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GEOLOGY OF THE CHITINA VALLEY AND ADJACENT AREA ALASKA

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GEOLOGY OF THE CHITINA VALLEY AND ADJACENT AREA, ALASKA

By Fred H. Moffit

ABSTRACT

The Chitina Valley and adjoining area form part of a rugged alpine region in the southeast corner of the main body of Alaska and include a portion of the Chugach Mountains and most of the southern half of the Wrangell Mountains, to the north. The Chitina River is an eastern branch of the Copper River and rises in ice fields and valley glaciers occupying most of the country near the international boundary north of Mount St. Elias. The adjoining area described in this report includes the Hanagita and Bremner River district and the westward continuation of the north side of the Chugach Mountains as far as Valdez Arm and Klutina Lake. In addition, the geology of the upper White River district is described because of its relation to that of the Chitina Valley.

The rocks of the area are dominantly bedded and are largely of sedimentary origin, although extensive areas of lava flows and tuff are included with the bedded rocks. Granitic and dioritic intrusive rocks are widely distributed in the area, yet they occupy only a relatively small part of it.

The rocks described range in age from late Paleozoic to Recent and show all stages of metamorphism between schist and gneiss, on the one hand, and fresh lava flows and unconsolidated clay, sand, and gravel, on the other. The oldest rocks that have been recognized are of Mississippian age. They include altered lava flows and tuffs and extensive areas of schistose sedimentary rocks, slate, and limestone, all cut by granular igneous intrusives of varied character. They occupy the axial part of the Chitina Valley and the north slope of the Chugach Mountains.

The older Paleozoic sediments and volcanic rocks were followed by a thick accumulation of Permian lavas and tuffs in which there are highly fossiliferous limestone beds and a little slate. Such rocks are widely distributed in the upper Nizina and White River areas and bear evidence of a time when the forces of volcanism dominated over the more ordinary processes of weathering and accumulation. The violent outbursts that yielded the alternating tuff beds and thin lava flows of the lower part of the section were followed by a more quiet welling forth of lavas that yielded the next succeeding formation. The Nikolai greenstone, well known because of its copper prospects, is a great accumulation of lava flows representing, at least in part, the final stages of Permian volcanic activity in this district. Possibly also it may represent a continuation of the same kind of activity into Mesozoic time and is therefore partly of Mesozoic age. The Nikolai greenstone is exposed chiefly along the north side of the Chitina Valley.

Rocks of unquestioned Mesozoic age were laid down in Upper Triassic, Jurassic, and Lower Cretaceous time. The oldest of them are the Chitistone and Nizina limestones and the overlying McCarthy shale, which together constitute the

finest section of Upper Triassic rocks in Alaska. The Chitistone limestone is an excellent horizon marker but is best known because it is the host rock for the Kennecott copper ores and other similar copper deposits in the Chitina Valley. The limestones and shale have much the same distribution as the Nikolai greenstone, which they overlie with structural conformity but with a probable discontinuity in time.

A great unconformity marks the boundary between Triassic and Cretaceous sedimentary rocks and probably also the boundary between Triassic and Jurassic. The Jurassic sedimentary rocks are much less extensive than the Cretaceous, occur in small scattered areas, and are imperfectly known, so that a clear understanding of their relations to the older and younger rocks is lacking. The Jurassic rocks include a small area of tuffaceous slate and conglomerate near the mouth of the Chitina River, containing the Middle Jurassic Tuxedni fauna; two small areas of black slate on McCarthy Creek, with the Upper Jurassic Naknek fauna; and isolated areas of sandstone, conglomerate, and limestone of probable Upper Jurassic age in the Kotsina-Kuskulana district. Considerable areas of rocks that were once referred to the Upper Jurassic are now regarded as younger and are included with the Cretaceous.

Rocks of Cretaceous age are widely-distributed in the area but are most abundant in the part of it on the north side of the Chitina Valley that extends eastward from the Kuskulana River. They include thick deposits of shale, sandstone, and conglomerate and are now referred to the Lower Cretaceous epoch, contrary to the former assignment of part of them. In general these rocks are less folded than the Upper Triassic and other underlying rocks, on the beveled edges of which they rest, but the softer shale members show much more distortion than the sandstone and conglomerate, which, especially in the localities where the greatest accumulation took place, are only slightly tilted.

A very widespread group of sediments, including the great succession of slate and graywacke beds that make up most of the Chugach Mountains and have been known as the Valdez and Orca groups of Prince William Sound, are provisionally assigned to the Mesozoic, because the work of recent years has indicated that probability, and definite evidence of Cretaceous age for part of the rocks north of Prince William Sound has been found.

In Tertiary time an outpouring of lavas began in the Wrangell Mountain area. The first of the molten lavas flowed over an old land surface of probable moderate relief that resulted from a long period of subaerial erosion. Succeeding flows buried the old surface to a depth of several thousand feet, and the extrusion of melted rock and ejection of fragmental material have continued to the present time. The lava beds and the tuff associated with them cap not only the high mountains between Mount Wrangell and Nizina Glacier but extend far to the east over the lower hills in the White River Valley. The nature of the Tertiary land over which the first flows spread is inferred from the fresh-water leaf-bearing clays and gravel deposits that accumulated in the depressions of the old surface. The latest of the volcanic materials were extruded through Quaternary gravel deposits and therefore are of recent date.

All the bedded rocks of the area, including even the Tertiary lava flows, are cut by intrusive rocks ranging in age from Mississippian or post-Mississippian to Recent. Gabbro and other coarse-grained basic intrusives cut the older Carboniferous sedimentary rocks but are uncommon in those of Mesozoic and later age. The most conspicuous and widespread of the igneous intrusives are dikes and sills of granite and diorite, or closely related species, that are distributed through the entire area and invaded the Lower Cretaceous and all older bedded rocks. Probably the granitic rocks represent several periods of intrusion and are connected with more than one period of mineralization.

The most outstanding of the later events in the geologic history of the area is the glaciation that began after most of the Wrangell lava had been erupted and is still in progress. Its most conspicuous effects are the result of its influence in the forming of the present topography and include, among others, mountain sculpturing, morainal deposition, and stream diversion.

The Chitina Valley is important as a producer of copper and gold and has possibilities for the production of other mineral wealth. This report describes the mode of occurrence of the mineral deposits and makes suggestions for prospectors in search of them, but it does not contain detailed descriptions of mines and prospects, as information of that kind has been given in earlier reports in a more extended form than is suitable for this summary statement.

INTRODUCTION

"Chitina" is the native Alaskan name for the large eastern branch of the Copper River or the Atna, as it was called by the original inhabitants of the region. The name is composed of two words, "chiti" and "na", which mean copper and river. Long before the coming of white men native copper was found by the Indians on tributaries of the Chitina River and was used by them for making such implements as knives, needles, spearheads, and arrowheads. It thus came to the notice of the early Russian explorers and finally led to the discovery of widely distributed evidences of copper mineralization and the development of one of the richest copper mines the world has known. The name "Chitina" therefore is appropriate for the river and its valley.

This rapid, silt-laden stream starts from glacial sources in the high mountains about the international boundary north of Mount St. Elias and flows west-northwestward for more than 100 miles to its junction with the Copper River, receiving much additional drainage from the Chugach Mountains on the south and from the Wrangell Mountains on the north. Its course is nearly parallel to the trend of the Chugach Mountains and to the stretch of Pacific coast line 100 miles to the south, and it drains an area about 120 miles long by 50 miles wide, not including the small part of the basin on the Canadian side of the international boundary. The relation of the Chitina Valley to the rest of Alaska may be seen from the index map (fig. 1).

Although the Chitina Valley is the area of prime consideration in the following descriptions, its geology is so closely related to that of the Hanagita and Bremner Valleys on the south, the Tonsina district on the west, and the White River district on the northeast that these bordering districts will receive consideration also.

The search for valuable metals in the Copper River Basin began in 1898. Copper and gold were the lures that led the early prospectors into the basin and in later years justified their labor by adding many millions of dollars to the value of Alaska's mineral output.

The importance of obtaining information about the mineral deposits of the Chitina Valley was early recognized by the United States

Geological Survey and led to the undertaking of topographic and geologic surveys, which have been carried on intermittently for more than 30 years. The writer has had a part in this work since 1907 and as a result of this experience has prepared the summary report which is here presented. The purpose of this paper is to bring together information about the geology and mineral resources of the Chitina Valley and bordering areas which is scattered through a considerable number of earlier reports, most of which are now out of print, to make corrections which later work has shown to be required in the assignment of formations to positions in the stratigraphic column, and to add new information concerning the geology and mineral resources which has been collected in recent years. Although two small areas, the Kotsina-Kuskulana and Nizina districts, have been surveyed in more detail than the rest of the area, the results here given must still be looked on as reconnaissance work, which is subject to revision as more detailed and accurate surveys are made. In fact, some parts of the territory considered have not yet been mapped by a topographer nor examined by a geologist.

PREVIOUS WORK

The earliest authentic information concerning the geology of the Chitina Valley was gained through the labors of two exploring expeditions, one conducted by Lt. Henry T. Allen (the late Major General Allen), under authority of the War Department in 1885, the other by Lt. Frederick Schwatka, of the United States Army, and C. Willard Hayes, of the United States Geological Survey, working in the interest of a syndicate of newspapers in 1891. Lieutenant Allen ascended the Copper River to Taral and the Chitina and Nizina Rivers to the mouth of Dan Creek. Then returning to Taral he went up the Copper River to Batzulnetas, near its head, crossed the divide to the Tanana River, descended that stream to the Yukon, and made a further exploration of the Koyukuk River before finally reaching St. Michael. This entire trip was completed in one season and is one of the most remarkable explorations ever made in Alaska.

Schwatka and Hayes reached the Chitina Valley from the east. They proceeded by way of the Taku River to the Teslin and Yukon Rivers as far as Fort Selkirk. Thence they made their way overland to the head of the White River, crossed the mountains through Skolai Pass to the Nizina River, and then descended the Chitina and Copper Rivers, finishing the exploration at Orca, near the present town of Cordova, on Prince William Sound. Both of these explorations were made under great difficulties involving hardship and danger, and as most of the time was given to the labor of overcoming the obstacles to travel, the geologic observations were of the most general character. In 1898 Frank C. Schrader, of the Geological Survey, was assigned to the Copper River military exploring expedition under Capt. W. R. Abercrombie and made an exploratory trip which began at Valdez and reached interior Alaska by way of Valdez Glacier and the Klutina River Valley. The exploration was then carried down the lower Copper River Valley to the mouth of the Tasnuna River and thence to Valdez through the Tasnuna and Lowe River Valleys.

