data on ground water, its depth and mineralization, in Yakutia, the Angara-Lena basin, Nordvik, the Tunguska basin, and other areas. A map at a scale of 1:5,000,000 shows the distribution of brines and salinity of ground water.—From Arctic Bibliography 62741.

735-894—65——17

Zaitsev, I. K., 1959, The main hydrogeological structures in the territory of the USSR [Osnovnye tipy gidrogeologicheskikh struktur na territorii SSSR]: Sovetskaia geologiia, no. 11, p. 3–15.

A description of the characteristics, types, and regional distribution of ground water. The main types of artesian basins distributed in the platforms, intermountain depressions, and crystalline shields are discussed, including those in the Soviet Arctic.—From Arctic Bibliography 62742.

Zaitsev, I. K., Gurevich, M. A., and Beliakova, E. E., 1956, Explanatory note on the hydrochemical map of Siberia and the Far East [Obiuiasnitel'naia zapiska k gidrokhimicheskoi karte Sibiri i Dal'nego Vostoka]: VSEGEI Trudy, new ser., v. 3, Gosgeoltekhizdat.

Zarubinskii, IA. I., 1957, Survey of water supply sources in the permafrost of the Transbaikal coal-bearing areas [Razvedka istochnikov vodosnabzheniia v usloviiakh mnogoletnei merzloty na zabaikal'skikh ugol'nykh mestorozhdeniiakh], Irkutsk, *in* Materialy po podzemnym vodam Vostochnoi Sibiri: Akad. Nauk SSSR, Vostochno-Sibirskii Filial, p. 149–156.

The characteristics of suprapermafrost and subpermafrost water in the region are described on the basis of surveys conducted in the last 3–5 yr, and the methods of investigation are outlined. Suprapermafrost water is found in alluvial deposits along and under large rivers, where the permafrost table is at a depth of 7–9 m. The water table is located at 0.5–2 m in summer and rises to the surface under pressure in winter. Subpermafrost water is confined to individual geological complexes, such as Mesozoic, Precambrian, and Jurassic deposits, carbonate and crystalline rock, and conglomerate formations. Subpermafrost water has a higher mineral content than suprapermafrost water.—From SIPRE 18014.

1959, Surveying for water sources under the permafrost conditions of the Transbaikal coal bearing areas [Razvedka istochnikov vodosnabzheniia v usloviiakh mnogoletnemerzlykh porod na Zabaikal'skikh ugol'nykh mestorozhdeniiakh], *in* Materialy po inzhernomu merzlotovedeniiu: Akad. Nauk SSSR, Inst. Merzlotovedeniia, p. 137–143.

The distribution, regime, and reserves of suprapermafrost and subpermafrost water in the Chernov and Bukachach coal areas are examined on the basis of surveys in the last 3–5 yr, and surveying methods are described briefly. Subpermafrost water is found in the Bukachach area in Jurassic, Paleozoic, and Precambrian deposits, appearing at the surface as wet spots or springs. Suprapermafrost water occurs as subsurface streams near the Agita River. Subpermafrost water in the Chernov area occurs in Jurassic deposits and the underlying sandy conglomerate without surface indications. Suprapermafrost water in alluvial deposits below and near large rivers does not freeze in winter. The ground-water level is at a depth of 0.5–2 m and rises to the surface in winter because of the pressure exerted by the freezing ground. Subpermafrost water is located directly below the permafrost layer at a depth of not more than 100–130 m and is under high pressure. Water is found in winter by drilling, using brine as the drilling fluid; freezing in the boreholes is prevented by heating or other methods.—From SIPRE 17795.

Zeits, R. F., 1937, Permafrost thickness in the Kolyma region [O moshchnosti vechnoi merzloty v Kolymskom krae]: Akad. Nauk SSSR, Kom. izuch. vechnoi merzloty Trudy, v. 5, p. 179–180.

Deep bore holes were put down on the Utinaia River, a tributary of the Kolyma River, at lat 62°28'N., long 151°05'E., at 503 m above sea level.

During an interruption in the drilling operations the water froze in one of the holes. The depth of the hole was 135 m. Water was added during drilling, but after a 16-day cessation of drilling, ice was encountered in the hole at a depth of 99 m. The ice was drilled through and water was encountered below the ice.—From I. V. Poiré, unpublished abstract, 1947.

Zemtsov, A. A., 1958, Distribution of perennially frozen rocks in western Siberia: Nauchn. Doklady Vysshey Shkoly, Geol.-geograf. nauki, no. 3, p. 190–194.

New data based on drilling between 1952 and 1955 in the central and northeastern sections of the West Siberian lowland shows that two layers of permafrost occur in many places. The upper, near-surface permafrost layer is the result of cooling of the climate in Recent time. The upper surface of the lower, relic permafrost lies at a depth of 60–150 m; the relic permafrost was formed before or during the last ice age and was thawed in its upper portion by the warm climate that followed the last ice age. Regional distribution of permafrost from north to south is as follows: (1) In Zapol'yar'ye there is a continuous layer of permafrost more than 200 m thick; (2) between the Arctic Circle and 62°N. lat are 2 layers of permafrost, the upper surface of the lower layer is at a depth of 60–100 m; and (3) south of lat 62°N. the upper surface of permafrost lies at a depth of 100–150 m. According to this data, the southern boundary of the area of relic permafrost in certain regions should be shifted south to latitude 60°30'N.—From Translation OTS 59–11643, Office of Technical Service, Dept. Commerce.

1959, Fossil permafrost in the western Siberian plain [Reliktovaia merzlota v zapadno-sibirskoi nizmennosti], *in* Lednikovyi period na territorii Evropeiskoi chasti SSSR i Sibiri, Geog. fak. i Muzei zemlevedeniia, Moskovskii Gos. Univ.: Moscow, Izd. Moskovskogo Univ., p. 331–334.

The results of long-period studies in west Siberia are reported, and data on the depth of the permafrost table and the thickness of permafrost in six areas are tabulated. A map showing the permafrost limit in the area is included. The permafrost table was found at depths from 1 to 228 m, being shallowest in the north (1–2 m at the mouth of the Taz River) and gradually becoming deeper toward the south (228 m at Var-Egan on the Agan River). The thickness of permafrost ranged from 39 m to more than 200 m. These findings point to the fossil nature of this permafrost, which is several kilometers south of the southern permafrost limit established by Sumgin. The permafrost limit recedes to the north in the eastern part of the plain. The permafrost probably originated during the Taz glaciation as a belt around the Taz Glacier. Geomorphological and geological evidence points to the degradation of the permafrost.—From SIPRE 17561.

1960, Deep-lying permafrost in western Siberia [Glubokozalegaiushchie tolshchi mnogoletnermerzlykh gornykh porod v Zapadnoi Sibiri]: Akad. Nauk SSSR Izv., Ser. geog., no. 4, p. 89–93.

The results of new studies on the distribution of permafrost in western Siberia are reported. Data are tabulated and graphed on the thickness of permafrost and the depth of its upper and lower boundaries at eight locations, and the lithologic and stratigraphic profile at three locations; a map of the distribution and southern limit of permafrost in the region is included. Three latitudinal permafrost zones are distinguished in western Siberia. The first above the Arctic Circle, is characterized by continuous permafrost more than 300–350 m thick, which is still in the process of aggradation. The second zone is located south of the Arctic Circle to 62°N. lat where two permafrost layers are found with the upper boundary of the lower, fossil permafrost layer, being located at a depth of 60–100 m. South of 62°N. lat to 60°30′N. lat permafrost is located at a depth of 100–200 m and more, is of the fossil type, and in the process of degradation. The discovery of this deep-lying permafrost layer sets the southern limit of permafrost several kilometers more to the south than determined by Sumgin and Popov.—From SIPRE 18602.

Zhdanova, E. I., 1959, Results of observations on ground water levels, and soil temperature and moisture in the flood valley of the Yakhroma River [abs.] [Resul'taty nabliudenii za urovnem gruntovykh vod, temperaturoi i vlazhnost'iu pochvo-gruntov v poime reki IAkhromy]: Moskovskii Inst. inzhenerov vodnogo khoziaistva, Inf. Sbornik 1, p. 16–17.