An expedition yielding much more specific geologic information relating to the Chitina Valley was conducted by Oscar Rohn in 1899. This expedition was also part of the work of the exploring expedition in

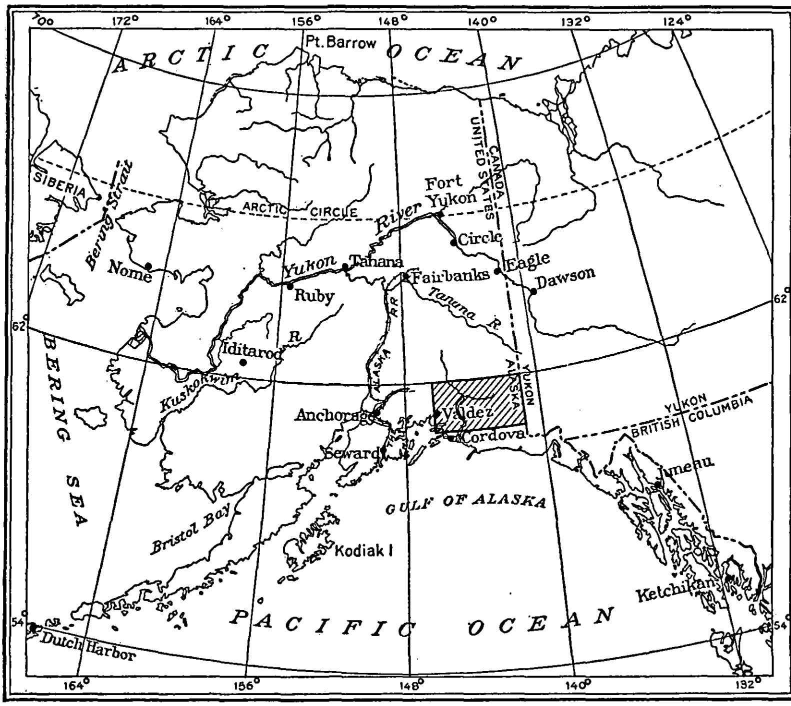


FIGURE 1.—Sketch map of Alaska showing the location of the Chitina Valley and adjacent area described in this report.

charge of Captain Abercrombie, but the geologic results were published by the United States Geological Survey. Rohn's route lay along the flanks of the Wrangell Mountains from the Kuskulana River to Nizina Glacier, thence up the glacier and across the divide to the Chisana, Nabesna, and Copper Rivers, and thus back to Valdez. His observations laid the groundwork for much of the work that followed and gave rise to many of the formation names now applied to the rocks of the Chitina Valley.

In 1900 systematic investigations were begun by the Geological Survey, and reconnaissance topographic and geologic maps of the lower Chitina Valley and of the Hanagita Valley, based on the work of that year, were later published. The topographic surveys were made by T. G. Gerdine and D. C. Witherspoon, the geologic surveys by F. C. Schrader and A. C. Spencer. Additional information on the Kotsina River was collected by W. C. Mendenhall in 1902, and the whole copper belt from the Kotsina to the Chitistone, together with the gold placers of Dan and Chititu Creeks, was revisited by F. H. Moffit and A. G. Maddren in 1907. A detailed topographic map of the Nizina district was made in 1908 and one of the Kotsina-Kuskulana district in 1912 and 1913, both by Witherspoon. Detailed geologic surveys of these same areas were made by S. R. Capps and Moffit in 1909 and by J. B. Mertie, Jr., Theodore Chapin, and Moffit in 1912 and 1914. A reconnaissance survey of the White River was made by Adolph Knopf, Capps, and Moffit in 1908, but the material relating to the White River used in this paper is based chiefly on topographic and geologic surveys made by C. E. Giffin and S. R. Capps in 1914. Additional topographic mapping was done by Witherspoon in the Hanagita and Bremner Valleys in 1911 and in upper Chitina Valley by R. M. Overbeck and Moffit in 1915. In 1914 G. C. Martin and Overbeck collected Mesozoic fossils from various localities north of the Chitina River from the Kotsina to the Nizina. Finally the writer, in addition to the work mentioned above, has spent all or a major part of six seasons, 1916, 1919, 1922, 1926, 1927, and 1928, in geologic investigations in some part of the Chitina Valley and the season of 1932 in the Tonsina district.

In giving this account of investigations in the Chitina Valley and adjacent areas there is no intention to slight the work of others not connected with a Government organization. Considerable work, mostly relating to ore deposits, has been done by mining engineers, but this work was nearly all done for private individuals and not for publication. Several accounts have been printed, however, and three are mentioned in the following list of papers. This list is made up of the more important papers dealing with either the geology or the mineral resources of the area, but it omits some short papers and many minor references to be found in publications of the Geological Survey. Most of the papers include topographic maps, to which reference has been made above, but a list of the original topographic maps is also given.

PAPERS DEALING WITH THE GEOLOGY AND MINERAL RESOURCES OF CHITINA VALLEY AND ADJACENT AREAS

Allen, H. T., Report of an expedition to the Copper, Tanana, and Koyukuk Rivers, in the Territory of Alaska, in the year 1885, Washington, Government Printing Office, 1887.

Hayes, C. W., An expedition through the Yukon district: Nat. Geog. Mag., vol. 4, pp. 117–162, 1892.

Rohn, Oscar, A reconnaissance of the Chitina River and the Skolai Mountains, Alaska: U. S. Geol. Survey 21st Ann. Rept., pt. 2, pp. 393–440, 1900.

Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska: U. S. Geol. Survey Special Pub., 1901.

Mendenhall, W. C., and Schrader, F. C., The mineral resources of the Mount Wrangell district, Alaska: U. S. Geol. Survey Prof. Paper 15, 1903.

Mendenhall, W. C., Geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, 1905.

Keller, H. A., The Copper River district, Alaska: Eng. and Min. Jour., vol. 85, no. 26, pp. 1273–1278, June 1908.

Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, 1909.

Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska, with a section on the Quaternary, by S. R. Capps: U. S. Geol. Survey Bull. 417, 1910.

Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, 1911.

Moffit, F. H., Geology of the Hanagita-Bremner region, Alaska: U. S. Geol. Survey Bull. 576, 1914.

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

Moffit, F. H., The upper Chitina Valley, Alaska, with a description of the igneous rocks by R. M. Overbeck: U. S. Geol. Survey Bull. 675, 1918.

Moffit, F. H., Mining in the lower Copper River Basin: U. S. Geol. Survey Bull. 662, pp. 155–182, 1918.

Bateman, Alan, and McLaughlin, D. H., Geology of the ore deposits of Kennecott, Alaska: Econ. Geology, vol. 15, no. 1, pp. 1–80, January 1920.

Moffit, F. H., and Mertie, J. B., Jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745, 1923.

Moffit, F. H., The metalliferous deposits of Chitina Valley: U. S. Geol. Survey Bull. 755, pp. 67–72, 1924.

Martin, G. C., The Mesozoic stratigraphy of Alaska: U. S. Geol. Survey Bull. 776, 1926.

Lasky, S. G., Transverse faults at Kennecott and their relation to the main fault systems: Am. Inst. Min. Met. Eng. Tech. Pub. 152, 17 pp., November 1928; Trans., 1929, Year Book, pp. 303–317.

Moffit, F. H., Notes on the geology of upper Nizina River: U. S. Geol. Survey Bull. 813, pp. 143–166, 1930.

Moffit, F. H., Geology of the Tonsina district, Alaska: U. S. Geol. Survey Bull. 866, 1935.

ORIGINAL TOPOGRAPHIC MAPS FROM WHICH THE MAP OF CHITINA VALLEY AND ADJACENT AREA CONTAINED IN THIS REPORT WAS COMPILED

[The report in which the new work first appeared is stated]

Chitina River and Copper River region; reconnaissance map; scale 1:250,000; by T. G. Gerdine and D. C. Witherspoon; surveyed in 1900. In special publication by Schrader and Spencer.

Central Copper River region; reconnaissance map; scale 1:250,000; by T. G. Gerdine and W. C. Mendenhall; surveyed in 1902. In Professional Paper 41.

Nizina district; detailed map; scale 1:62,500; by D. C. Witherspoon and R. M. Lafollette; surveyed in 1908. In Bulletin 448.

Chitina quadrangle; compiled and extended reconnaissance map; the new work covering the Hanagita and Bremner Valleys was surveyed by D. C. Witherspoon in 1911. In Bulletin 576.

Kotsina-Kuskulana district; detailed map; scale 1:62,500; by D. C. Witherspoon; surveyed in 1912 and 1913. In Bulletin 745.

Chisana-White River district; reconnaissance map; scale 1:250,000; by C. E. Giffin; surveyed in 1914. In Bulletin 630.

Upper Chitina Valley; reconnaissance map; scale 1:250,000; by T. G. Gerdine, D. C. Witherspoon, International Boundary Commission, and F. H. Moffit; surveyed in 1900, 1908, 1913, and 1915. In Bulletin 675.

Tonsina district, Alaska; reconnaissance map; scale 1:250,000; by C. F. Fuechsel and J. W, Bagley; surveyed in 1912, 1915, 1931, and 1932. In Bulletin 866.

The maps listed above contain the first published results of the different topographic surveys, and all have been used in compiling the base map that accompanies this report (pl. 1), although not all the maps based on these surveys are listed. The conditions under which the surveys were made, the long period of years through which the work was carried on, and the fact that to a certain degree each survey was begun and conducted independently of the others inevitably led to discrepancies in horizontal and vertical control and have made the adjustment of one map to the others a matter of great difficulty. This difficulty would not have arisen if a primary triangulation system could have been established before the topographic work was done, and it cannot be satisfactorily overcome until such a system is established.

The writer is indebted for suggestions and assistance to all the workers who preceded him in this area, and especially to those who have been associated with him in continuing the investigations. More favorable conditions for field work and more time for carrying it out have made possible the revision and extension of the observations of earlier workers, thus clarifying many points that were doubtful and giving a better conception of the distribution and structure of the geologic formations than was possible before.

GEOGRAPHY

The area to be described includes all of the Chitina Valley within the boundaries of Alaska except the high mountains a few miles back from the flood plain of the Chitina River above the Tana River and Canyon Creek. It also includes certain adjacent areas that are part of the general district or are tributary to it—namely, the head of the White River, a part of the Bremner River Valley, and the Tonsina district. This part of Alaska (pl. 1) is preeminently a region of high, rugged mountains, narrow valleys, and swift glacier-fed streams. The great ice rivers on the northwest flanks of Mount St. Elias and in the amphitheater between the high peaks of Mounts St. Elias, Logan, and Natazhat are part of one of the greatest ice fields of the continent. Some of the highest mountains of Alaska are grouped around the valley, and only in the western part, where it opens into the wide basin of the Copper River, is there a suggestion of any considerable area of low relief.

The area is commercially important because of its mineral resources, which so far as developed include copper, gold, and silver. The roads and trails leading to it were established because of these resources, and the distributing points for supplies within it were determined in accordance with their distribution. Some account of these features, as well as of the obvious natural features of the district, including its climate and vegetation, is therefore necessary for a clear picture of it.

RELIEF

The character of the relief of the region has already been suggested in the statement that this area comprises a part of the Chugach and Wrangell Mountains. The Chugach Mountains are part of the Coast Range system, merging into the St. Elias Range toward the east and continuing around Prince William Sound to the Kenai Peninsula on the west. The Wrangell Mountains are an independent group, partly of volcanic origin, lying between the Chugach Mountains and the main Alaska Range, north of them, but are not clearly marked off from the Nutzotin Mountains to the east. These two mountain areas are separated by the open valley of the Chitina River, which extends westward from the international boundary to the broad basin of the upper Copper River.

The highest points within the area are in the Wrangell Mountains and in the mountains between the upper Chitina Valley and the White River, where several peaks ranging from 12,000 to over 16,000 feet are found. Mount Bona (16,420 feet), the highest, is doubtless the least known, as it is also the least accessible. Mounts Blackburn (16,140 feet; pl. 3, *A*), Wrangell (14,000 feet; pl. 4), and Regal (13,400 feet) are the conspicuous peaks of the lower Chitina Valley. They rise above the line of perpetual snow and with the other high peaks of the Wrangell group, Sanford (16,200 feet) and Drum (12,000 feet), must be numbered among the finest mountain groups of Alaska. The mountains south of the Chitina River are less imposing but reach altitudes of more than 8,000 feet. West of the Copper River and in the Tonsina district the topography is much like that of the Chugach Mountains south of the Chitina. Somewhat isolated, smooth-topped mountains border the lowland area on the north margin of the range, but farther south a confused mass of closely crowded, ragged-topped peaks bearing numerous small glaciers makes up the watershed between the streams tributary to the upper Copper River and those flowing into Prince William Sound and the lower Copper River. One or two of these peaks rise above 8,000 feet, but the highest altitudes in this part of the range are found farther west, beyond the limits of the area under consideration.

The Chitina Valley is open, and its floor is fairly even and regular except where the streams have entrenched themselves in it or isolated hills rise above it. The valleys of the minor streams, with few exceptions, are narrow, although in most of them the original V-shaped cross sections have been modified to the characteristic U-shaped section resulting from intense glaciation. In the higher parts of the area, as in the Wrangell Mountains and about the head of the Chitina Valley, the ruggedness of the country is somewhat masked by accumulations of snow and ice, which fill the depressions and seem to reduce the inequalities of the land surface.

A clearer idea of the relief of this area will be obtained from a comparison of the altitudes of the higher peaks that have been mentioned with the elevations of different parts of the valleys. The mouth of the Bremner River is 200 feet above the sea, and that of the Chitina is about 450 feet. The town of McCarthy is 1,414 feet; the mouth of Young Creek, 1,421 feet; the mouth of the Chitistone River, 1,733 feet; the head of the Chitina River, at the foot of the glacier, 2,000 feet; the surface of Klutina Lake, 1,790 feet; and that of Tonsina Lake, 1,930 feet. From these figures it is readily seen that the relief is great and that the high peaks rise far higher above the local baselevel of the nearby valleys than many better-known peaks in other, more frequented regions. A view from almost any high point within the area gives the impression of an endless succession of mountain tops stretching away as far as the eye can follow.

DRAINAGE

The region is drained by several streams, of which the larger ones to be considered are the Copper, Chitina, White, Bremner, Tonsina, and Klutina Rivers, together with some of their tributaries, particularly those belonging to the Chitina. The Copper River is not one of the larger streams of Alaska, notwithstanding the prominence it has attained in the literature. Its drainage basin covers a little more than 23,000 square miles, or 4 percent of the area of the Territory. The Chitina Valley makes up nearly one-third of this basin. The Copper River headwater streams rise in the north side of the Wrangell Mountains and the south slopes of the adjacent Alaska Range. The river sweeps around the west side of the Wrangell Mountains in a great half circle, through a wide open basin, to its junction with the Chitina River, whence it crosses the barrier of the Chugach Mountains to the Gulf of Alaska through a crooked, open canyon about 100 miles long. Much of its water, like that of the Chitina, comes from melting glacier ice and is heavily laden with silt. The current is swift except at the mouth and in the stretch between the Bremner River and Abercrombie Rapids, where it is dammed back by Allen and Miles Glaciers. The upper part of the Copper River, unlike the canyon section, is entrenched in unconsolidated deposits and in many places is confined within high banks of sand, gravel, and unassorted glacial deposits.

Neither the Copper River nor the Chitina may properly be called navigable streams, although several light river steamers were operated on them in the construction days of the Copper River & Northwestern Railroad. These boats were built to meet an emergency and were abandoned as soon as the need for them was ended.

The principal tributaries of the lower Copper River are roughly parallel to the Chitina River—that is, their courses except in their upper parts are a little south of east on the west side of the river and a little north of west on the east side. A study of the topographic map brings out the fact that in much of the area (pl. 1) the stream courses form a fairly well defined pattern of rectangularly arranged lines running west-northwest and north-northeast. The Chitina and Bremner Rivers are the two principal streams coming in from the east; the Tasnuna, Tiekel, and Tonsina from the west. A considerable volume of water undoubtedly comes into the Copper River from Miles and Childs Glaciers, but this water empties directly into the river from beneath or at the sides of the ice and is not known as distinct streams.

The Chitina River occupies a well-defined open valley which is nearly straight and trends west-northwest, opening into the broad basin of the upper Copper River. Near the mouth of the Nizina River and thence to the Copper River, the Chitina, like the upper Copper, is deeply entrenched in gravel deposits and the underlying bedrock. Above the Nizina River it flows over a broad flood plain more than 5 miles wide in places. This entire valley was once occupied by a great glacier and shows the broad U-shaped cross section common to many glaciated Alaskan valleys. The Chitina River heads in Chitina Glacier at a point 25 miles west of the international boundary. Logan Glacier, which is the southern branch of Chitina Glacier and crosses the boundary 35 miles north of Mount St. Elias, contributes a part of this drainage, and Barnard and Hawkins Glaciers, coming in from the north a short distance below Chitina Glacier, make a further contribution. The Chitina River has a number of locally well-known tributaries, among which the Tebay, Chakina, Tana, and Kiagna are the largest of those coming from the Chugach Mountains, and the Kotsina, Kuskulana, Chokosna, Lakina, and Nizina with its tributaries the Kennicott and Chitistone are the largest of those coming from the Wrangell Mountains. Nearly all these streams receive part of their water, many of them the larger part, from melting glacier ice. They are consequently loaded with silt and are never clear except in winter, when thawing ceases. The Chitina crowds against the base of the mountains on the south side of its valley in the lower stretches of its course, and its northern tributaries have cut narrow rock-walled canyons across the bedrock floor of the valley to reach it. All the tributaries in their upper parts flow in open valleys over broad gravel flood plains, built up by the debris from the glaciers (pl. 3, *B*).

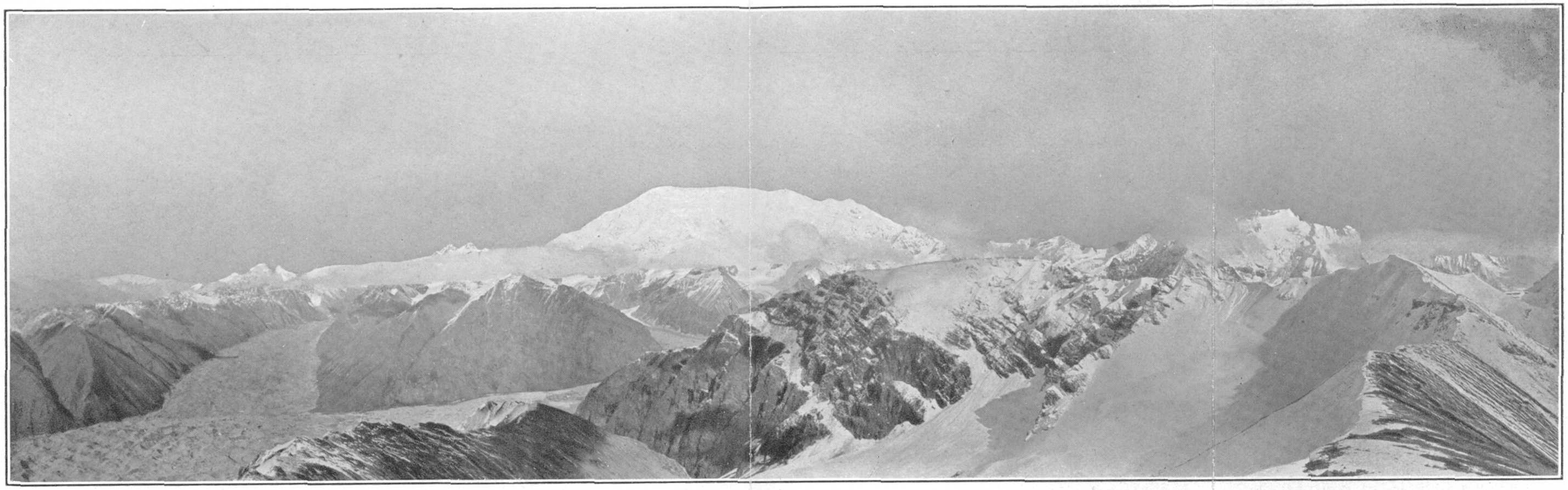
The tributaries of the upper Chitina are less well known than those of the lower river. The Chakina and Klu Rivers cross the head of the Hanagita Valley. The Tana is the largest of those coming in from the south and receives most of its water from glaciers that form part of the vast ice field extending westward from Mount St. Elias. The Kiagna River receives much of its water from a similar source. Among the northern tributaries of the upper Chitina, Barnard Glacier contributes the largest volume of water. The stream from this glacier is variable in position and does not always issue from the same part of the ice front. At times it is a serious obstacle to travel. The streams from Hawkins Glacier and Canyon Creek are smaller streams of no particular note except that Canyon Creek has yielded a little placer gold.

The White River and Skolai Creek, a tributary of the Nizina River, drain Russell Glacier, but the White takes most of the water. This stream flows east and north to the Yukon and is comparable in size to the Chitina. Only its headwaters are considered in this paper.

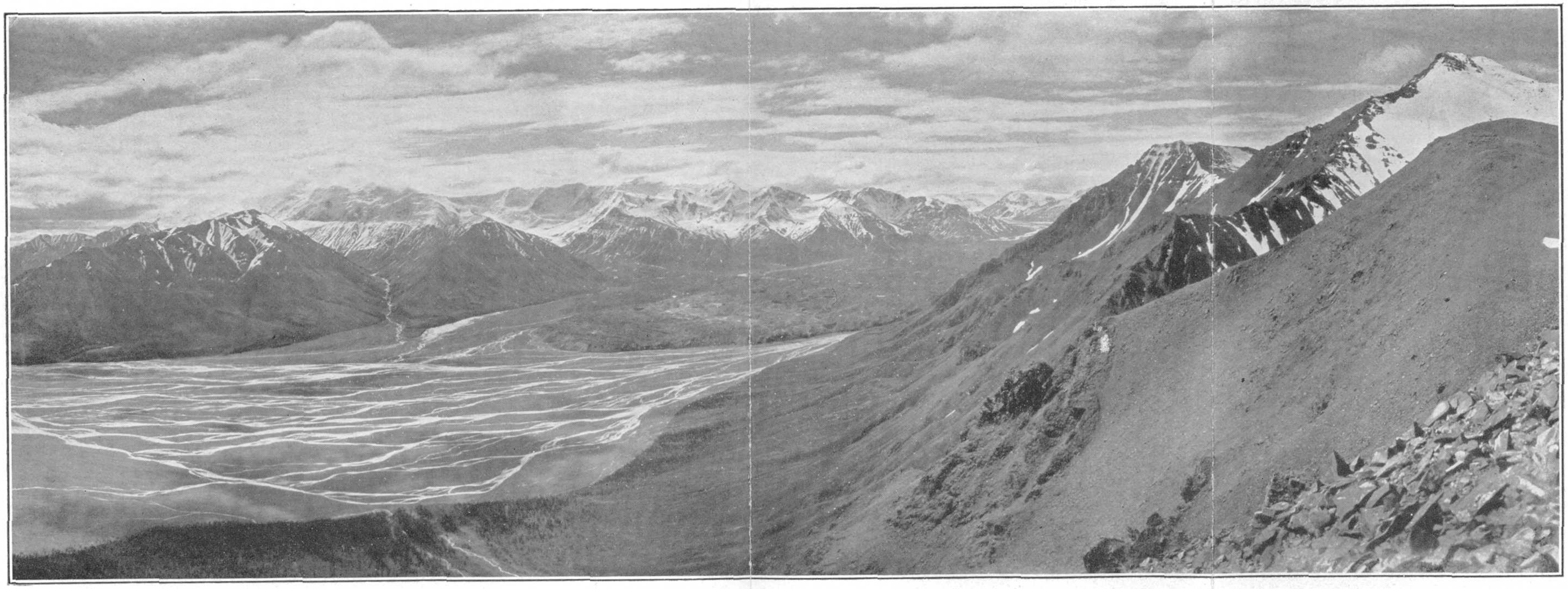
The Bremner River, which lies 25 miles south of the Chitina River and is parallel to it, flows into the Copper River and is another glacial stream. It has two main branches heading in the high mountains west of the Tana River and a small branch called the Little Bremner which comes in from the north near the mouth. Between the Chitina and Bremner Rivers is Hanagita Valley, a minor valley, which is occupied principally by tributaries of the Tebay River.