The results of studies in the autumn-winter-spring period at various points in this valley (Moscow region) are reported. Ground water began to rise at the beginning of snow melting, indicating the existence of unfrozen soil. The soil began to thaw first from the bottom and then from the surface (after the disappearance of snow). Mineral soil was completely thawed 10 days earlier than peaty soil. A considerable amount of moisture (1,000 cu m per hectare) accumulated in the freezing layer during autumn and winter, half of which was lost on evaporation during the melting period. Vertical ice lenses formed in a dry peat bed, while horizontal ice layers were found in an undrained swamp.—From SIPRE 18364.

Zhukov, V. F., 1950, Typical accidents occurring in the sinking of inclined shafts in permafrost [Kharakternye avarii pri prokhodke polonnykh shakhtnykh stvolov v usloviiakh vechnoi merzloty]: Akad. Nauk SSSR, Otdel. tekh. nauk Izv., no. 9, p. 941–946.

Construction of vertical and inclined mine shafts in areas of continuous and deep permafrost can be accomplished with relative ease without extensive timbering and shaft lining. Vertical shafts are recommended in areas with sporadic permafrost. Inclined shafts require 7–10 m of permafrost between the axis of the shaft and the active layer. Accidents were caused primarily by the lack of knowledge of permafrost profiles and the ground-water conditions.—From SIPRE U–3106.

1958, The concepts of "zero curtain" and "temperature inertia of soil" [Po povodu poniatsii "nulevaiia zavesa" i "temperaturnaia inertsiia pochvy"]: Akad. Nauk SSSR Izv., Ser. geog. no. 5, p. 98–102.

The validity of terms as used by Chekotillo, Stotsenko, and Ignatenko, and others is examined critically; inconsistencies in the studies of these authors are pointed out; and the true meaning of these terms and their applicability are discussed. Neither of the terms as used recently explains the physical processes involved in soil freezing and thawing, and confuse the issue. "Zero curtain," introduced by Sumgin as characterizing the effect of soil moisture on seasonal freezing and thawing as a result of the heat of crystallization and melting of ice, should be understood as the change in the heat content of the freezing layer in the heat balance equation:

$$A = B + C$$

A is the quantity of heat lost through the freezing layer to the atmosphere;
B the quantity of heat suppiled by the lower unfrozen layer; and
C the "zero curtain."

The "temperature inertia of soil" as used by Chekotillo to mean the long-lasting stability of soil temperature at a certain depth in winter does not conform to the classical determination of Newton's law of inertia, which expresses the tendency of a body to retain its state, and not the state in which the body exists. The terms "zero curtain" and "temperature inertia of soil," as used in certain literature, erroneously express the meaning of the concepts and should be eliminated from scientific terminology. (See Chekotillo, 1955b; Sumgin and others, 1940.)—From SIPRE 17095.

Znamenskii, V. A., 1959, Certain characteristics of the hydrogeology of the Sangar coal-bearing area, Yakutia [Nekotorye osobennosti gidrogeologii raiona Sangarskogo kamennougol'nogo mestorozhdeniia v Yakutii], *in* Materialy po obshchemu merzlotovedeniiu: Akad. Nauk SSSR, Inst. Merzlotovedeniia, p. 142–145.

The hydrogeological conditions of the area are described on the basis of observations during a 10-yr period in more than 200 boreholes 100–500 m deep. The area is located in a region of continuous permafrost up to 207 m thick (except under the Lena River) with subpermafrost ground water circulating in fissures and through the pores of loose deposits, sometimes under pressure. The ground water yield is insignificant and cannot serve as a possible source of water supply for a large industrial area. The results of analyses on the chemical composition of the water are described and tabulated.—From SIPRE 17940.

Zonov, B. V., 1944, Naleds and polynyas on rivers of the Yana-Kolyma mountainous area [Naledi i polyni'i na rekakh IAnsko-Kolymskoi gornoi strany]: Akad. Nauk SSSR, Inst. Merzlotovedeniia im. V. A. Obrucheva Trudy, v. 4, p. 33–92.

The physiography of this permafrost area and the ice conditions in the rivers are described, and their influence on naleds and polynyas is analyzed. Severe winters, scant snow cover and rivers freezing solid for short stretches cause the naleds, which vary in type and size depending on the relief and river runoff. Polynyas in widespread areas of the Yana-Kolyma region are associated with the local influx of warm ground water, in particular with warm springs flowing through fissures in permafrost.—From SIPRE 11672.

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