The Klutina and Tonsina Rivers are glacial streams that originate in the high divide of the Chugach Mountains north of Valdez. They flow northeastward across the trend of the mountains and occupy U-shaped glaciated valleys in their upper courses within the mountain area but bury themselves in deep canyons in the gravel and silt of the Copper River lowland, which they cross to reach the Copper. The Klutina is the larger of the two streams. It heads in glaciers that are continuous with the Valdez Glacier, and its valley thus became part of the route by which the prospectors who landed in Valdez in 1897 and 1898 reached the interior basin of the Copper River before Thompson Pass and the route now followed by the Richardson Highway were discovered. Both the Klutina and the Tonsina flow through lakes that lie within the mountain area and act as quiet settling basins to relieve the streams of part of their load of glacial silt. The valley floors above the lakes are a confusion of swamps and wandering watercourses which are almost impassable in summer. They are gradually encroaching on the heads of the lakes, where the streams drop their loads of gravel and sand.

The Tiekel River is another glacial stream, which receives most of its water from tributaries arising in the same high mountain area as the Tonsina River. The Tiekel, however, flows eastward to the Copper



A. MOUNT BLACKBURN FROM A HIGH POINT ON THE MOUNTAINS NORTH OF SLATKA CREEK.

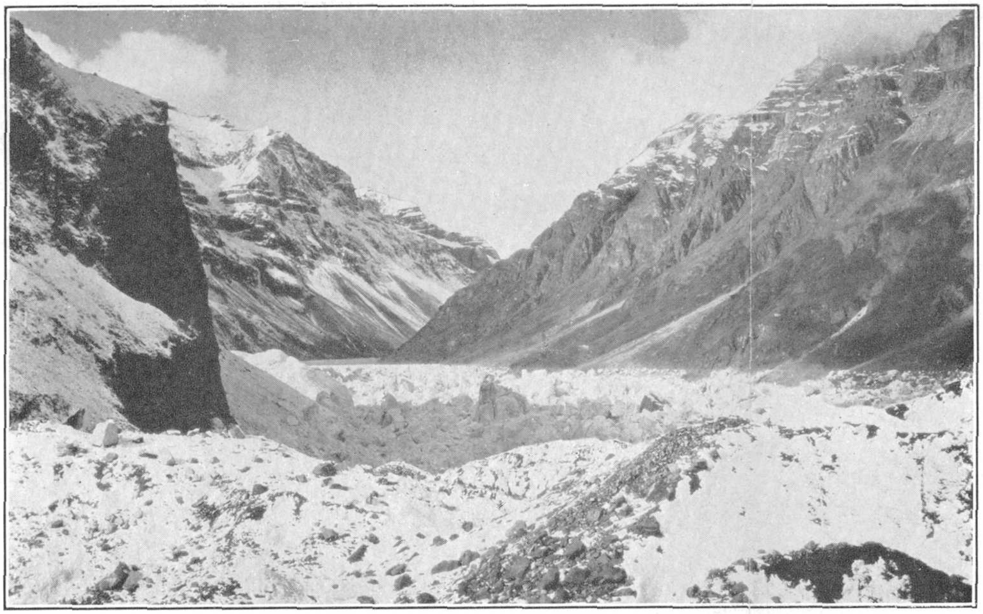


B. RUSSELL GLACIER AND THE HEAD OF THE WHITE RIVER.

View looking southeastward. This picture shows a good example of anastomosing streams.

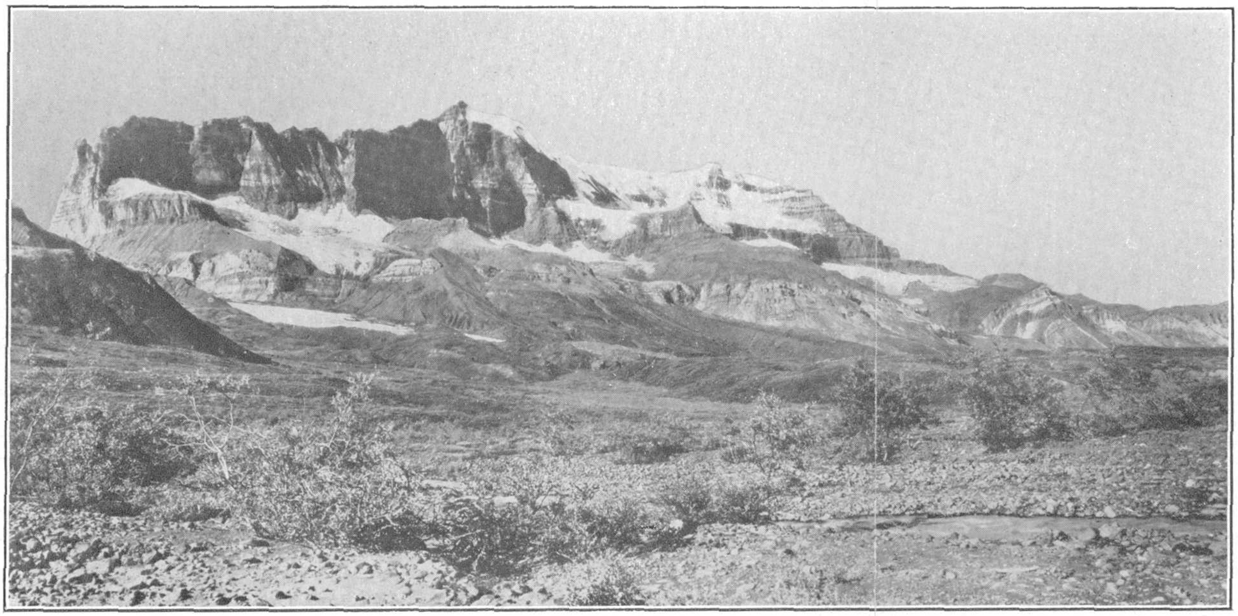
MOUNT WRANGELL FROM THE MOUNTAINS WEST OF THE KLUVESNA RIVER.

Mount Drum on the extreme left. Taken from an altitude of about 6,000 feet.



A. HIDDEN CREEK LAKE, FROM THE WEST EDGE OF KENNICOTT GLACIER.

View westward up the valley of Hidden Creek. The water accumulates because the Kennicott Glacier dams the side valley. It is covered with floating bergs broken from the glacier and drains out periodically beneath the glacier, usually in August.



B. VIEW OF THE MOUNTAINS SOUTH OF SKOLAI CREEK BETWEEN THE SMALL GLACIER OPPOSITE THE MOUTH OF FREDERIKA CREEK AND THE NIZINA RIVER.

Above are Tertiary volcanic rocks. Beneath them are Permian volcanics and the interbedded Permian limestone, indicated by the lower, light-colored cliffs. View to the southwest.

River and joins that stream 30 miles below the mouth of the Chitina. Its lower course is through a deep canyonlike valley, parallel to the trend of the mountains, which is traversed with so much difficulty that few persons have been through it.

Many lakes and ponds are scattered through the Chitina Valley and the other areas under consideration. Almost all of them are of glacial origin. They include lakes that lie in depressions scooped out by the ice in bedrock of the valley floors, lakes that were formed behind dams of gravel filling, lakes that occupy sinks and other depressions in the debris that was dumped on the wide valley floors, and lakes formed by a combination of various factors.

The largest lake of the area is Klutina Lake, which is an L-shaped body of water about 16 miles long and 2½ miles wide at its widest part near the bend. Next after Klutina Lake is Tonsina Lake, which is 6 miles long and over 1 mile wide. Although no lakes approaching these in size are found in the Chitina Valley, many small lakes and ponds are scattered through it, for the uneven valley floor was strewn with unassorted glacial deposits, and the drainage is poorly developed. The largest permanent lake in the Chitina drainage basin is at the head of the Tebay River. It is 4 miles long and three-fourths of a mile wide. Ptarmigan Lake, north of the White River and a few miles west of the international boundary, is of about the same length and a little wider.

Most of the smaller lakes and ponds are caused by irregularities of the land surface due to the dumping of vast quantities of debris carried by the glaciers that formerly filled the valleys. Much of this material was not sorted by the streams and deposited in well-made beds but was left in disorder when the ice melted. Many of the depressions between the mounds and ridges of rock waste are now filled with water.

Another type of lake of special interest is formed where an ice stream in a main valley closes the mouth of a tributary valley free of ice, obstructing the drainage and making a dam behind which the water accumulates. These lakes break out periodically and may cause serious damage to bridges and other structures within the reach of their flood waters. The release of the water is not due to the overflowing of a barrier dam but to the breaking down of some obstruction beneath the ice after sufficient head has accumulated, and as a rule the escaping water does not follow the sides of the glacier but makes its way through courses beneath the ice. The best known lakes of this kind within the area are Skolai Lake, on the east side of Nizina Glacier; Hidden Creek Lake (pl. 5, *A*), which occupies the lower part of the Hidden Creek Valley on the west side of Kennicott Glacier; and a lake at the head of the Kotsina River. Another is formed at times in the Flood Creek Valley on the north side of Russell Glacier, and a much larger one called Barkley Lake is believed to discharge through the Tana River Valley. Barkley Lake is reported to be several miles long at the high stages of water and to empty at irregular intervals of several years, but the information regarding it is meager.

As a rule these glacial lakes break out each year sometime in late summer, after enough water has accumulated to form the head necessary to break through the barrier. The lake on the Kotsina River has been known to break in winter. Skolai Lake has held for 3 years before breaking and during part of the time had a natural overflow at the high-water level. A small lake has usually formed on the north side of Chitistone Glacier, but it disappeared in 1928, owing to the retreat of the ice from the rock wall that deflects the glacier to the southwest. After the barrier preventing the discharge of these glacial lakes gives way the emptying of the basin is rapid, requiring from a few hours to a day, and a great volume of water is released which spreads over the flood plain and piles up in the canyons. Great quantities of ice, some of it rounded like boulders, are left on the river bars. At times much timber is destroyed by the cutting away of wooded gravel benches. The bars of the upper Nizina River were piled up with tangled masses of trees brought down by the flood of 1927. A characteristic effect of such floods is that the river channels in the flood plain are filled with gravel and sand, so that for a short time after the waters have subsided, it is possible to ford even a stream like the Nizina River without getting into deep water.

ROADS AND TRAILS

Valdez, on Prince William Sound, was the port of entry for all the Copper River Basin from the time when the first prospectors landed there, in 1897, till the Copper River & Northwestern Railroad was completed in 1911. During those years supplies for the Chitina Valley were brought by sled over the military trail to Upper Tonsina, thence on the ice of the Tonsina and Copper Rivers to the Kotsina or the Chitina River and so to the Kuskulana, Lakina, Nizina, or other convenient stream for reaching the mining claims. The summer trail led from Tonsina to the Copper River at Billum's Crossing, near the mouth of the Tonsina River, and thence along the north side of the valley to the different camps.

Cordova is now also a port of entry, and the Copper River & Northwestern Railroad provides most of the passenger and freight service to the Chitina Valley, although the Richardson Highway out of Valdez is much used in summer. The railroad is 194 miles long and ends at Kennecott, where it receives much the larger part of its tonnage from the copper mines. A division point is located at Chitina, opposite the mouth of the Chitina River, where a branch of the Richardson Highway provides a connection by automobile with either Valdez or Fairbanks. Strelna, at mile 146, is the supply point for the Kotsina and Kuskulana Rivers. McCarthy, at mile 191, which is the starting point for travelers to the White River and was originally called "Shushanna Junction", is the distributing point for supplies on Dan and Chititu Creeks.

The old pack trail from Billum's Crossing on the Copper River to the Nizina River is no longer used, and much of it is now difficult to follow because of burned timber and washouts. Other old trails within the area have been replaced by wagon or automobile roads where traffic was sufficient to warrant the change. Some of these roads were built by mining companies, and some by the Alaska Road Commission. A wagon road 20 miles long was constructed from Strelna to the copper prospects on Nugget Creek near Kuskulana Glacier. This road is now little used. It has a branch leading to Berg Creek, on the east side of the Kuskulana River, by way of a bridge that was built by the Alaska Road Commission. Another branch built by the Alaska Road Commission leads into the Kotsina Valley. In the Nizina district a road 4 miles long connects the town of McCarthy with Kennecott, and another about 13 miles long follows McCarthy Creek to the old Mother Lode camp. This road was constructed privately but is now controlled by the Alaska Road Commission. The longest road in the district runs from McCarthy to the gold placer mines on Dan and Chititu Creeks. This road also was built by the Alaska Road Commission. It crosses the Nizina River by a long bridge 2 miles west of the mouth of Young Creek. At the roadhouse on May Creek 1 mile east of Young Creek the road forks, one branch going to Dan Creek and the other to Chititu Creek. The trail to the White River leaves the Dan Creek road at Dan Creek and extends north to the Chitistone River, where a choice of two routes is offered. One leads up the Chitistone River to the head of Skolai Creek, part of the way over a high mountain trail commonly known as "the goat trail"; the other leads up the Nizina River to the mouth of Skolai Creek and then up Skolai Pass and the White River. A choice of trails is offered on this route also, for one branch goes along the west side of Nizina Glacier for several miles before crossing the ice to Skolai Lake, and the other keeps to the east side of the glacier and climbs over a high rocky point before coming down to the main trail on Skolai Creek. The Alaska Road Commission built and maintains relief cabins for winter travelers at the lower end of Nizina Glacier, at the mouth of Frederika Creek, and at the head of Skolai Creek.

A trail from the Nizina River bridge to the upper Chitina River was laid out by the Alaska Road Commission and has had a little development work done on it. It runs through the lowlands west of Young Creek to the river bars, instead of crossing the divide between the head of Young Creek and the Chitina River, like the trail formerly used. Little money has been available for improving this trail, but the results of the expenditure so far have been of much help to the prospectors using it.

Numerous shorter trails have been built throughout the district, but for the most part they were not intended for public travel and need not be described. The trails through the Hanagita and Bremner Valleys should be mentioned, although they have been traveled so little in recent years that it is doubtful whether parts of them could be followed now. Starting at the crossing of the Copper River at Taral, below Chitina, a trail ascends Taral Creek and crosses the divide to the Hanagita Valley. It then goes east to Monahan Creek and to Golconda Creek, from which it leads by way of the Bremner, Little Bremner, and Tebay Rivers back to the starting point. No summer trail for horses was ever built on the Bremner River between the Little Bremner and Copper Rivers.

CLIMATE

The Chitina Valley is part of the Copper River Plateau climatic province, one of the eight climatic provinces into which Abbe[1] divided Alaska. This province is in some respects intermediate between the Pacific coast, with its temperate, humid climate, and the interior plateau north of the Alaska Range, which is characterized by great extremes of temperature and very moderate rainfall. Minor local variations in precipitation and temperature exist within the province as a result of differences of altitude, the effect of mountain ridges, and similar variables, and only such climatic conditions as apply generally in the Chitina Valley will be described here.

Records of precipitation and temperature have been kept at several places in the Chitina Valley and nearby points and have appeared in the published reports of the United States Weather Bureau. These published records, covering a period from 1902 to 1930, are the source of the information to be given in the tables. The records are not complete and vary widely in the length of time covered, but those chosen include a sufficient number of years for the averages to give a fairly accurate picture of climatic conditions in the area. The places chosen for comparison are Chitina, Copper Center, and Kennecott. Weather observations were made at Strelna and Tiekel for several years, but only parts of the records are included here. The records from Copper Center go back to 1902 but stop with 1919. Those from Kennecott extend from 1916 to 1930, and the Chitina records from 1917 to 1923. Years or parts of years are missing from the records of each place.

[1] Abbe, Cleveland, Jr., in Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, p. 140, 1906.

Climatic records for stations in or near the Chitina Valley

Mean monthly and annual precipitation (inches)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Chitina	1.16	0.88	0.34	0.34	0.34	0.67	1.13	1.28	1.56	1.10	1.59	1.01	11.40
Copper Center	.57	.51	.26	.21	.40	.86	1.56	1.10	1.32	.93	.82	.61	9.15
Kennecott	1.55	1.36	1.25	1.30	1.10	1.40	2.28	2.38	3.16	2.06	1.63	1.32	20.79

Mean monthly and annual snowfall (inches)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Chitina	14.5	7.6	3.0	1.6	1.0	0	0	0	0.4	9.2	16.0	12.9	66.2
Copper Center	6.5	3.8	2.9	1.0	Tr.	0	0	0	.7	7.5	7.8	8.2	38.4
Tiekel	13.2	9.3	11.4	3.2	Tr.	Tr.	0	0	1.1	9.5	21.0	18.9	87.6

Mean monthly and annual temperature (°F.)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Chitina	−3.2	6.4	14.2	32.3	45.2	54.8	57.7	54.2	45.4	32.3	11.8	−6.3	28.7
Copper Center	−11.5	3.8	12.7	28.8	44.8	54.0	56.3	53.5	42.8	27.4	5.1	−4.4	26.1
Kennecott	5.0	11.4	18.1	28.6	41.9	50.7	52.1	49.5	43.0	31.2	14.5	5.4	29.28

Highest monthly and annual temperature (°F.)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Chitina	47	46	47	60	74	77	87	86	71	60	42	48	93
Copper Center	49	49	49	67	80	96	88	87	80	66	49	50	96
Kennecott	41	46	45	58	67	79	78	73	74	58	53	40	79
Strelna	46	49	46	56	71	80	91	78	78	66	47	43	91

Lowest monthly and annual temperature (°F.)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Chitina	−49	−37	−30	−20	20	28	35	28	28	−8	−40	−58	−58
Copper Center	−74	−55	−48	−26	11	21	22	20	3	−26	−46	−53	−74
Kennecott	−35	−39	−29	−15	19	27	34	30	11	−4	−27	−36	−39
Strelna	−52	−46	−38	−29	20	26	31	26	18	−12	−31	−51	−52
Tiekel	−45	−36	−28	−21	15	25	28	24	11	1	−23	−31	−45

Average number of days with minimum temperature of 32° and lower

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Chitina	31	27	31	26	13	0	0	1	10	23	30	31	223
Copper Center	31	28	30	29	20	5	1	9	18	28	29	31	259

Average number of days with maximum temperature of 70° and above (ordinary figures) and minimum of zero and below (black-face figures)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	
													70°	Zero
Chitina	**23**	**16**	**15**	**3**	1	9	9	5	0	**0**	**14**	**24**	24	**95**
Copper Center	**26**	**19**	**17**	**4**	3	12	14	9	1	**3**	**17**	**25**	39	**111**

The tables show that Kennecott has more than twice the annual precipitation of Copper Center and that the snowfall at Tiekel is considerably greater than it is farther from the coast. The mean annual temperature at the three stations is below freezing. The highest temperature (96°) and the lowest (−74°) are both recorded at Copper Center.

In a more general way it may be said that the summers of Chitina Valley are short and usually pleasant, the temperatures generally moderate, though high at times, and there are many clear days, particularly in the spring and early in summer. The ice goes out of the Chitina River late in April or early in May. Snow disappears from the lower valleys by the middle of May, but in the upper valleys, in gulches and protected places, it persists till late in summer or does not melt at all. Frost may occur in the valleys in any month of the year but is uncommon in June and July. A slight fall of snow may be seen on the high mountain tops after almost every summer rain lasting a day or more, but the snow disappears in a few hours when the clouds lift. The lower limit of the heavy storm clouds marks the lower limit of summer snow. Below this plane precipitation takes the form of rain. Many of the rains are local, being confined to one of the larger valleys or to one side of a ridge. At times rain falls only in the mountainous area, while the clouds are absent and the sun is shining over the lowland.

In summer, during the warm days of late June and of July, the large streams that head in glaciers have their maximum normal discharge. High water on the smaller streams comes in June, when the snows are melting on the mountains, and subsides, except at times of heavy rain, when the snow is gone. The period of high water in the large streams is therefore longer than on most of the tributaries, for the glaciers are a source of supply that never fails till cool weather puts an end to the melting of the ice.

TIMBER AND GRASS

All of the area under consideration is timbered below an altitude that is somewhat variable, ranging from 2,500 to 3,000 feet, although scattered trees are sometimes found at higher levels. Spruce is the prevailing tree and the only one of value for general mining uses. Cottonwood, birch, and poplar are common where favorable conditions prevail but have no value for lumber. The spruce does not reach the size of the best timber on the coast and is not as good for bridges, heavy framing, or general building as the lumber shipped in from Seattle but is well adapted for many local purposes and has been much used. The best growth is found on the lower slopes of the hills and in the smaller valleys. Most of the trees on the floor of Chitina Valley are small and of inferior quality because of poor, cold soil and insufficient drainage. Many square miles of such mossy timberland has been burned off, either through accident or by intention, and the place of the spruce is being taken by willow and aspen. Unfortunately much of the best timber on the hill slopes has been killed by bark beetles. These insects were noted on the north side of the Chitina Valley from the Kotsina River to the Chitistone and may always be counted on to attack the biggest and finest trees. The timbered areas of the Chitina and Bremner Valleys are not under the supervision of the United States Forest Service but of the General

Land Office, which collects stumpage on the trees cut for lumber. Unlike the Forest Service it has no organization for fighting forest fires, which after they are once started burn without interference till the inflammable material is exhausted or rain puts them out. Practically no attempt is ever made to control forest fires except when private property is threatened.

The Chitina Valley does not possess as luxuriant grass lands as some other parts of Alaska, notably the Cook Inlet region. Nevertheless there is abundant grass for forage in many places. Grass thrives best in the vicinity of timber line in the smaller valleys and often grows abundantly at this altitude after the brush and trees have been burned, a practice which many of the early prospectors followed to insure feed for their stock. These old sidehill burns now provide some of the best forage in the valley. The most abundant grass growing in these places is commonly known as redtop. It grows rapidly but does not cure on the stalk and is of no value after it is frosted. On the other hand, the so-called "bunch grass", which grows on some of the lower gravel benches, cures and is nourishing at all times, but it is neither widely distributed nor abundant. The lowlands forming the broad valley floor of the Chitina Valley furnish little grass except some coarse varieties which grow around the edges of the ponds and lakes, so that in this part of the area feed for animals is often hard to find.

Since the completion of the railroad the problem of providing feed for stock is less pressing than formerly, as both hay and grain can be shipped in at any time. Moreover, the automobile has eliminated much of the need for stock feed, as comparatively few horses are now in use. The farmers near McCarthy raise hay for the stock required in farming, and because of the shortness of the season and the fact that grass does not mature till the unfavorable fall weather has set in they employ a somewhat novel method for curing it, probably adapted from the usage of the Scandinavian countries. The grass is cut and hung over wires stretched between posts like a wire fence and is allowed to hang till it is ready to be put into the barn, which may not be till after snow has come.

DESCRIPTIVE GEOLOGY

OUTLINE OF THE GEOLOGY

The rocks of the Chitina Valley and the adjoining area here considered are dominantly bedded rocks. This statement, however, is not intended to imply a restriction of the term "bedded rocks" to clastic rocks deposited in water, for bedding may originate in other ways. The bedded rocks include chiefly sediments derived by weathering from older sedimentary and igneous rocks, and, in addition, sediments of volcanic origin (tuffs), together with a great thickness of bedded lava flows. They range in age from early Carboniferous to the present and exhibit varying degrees of metamorphism, ranging from schists and gneisses on the one hand to practically unaltered rocks on the other. Although the bedded rocks predominate in this region, intrusive igneous rocks—granite, quartz diorite, diorite, diabase, and others—are widely distributed among them.

The oldest rocks of definitely determined age within the area are Carboniferous (Mississippian). They comprise schist and slate, locally associated with a minor amount of altered limestone, tuffaceous beds, and basalt flows, and are intruded by granular igneous rocks. They include among others definitely the Strelna and possibly the Klutina and other formations that form a belt of variable width extending from the Tana River, on the upper Chitina, to Klutina Lake, west of the Copper River, and thence beyond the limits of the area. The Chitina River throughout most of its length is entrenched in these oldest rocks, which form a narrow wedge-shaped area expanded toward the west and flanked on both north and south by less altered younger rocks.

The next younger rocks comprise a great thickness of lava flows, tuff, and volcanic breccia interstratified with shale, limestone, limy shale, limy sandstone, and conglomerate having an undetermined relation to the Mississippian rocks. These rocks, formerly regarded as in part of Pennsylvanian age, are now all assigned to the Permian. They appear in some localities to rest unconformably on the Mississippian rocks and to be overlain conformably by a great thickness (5,000 feet at least) of basaltic lava flows that have long been known as the Nikolai greenstone.

The Nikolai greenstone, in turn, is overlain with apparent structural conformity by about 3,000 feet of Upper Triassic limestone (Chitistone and Nizina limestones) that grades upward into black shale (McCarthy shale) whose thickness is not known but is estimated as from 1,500 to 2,500 feet. All the limestone was formerly called Chitistone, but the upper part, consisting of less pure, thinner beds, containing more or less shale in the form of thin partings between limestone layers, was renamed the Nizina limestone by Martin.[2] Both the limestone and the overlying black shale are of Upper Triassic age.

So far as is now known, Middle Jurassic time is represented in this area by the rocks of only a single small locality near the mouth of the Chitina River, where some much folded tuffaceous slate and conglomerate yielded Middle Jurassic fossils (Tuxedni fauna). The true relation of these beds to the surrounding Carboniferous beds has not been made clear. Furthermore, it is not possible with the evidence at hand to correlate them with any other of the known Jurassic rocks in

[2] Martin, G. C., The Mesozoic stratigraphy of Alaska: Geol. Soc. America Bull., vol. 23, p. 724, 1912; Triassic rocks of Alaska: Idem, vol. 27, p. 690, 1916.

the Chitina drainage basin, such as those occurring in scattered areas in the Kotsina and Kuskulana Valleys.

Two small areas of black shale are the only recognized representatives of Upper Jurassic time in the area. They are folded into similar black Triassic and Cretaceous shales and are of unknown extent. For a long time they were not identified and differentiated from the associated rocks, but they are now known to carry the characteristic fauna of the Naknek formation of the Alaska Peninsula. The supposedly Jurassic beds of the Kotsina and Kuskulana Valleys may also belong to the Upper Jurassic and possibly lie near the top of the section.

A large group of dominantly sedimentary beds, consisting of slate, graywacke, arkosic sandstone, limestone, and conglomerate with large extrusive and intrusive masses of basic igneous rock, is here provisionally assigned to a place in the upper part of the Mesozoic era, although its age is not known definitely and it may contain beds of widely varying ages. These rocks comprise the Valdez and Orca groups of the early reports. They occupy most of the area south of Hanagita Valley and extend westward into the mountains north of Prince William Sound.

The Upper Triassic and older sedimentary rocks of the Chitina Valley were folded, subjected to erosion, and, after being submerged beneath the sea, covered by conglomerate, sandstone, and shale, whose age and stratigraphic relations are still imperfectly understood. These rocks are known only north of the Chitina River. Part of them have been referred in previous descriptions to the Upper Jurassic and part to the Cretaceous, but it is now believed that most of them are Cretaceous, although they include some rocks of Upper Jurassic age. In places they are also considerably folded, but elsewhere they show little deformation beyond moderate tilting.

The Tertiary bedded rocks of the Chitina Valley are dominantly of volcanic origin and include several thousand feet of vesicular lava and tuff, which are slightly tilted in places but are otherwise little altered. Fresh-water conglomerate, variegated clays, and thin sandstone and shale beds are present at the base of the volcanic rocks in a few places. In places the Tertiary sedimentary and volcanic rocks rest unconformably on the underlying rocks. They are confined to the higher parts of the Wrangell Mountains, except on Skolai Creek, where they are the only rocks exposed in the upper part of the valley.

The youngest of the bedded deposits of the region are unconsolidated Pleistocene and Recent gravel, sand, silt, morainal accumulations, and other clastic materials, some of which are forming at present. Some of the unconsolidated deposits are only partly bedded and have not undergone sorting by water to any marked degree.

The intrusive igneous rocks belong to different periods of igneous activity, beginning sometime after the bedded rocks of the Mississippian epoch were formed. They include granite, granodiorite, quartz diorite, and subordinate more basic intrusives that show varying degrees of alteration. Probably most of them are of late Mesozoic or Tertiary age. Some of the later intrusives are believed to have had a part in the formation of the copper and gold deposits.

GEOLOGIC MAP

The accompanying geologic map (pl. 2) includes results of field work carried on intermittently by different geologists through a period of over 30 years. The writer has had a part in this work during most of that time, and it is correct to say that the map as it is given, except part of the White River section and a few minor localities, represents his work and that of those associated with him, for practically all the area mapped before 1909 has been revisited and the geologic mapping has been revised.

The original surveys and many later corrections appeared on maps accompanying publications of the United States Geological Survey. Most of these maps were printed on a scale of 1:250,000, or about 4 miles to the inch, although two were on the larger scale of 1:62,500, or about 1 mile to the inch. The present map is also on the scale of 1:250,000, and for this reason some of the details of the larger-scale maps are omitted from it, being too small to be shown on the present scale. An attempt has been made in this connection to simplify as far as possible the cartographic units to be represented. This is done by correlating some formations formerly supposed to be distinct but now known to be the same and by grouping others concerning which there is little evidence for correlation on the one hand and even less for separation on the other.

BEDDED ROCKS

An outline of the geology was given in the preceding section in order to put before the reader a short, comprehensive view of the whole subject. In the following sections the bedded rocks, including certain formations of volcanic origin, bedded lava flows, and fragmental material ejected during volcanic eruptions and deposited in water, as well as sedimentary beds in the usual sense, are described at greater length in the order of their age, the oldest first.

PALEOZOIC BEDDED ROCKS

MISSISSIPPIAN ROCKS

CHARACTER AND DISTRIBUTION

The bedded rocks that are here assigned to the Mississippian epoch on the evidence of fossils and the rocks of less well-established age that are correlated with them show many differences in composition but have a common characteristic in that they have undergone a greater degree of metamorphism than any other rocks of the region. They include schist, gneiss, slate, and recrystallized limestone, some of which are derived from sedimentary rocks and some from volcanic igneous rocks. They are intruded by igneous rocks of various kinds, some of which are much altered. These rocks have not been studied in detail but are fairly well known in a few localities. As represented on the geologic map they include the Strelna formation,[3] the Klutina series of Schrader,[4] the Dadina schist of Mendenhall,[5] and some other rock groups that have not received formation names, although they are extensively developed.

The Strelna formation is typically exposed on Strelna Creek, in the Chitina Valley, and has been studied more than any other of the Mississippian rocks. This formation is a complex of bedded lavas and tuffs interstratified with sedimentary beds and cut by basic intrusive rocks. Tuffaceous beds and lava sheets constitute the major part of the formation. Dense black basaltic flows are common. The tuffs for the most part are so fine grained, especially in the upper part of the formation, that their clastic character is recognized with certainty only under the microscope, yet some beds appear to be conglomeratic.

The sedimentary rocks are black argillites that locally may be described as slates, thin-bedded cherts probably derived in part from altered limestone, and more or less completely silicified limestone. Argillaceous beds are found at several horizons in the Strelna formation. As a rule they are dark-gray, well-indurated rocks without good cleavage that are best described as argillites, although in places they have developed a good secondary cleavage. In the field some of the argillites are difficult to distinguish from crushed and altered phases of the dense black basalt.

The origin of the cherts is not everywhere evident. Some of them appear to be altered thin-bedded limestone; others are more probably silicified fine-grained tuffs. Cherts are well developed in parts of the Strelna formation, and most of them are probably of the fine-grained tuff variety.

The limestone of the Strelna formation is white or light gray and makes rather prominent exposures. As a rule the exposures are not large and represent parts of beds that have been much folded and faulted. Few of the limestone areas are continuous for as much as a mile, although some exposures show beds of massive limestone not

[3] Moffit, F. H., and Mertie, J. B., Jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745, p. 21, 1923.

[4] Schrader, F. C., A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska, in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, p. 410, 1900.

[5] Mendenhall, W. C., Geology of the Central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, p. 27, 1905.

less than 200 feet thick that must originally have been part of a continuous bed of considerable extent.

The bedded members of the Strelna formation were intruded by igneous rocks, mostly of basic composition. Intrusive gabbro and pyroxene diorite are found in many localities.

This complex of igneous and sedimentary rocks has been subjected to long-continued, recurring pressure and heat, which have brought about chemical and mineralogic changes and produced an intricate system of folds and faults. The following incomplete section is given to indicate the nature of the Mississippian rocks at one locality:

Partial section of Strelna formation in Nugget Creek Valley near Kuskulana Glacier

	Feet
Fine-grained basalt	360
Water-laid and subaerial tuff	885
Fine-grained basalt	450
Shaly, argillaceous beds	405
Siliceous beds	10
Fine-grained basalt	450
Silicified limestone	5
Gabbro with some tuffaceous beds	405
Chert	225
Gabbro	650
	3, 845

This formation is exposed on the north side of the Chitina River as far eastward as the mouth of the Nizina River.

The mountains south of the Chitina River as far east as the Tana River consist of interstratified schist, slate, and limestone beds in which the schist and slate greatly predominate, although the limestone is exposed in many places and one or two beds are several hundred feet thick. The schists show considerable variation in appearance, ranging from silvery gray to green and black. Locally they are profoundly altered by intrusions of igneous rock and in extreme occurrences are so intimately invaded and recrystallized that the two rocks resemble banded gneiss. The limestone is recrystallized and locally is highly silicified as a result of the intrusion. These beds either include a smaller proportion of volcanic material than the Strelna formation in its type locality, or their original character is masked by metamorphic changes, but nevertheless they are correlated with the Strelna on the evidence of a few fossils collected from the limestones. They make up nearly all of the mountain mass north of the Hanagita Valley and some of the mountains south of it, extending westward across the Copper River to the vicinity of Klutina Lake, where they constitute at least a part of the Klutina series of Schrader and consist of mica schist, quartz schist, locally cherty or jaspery, and crystalline limestone or marble.

The name "Dadina schist" was used by Mendenhall to designate the rocks of several small areas on the Dadina and Chetaslina Rivers, where the overlying younger lava flows have been eroded away, exposing near the base of the section a succession of dark bedded rocks derived from altered andesitic lavas, amphibole schists, mica schists, and small bodies of gray marbleized limestone. These older rocks are intruded by dikes of unaltered and locally coarse-grained quartz diorite. Pale-greenish quartz-calcite schist, probably an altered sedimentary rock, and biotite schist are intruded by sheared gabbro on a tributary of the Chetaslina River, and these in turn are cut by diorite dikes. Amphibole schists cut by diorite dikes are exposed on the main Chetaslina River and chloritic schists and amphibole schists on the East Fork. Mendenhall correlated these rocks with the Klutina series of Schrader.

At the east end of the Chitina Valley the Carboniferous rocks are exposed on both sides of the river in the vicinity of Chitina Glacier. Some of these rocks are fossiliferous, so that their age determination appears fairly certain. Others have not yielded fossils, and their age assignment is provisional. The rocks regarded as of Carboniferous (Mississippian) age include schist, crystalline limestone, impure schistose limestone, massive limestone, conglomerate, grit, argillite, tuff, and chert. It is immediately evident that these rocks differ from those already described in the abundance of calcareous rocks. Also volcanic rocks form a smaller proportion of the whole. The limestones of this vicinity are more extensive in both distribution and thickness than in other parts of the Chitina Valley and have had a marked influence in controlling topography. The Carboniferous rocks are all strongly folded and much faulted and show wide differences in degree of metamorphism. These differences are possibly due in part to the influence of the granitic intrusives which invaded them in many places. The early geologic map [6] of this vicinity does not show the Carboniferous rocks south of the Chitina River. The writer is indebted to Mr. Martin Harrais, of McCarthy, for the information that they are present in the lower slopes of the mountains near the river.

THICKNESS AND STRUCTURE

The bedded Carboniferous rocks of the Kotsina-Kuskulana district have been studied more carefully than any of the rocks elsewhere that have been correlated with them, yet even here the evidence as to their thickness so far discovered is meager. One reason for uncertainty on this point is that the base of the succession has not been recognized. Another is that the rocks are folded and much faulted, as is made plainly evident by the contorted and discontinuous limestone beds and by the fact that all the bedded rocks are schistose.

[6] U. S. Geol. Survey Bull. 675, pl. 3, 1918.

Such evidence as could be found in the Kotsina-Kuskulana district indicates a thickness of not less than 6,500 feet for the Strelna formation. It is not known whether this formation as exposed in this district represents the whole or only a part of the Mississippian Carboniferous rocks, for none of the individual beds north of the Chitina River have been correlated with any of those south of it, and no beds to serve as horizon markers are known. Furthermore, the differences in lithologic character of the beds here and at the head of the river introduce other uncertainties, as it is not known whether the massive limestone and conglomerate beds of the upper river were contemporaneous with those of the lower river or whether they are older or younger. The apparent thickness of the beds near Chitina Glacier is fully as great as that of the Strelna formation. At present it is not possible to suggest even an approximate thickness for the beds exposed in Hanagita Valley and on the west side of the Copper River, and the most definite statement that can be made about the thickness of the Carboniferous bedded rocks of the Chitina Valley is that it probably is not less than 6,500 feet and may be greater.

Some characteristic structural features of the beds have already been indicated. The rocks are folded in a complicated way, with the axes of the major folds in general bearing a little north of west, parallel to the trend of the Chugach Mountains but with many local divergences from this direction. The cleavage, like the bedding, shows many dips to the north as well as to the south and in most places is steep or even vertical. The base of the beds has not been recognized. The Strelna formation east of Strelna Creek and in the exposures between the Kuskulana and Kluvesna Rivers appears to be overlain without angular unconformity by the Nikolai greenstone, although evidence obtained on the Chitistone and Nizina Rivers indicates that the greenstone flows were extruded in later Permian time or possibly even in Triassic time and that therefore unconformity between the Strelna formation and the Nikolai greenstone might be expected. The contacts of the Mississippian rocks in many places on both the north and the south boundaries of the area occupied by them are plainly fault contacts along southward-dipping faults of great longitudinal extent. The direction of motion on both the major fault lines was such that the rocks south of the faults are now raised relatively to those on the north, apparently being thrust over from the south. Possibly similar parallel faults may cut the rocks within the area, but in the lack of evidence of younger rocks in contact with the Mississippian rocks or of horizon-marking beds within them such faults are difficult to identify.

AGE AND CORRELATION

The bedded rocks that have been described are assigned to the lower part of the Carboniferous (Mississippian) on the evidence of fossils collected in a few widely separated localities. Some of the rocks regarded as of Mississippian age are doubtfully referred to this epoch. The scarcity of fossils in most of these rocks makes it necessary to depend chiefly on lithologic features and stratigraphic evidence for making correlations, and in view of the advanced degree of metamorphism shown by the rocks there is a possibility that sedimentary rocks of determined Mississippian age may be correlated with others of widely varying age. The areas represented on the geologic map as occupied by Mississippian rocks therefore may include some rocks that are older and some that are younger, although the first possibility seems unlikely.

Fossils were collected from limestone beds at ten or more localities of the Strelna formation, from limestone beds near Taral, south of the Chitina River, and from arkosic sandstones and conglomerate near Chitina Glacier. The localities are listed below in the chronologic order of the collections.

Fossils from the Mississippian rocks

	11AC40	11AC43	8170	8171	8172	8173	Lot 1	Lot 2	Lot 3	Lot 4	Lot 519	1807	1808	1808a	1808b	1808c	1808d	1808e	1808f
Zaphrentis sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--
Zaphrentis? sp	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Amplexus sp	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Syringopora? sp	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--
Crinoid stems	×	×	--	×	×	--	×	×	--	×	--	--	--	--	--	--	--	--	--
Platycrinus? sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--
Echinoid spines	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--
Batostomella sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--
Fenestella sp	--	--	--	--	--	--	--	×	×	×	--	--	--	--	--	--	--	--	--
Fenestelloid bryozoan	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--
Polypora sp	--	--	--	--	--	--	--	×	×	--	--	--	--	--	--	--	--	--	--
Pinnatopora sp	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Lingula sp	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Rhipidomella sp	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Schizophoria cf. S. resupinata	--	--	--	--	--	--	--	--	--	--	--	--	×	×	--	×	×	×	--
Derbya? sp	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--
Chonetes sp	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--
Productus cf. P. longispina	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×
Productus semireticulatus	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	×	--	--	×
Productus sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	×	--	--	--
Overtonia? cf. O. fimbriata	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--
Pustula cf. P. elegans	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Pustula cf. P. pustulosa	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Pustula cf. P. venusta	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	×	--	--	--
Pustula sp	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Camarophoria sp	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--
Rhynchonelloid, small (Pugnax)	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--
Rhynchopora? sp	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Dielasma? sp	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Terebratuloid, small	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--
Spirifer cf. S. convolutus	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--
Spirifer cf. S. integricosta	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--
Spirifer cf. S. pinguis	--	--	--	--	--	--	--	×	×	--	--	--	--	--	--	--	--	--	--
Spirifer cf. S. striatus	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--
Spirifer sp	--	--	--	--	--	--	--	--	--	×	×	--	--	--	--	×	×	--	--
Squamularia? sp	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--
Cleiothyridina? sp	--	--	--	--	--	--	--	--	×	--	--	--	--	×	--	--	--	--	--
Composita? sp	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--
Conocardium? sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--
Schizodus? sp	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--
Cypricardella? sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--
Plagioglypta? sp	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--
Euphemites? sp	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--
Pleurotomaria sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--
Euomphalus? sp	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Straparollus sp	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--
Platyceras sp	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Griffithides sp	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--
Phillipsia sp	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--

11AC40. Tributary of Canyon Creek, 8 miles southeast of Taral or 6.5 miles southwest of mouth of Nerelna Creek. Collector, Theodore Chapin, 1911.

11AC43. Near locality 11AC40. Collector, Theodore Chapin, 1911.

8170. Strelna Creek, east side above main forks. Limestone member in sedimentary series of limestone, shale, conglomerate, and cherty siliceous beds. These appear to dip beneath the greenstone and may underlie it or be the lower part of it. Collector, Theodore Chapin, 1912.

8171. Ridge between main forks of Strelna Creek. Cherty limestone beds associated with greenstone. Collector, Theodore Chapin, 1912.

8172. Ridge south of west fork of Strelna Creek. Limestone, chert, and shale interbedded with greenstone. Collector, Theodore Chapin, 1912.

8173. West fork of Strelna Creek. Collector, Theodore Chapin, 1912.

Lot 1. 6,500 feet N. 74° W. from the forks of Strelna Creek; altitude 4,700 feet. Collector, J. B. Mertie, Jr., 1914.

Lot 2. 7,000 feet S. 48° W. from Iron Mountain; altitude 4,000 feet. Collector, J. B. Mertie, Jr., 1914.

Lot 3. 7,500 feet S. 84° W. from Iron Mountain; altitude 5,300 feet. Collector, J. B. Mertie, Jr., 1914.

Lot 4. 10,250 feet N. 78° W. from Iron Mountain; altitude 5,700 feet. Collector, J. B. Mertie, Jr., 1914.

Lot 519. Same locality as lot 1. Collector, Fred H. Moffit, 1914.

1807. Limestone boulder in moraine of Short River glacier; altitude 2,300 feet. Collector, Fred H. Moffit, 1915.

1808 to 1808f. Float on north side of Chitina Glacier. Collector, Fred H. Moffit, 1915.

The fossils listed above were determined by G. H. Girty,[7] who regarded them as representing the same fauna as that of the Lisburne limestone or the upper part of the Mississippian, although he recognized a possibility that they may be Pennsylvanian. More recently, as a result of study of Carboniferous fossils from many parts of Alaska, he reached the conclusion that marine sediments of Pennsylvanian age are almost unrepresented in Alaska and reassigned faunas once thought to be Pennsylvanian either to the upper Mississippian (the widely distributed marine Lisburne fauna) or to the Permian.

The upper Mississippian rocks are very extensively developed in Alaska. Their outcrops are found from the Arctic Ocean to the Pacific, indicating that the upper Mississippian seas covered much if not all of the mainland and many of the adjacent islands. In northern Alaska, where the Mississippian rocks include the Noatak formation and the Lisburne limestone, they reach a thickness of many thousands of feet and consist chiefly of sandstone, shale, quartzite, massive limestone, and chert. This thickness is possibly greater than that suggested for the Carboniferous beds of the Chitina Valley, and the lack of volcanic deposits is notable.

[7] Moffit, F. H., Geology of the Hanagita-Bremner region, Alaska: U. S. Geol. Survey Bull. 576, p. 20, 1914. Moffit, F. H., and Overbeck, R. M., The upper Chitina Valley: U. S. Geol. Survey Bull. 675, p. 21, 1918. Moffit, F. H., and Mertie, J. B., Jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745, p. 27, 1923.

A section of Mississippian rocks that has received particular study is that at Calico Bluff, below Eagle, on the Yukon River. The Calico Bluff formation [8] consists essentially of alternating beds of limestone and shale with some slate and exposes a thickness of about 1,270 feet at this locality. It is highly fossiliferous and has yielded a large number of species which Girty regards as indicative of upper Mississippian age. The Calico Bluff formation, however, represents only a part of the Mississippian section of the region. Below it in descending order are the Rampart group, consisting of several thousand feet of sedimentary rocks and lava flows, and the Livengood chert, which also is several thousand feet thick. The total thickness of Mississippian rocks is therefore great, although not definitely known.

According to Girty [9] the Mississippian faunas of Alaska and those of the typical localities of the southeastern United States differ greatly in character, the Alaskan faunas being more closely allied to those of Eurasia.

PERMIAN ROCKS

CHARACTER AND DISTRIBUTION

In the northeastern part of the area shown on the geologic map, including the White River, Skolai Creek, a part of Nizina Glacier, and the upper part of the Chitistone River, is exposed a great thickness of bedded rocks consisting dominantly of lava flows and pyroclastic beds but including also a considerable proportion of sedimentary beds, chiefly limestone and shale with a little limy grit and conglomerate. These beds probably occupy all the area around the head of the White River except where igneous rocks that have been intruded into them are exposed or where they are covered by Tertiary lava flows or more recent gravel deposits. The occurrence of these Permian rocks on the White River and Skolai Creek was described by Capps, who examined them in 1914. The Skolai Creek, Nizina Glacier, and Chitistone River localities have been examined more recently and in greater detail by the writer. According to Capps [10] the Permian rocks of the area studied by him may be separated into several stratigraphic divisions, as shown in the following generalized section, in which the oldest rocks are given at the bottom:

1. Bedded lavas, with little sedimentary material.
2. Massive limestone beds of Skolai Creek, with interbedded lavas and minor amounts of shale and conglomerate.
3. Lavas and pyroclastic rocks, with a small amount of sediments.
4. Massive limestone, associated with shales, thin-bedded limestones, and a little sandstone and conglomerate.
5. Lavas and pyroclastic beds, with some shale.

[8] Mertie, J. B., Jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, pp. 95–109, 1930.

[9] Girty, G. H., personal communication.

[10] Capps, S. R., The Chisana-White River district: U. S. Geol. Survey Bull. 630, p. 39, 1916.

The distribution of geologic formations in the White River Basin below Russell Glacier, on Beaver Creek, and on the headwater tributaries of the Chisana River is shown on plate 2 as they were mapped by Capps, who says of the formation boundaries that they could not be followed out in detail in the time available and in places are only approximate. The following account of the Permian rocks in this district is also condensed from his description.[11]

The lowest members of the section, including the massive limestone of member 4, are exposed on tributaries of Beaver Creek and the Chisana River near the north limit of the area shown on plate 2. The upper three members are all found in the White River Basin and, unlike the basal members on Bonanza Creek, tributary to the Chisana River, are not known to be associated with any rocks older than Permian. For this reason they are mapped as Permian rather than Carboniferous and Devonian, as on Capps' original map. They may, however, include some Mesozoic rocks, particularly on the upper tributaries of the White River, where Jurassic fossils are said to have been found. In the small area north of the White River much of the Permian is concealed by nearly horizontal lava flows that were poured out over an original surface of moderate relief, but it is well exposed in the mountains between Ptarmigan Lake and Beaver Creek, where it consists of lavas and tuffs with subordinate sedimentary rocks. The two upper members of the section, possibly including also some of the lower members, are extensively developed in the mountains south of the White River, between Russell and Chisana Glaciers, and on Skolai Creek. The limestone and shale members, are more conspicuous in these areas and are in places abundantly fossiliferous. Capps states that the Carboniferous rocks of the Chisana-White River district are dominantly of volcanic origin and consist chiefly of lavas, volcanic breccias, tuffs, and agglomerates. The pyroclastic or volcanic fragmental materials were in part, at least, laid down in water, for they are interbedded with purely sedimentary material that locally contains marine fossils. These beds are generally of light color, in tones of cream, brown, buff, or gray, and vary in coarseness from fine-grained rocks to agglomerates that contain angular blocks a foot in diameter. The lava flows also are believed to have been poured out in part into the sea. They are bedded with the pyroclastic and sedimentary rocks, and individual flows range from a few feet to 100 feet in thickness. In general the individual flows are dark-colored, the prevailing colors being red, purple, brown, and green. They are commonly amygdaloidal, with cavity fillings of zeolites, calcite, chlorite, epidote, and chalcedony, yet in places the cavities are empty.

[11] Capps, S. R., The Chisana-White River district: U. S. Geol. Survey Bull. 630, pp. 33-39, 1916.

The shale members of the Permian range in color from black to bluish and gray and generally are well indurated, in many places being dense and hard and without cleavage. They grade from typical fine-grained black shale through limy shale to impure argillaceous limestone and from sandy shale to sandstone. The differences in hardness and composition of the argillaceous beds give rise to characteristic topographic forms, expressed in bold cliffs of the resistant rocks and in smooth, flowing surfaces or narrow gulches in the soft beds.

The limestones have been folded and faulted, forming many isolated outcrops, but in general they are little altered. No marbleized limestones were noted on the White River or Beaver Creek. The colors are gray, white, and buff, which contrast strongly with the dark colors of the other Permian rocks. The limestones also have a characteristic topographic expression and form bold cliffs or rough, sharp peaks that are conspicuous features of the landscape.

On upper Skolai Creek and the head of the Chitistone River the Permian rocks are buried beneath Tertiary lava flows and tuffs, but they are exposed on lower Skolai Creek, on both sides of Nizina Glacier, and in the vicinity of Chitistone Glacier, where erosion has removed the overlying lavas and revealed them. The base of the Permian section has not been recognized west of Russell Glacier. The lowest beds referred to this epoch are dark lava flows and tuffs, which occupy most of the lower slopes of Skolai Valley from Frederika Glacier to Nizina Glacier and presumably correspond to member 3 of Capps' White River section. (See p. 29.) Similar rocks crop out beneath the Permian limestone at the north end of Russell Glacier. These volcanic beds are everywhere folded and faulted and locally have taken on a subschistose structure. The rocks above them are dominantly sedimentary, including thick limestone beds and limy shale and grit, but contain a considerable proportion of tuff beds and lava flows. This part of the Permian section does not appear to be uniform throughout the area, the most conspicuous difference being the absence of the massive limestones in places, although possibly the variation in other members is as great. A brief description of the Permian beds seen at several localities will bring out the differences mentioned.

The lower Skolai Creek Valley is an area where the limestone members of the Permian stratigraphic section are particularly well developed. At least two thick limestone beds are present—an upper bed, which is measured in hundreds of feet and is a prominent feature of the landscape, and a lower bed, which in some places is not more than 25 feet thick but in others may be thicker.

The massive Permian limestone is conspicuous in the upper mountain slopes on both sides of Skolai Valley midway between Frederika and Nizina Glaciers. It forms the prominent limestone peak called the "Golden Horn" and is crossed by the trail on "Tinplate Hill." The limestone of the Golden Horn is not less than 800 feet thick. This locality is one of the more favorable places for observing it but possibly does not exhibit the full original thickness, for erosion may have removed part of the limestone as well as other overlying Permian beds. The limestone of the Golden Horn weathers to a reddish or yellowish brown, thus giving the mountain its name, and in places is recrystallized to a fairly coarse marble, probably as the result of intrusion by igneous rocks. The rocks underneath the thick limestone include brownish shale and sandstone, coarse limy sandstone in lenticular beds, grit, chert, and another thin limestone bed interstratified with tuffs and lava flows, some of which have pillow structure. These beds are probably better exposed on the south side of Skolai Creek, south of the Golden Horn (pls. 5, *B*, and 6, *A*). The upper limestone disappears toward the east, but the lower bed is seen in several gulches.

Beds of hard gray fossiliferous limestone and white crystalline limestone appear on the west side of Frederika Glacier about 2 miles northwest of the south end and extend northward a considerable but unknown distance. These beds are the northward continuation of those in the Golden Horn, but the connection is hidden by Tertiary lava flows. The horseshoe-shaped glacier on the south side of Skolai Creek opposite Frederika Glacier occupies a high valley, known as the "Hole in the Wall", with almost vertical walls. The lower part of the west wall near Frederika Creek is made up of Permian rocks that are overlain by younger volcanic rocks. The following section was examined at the edge of the ice 2 miles south of Skolai Creek. The measurements are estimated, for the wall could not be climbed.

Section of Permian rocks 2 miles south of Skolai Creek

	Feet
Sandstone and quartzite	300+
Tuff and fragmental material	40
Thin-bedded shale and sandy beds	100
Basalt flow	30
Banded siliceous rock (tuff), white or yellowish white, speckled in places	50
Thick basalt flows.	

The sedimentary members of this section, which is believed to be stratigraphically lower than the massive limestone appearing farther to the west in the Skolai Valley, are all fossiliferous. Presumably the overlying massive limestone was removed by erosion at this locality before the Tertiary lavas were poured out.

Permian sedimentary rocks are exposed on the west side of Nizina Glacier in the lower slopes of Chimney (Goat) Mountain up to an altitude of 1,000 feet above the ice. They dip southwest and consist chiefly of limestone, which is abundantly fossiliferous, containing great numbers of crinoids. The top beds are impure and knotty and overlie white crystalline limestone containing siliceous lenses several inches in maximum thickness. A hard reddish-brown member with abundant small crinoids is also present. The limestone area is several miles long but less than a mile wide. At the south end the limestone is overlain by 75 to 100 feet of brown-weathering sandy or tuffaceous beds with a few rolled pebbles and cobbles. Above these beds is 30 to 40 feet of soft gray tuffaceous beds containing angular blocks of white and reddish-brown limestone, in which are crinoids, corals, and fragments of other rock. These in turn are overlain by lava flows, which to the south are covered by the ice of Regal Glacier.

An instructive section of Permian beds is exposed along the east side of Nizina Glacier south of Skolai Lake, where a small stream flows through a shallow box canyon parallel to the ice edge for half a mile or more. The stream crosses the upturned edges of the beds, which strike from N. 50° W. to west and dip about 75° S. The youngest beds (top of the section) are at the south end of the canyon.

Section of Permian rocks on the east side of Nizina Glacier below Skolai Lake

	Feet
Amygdaloidal basalt, presumably of Nikolai age.	
Coarse tuff	75
Fine-grained brownish tuff	10
Black shale with thin beds of limy sand or grit; strike N. 50° W., dip 75° W	125
Thin lenses of brownish shale in limy grit	20
Light-gray, yellow-weathering fine-grained flow	75
Hard fine-grained white pyritiferous limestone in beds as much as 2 feet thick, interstratified with black shale	30
Basalt	20
Black shale with white limy beds and knotty limestone interstratified with grit or fine conglomerate grading downward into thin-bedded shale and sandstone in beds as much as 2 feet thick	200
Thin-bedded shale and coarse limy sandstone or grit, limy conglomerate with shaly phases, and impure limestone	300
Basalt	50
Black shale	150
Basalt and tuff	50
Thin-bedded hard white crystalline limestone in beds as much as 3 feet thick	25
Basalt	15
White crystalline limestone	10
White and speckled grit or fine conglomerate with a few quartz pebbles as much as half an inch in diameter; strike east, dip 75° S	90
Basalt	20
Gray limy beds and black shale; strike N. 65° E., dip 75° S.; resting on fine gray tuffaceous limy conglomerate and shale	275
Basalt and tuff with a little shale and fossiliferous limy beds	(?)
	1, 505+

The thicknesses given are paced distances and do not take into account the dip of the beds. Nearly all the sedimentary members of the section are abundantly fossiliferous. A great thickness of tuff and basalt underlies the section, and another great thickness of volcanic rocks, which appear to be mostly if not wholly lava flows, overlies it. The writer regards the overlying lava flows as the base of the Nikolai greenstone but was unable to trace them southward to the Chitistone limestone at the end of Nizina Glacier, because they are hidden by Cretaceous deposits in the intervening area.

Another area of Permian sedimentary rocks, including a part of the Chitistone Valley adjacent to Chitistone Glacier, gives further evidence concerning these rocks and their relation to the Nikolai greenstone. The size of the area is not known, but it probably extends south into the glacier valley and east to Russell Glacier, although the higher parts of the area are Tertiary lava flows. The following approximate section gives an idea of the rocks along the south side of the Chitistone River for a distance of 2½ miles southwest from the glacier. All the beds dip steeply southwestward. The Nikolai greenstone is the top of the section and occupies all the intervening area between the Permian sedimentary beds and the Chitistone limestone west of Glacier Creek. The section is given to show the character of the rocks rather than their thickness, as accurate measurements were not made.

Section of Permian beds on Chitistone River

	Feet
Nikolai greenstone.	
Greenstone tuff grading into lava flows above.	
Thin-bedded chert containing beds or lenses of brownish-weathering tuff; strike N. 45° W., dip 40° SW	75–100
Light-gray, bluish-gray, and black cherts in beds as much as 6 inches thick	Several hundred
Basalt flows	Several hundred
Black or dark-gray slate, containing a few beds of sandstone as much as 6 inches thick and one bed of angular conglomerate 3 inches thick overlainby 18 inches of coarse sandstone	300
Yellowish-weathering conglomerate, mostly fine but with scattered pebbles as much as 2 inches in diameter	20
Interbedded brownish-weathering sandstone and shale	Several hundred
Basalt flows	Several hundred
Yellowish-weathering cherts and basalts.	

This section probably represents several thousand feet of sedimentary and volcanic deposits. Thin beds of limestone conglomerate are present, but the absence of limestone is noticeable, as is also the relative scarcity of fossils.

All the areas of Permian rocks bear evidence that their formation took place during a time of recurring volcanic activity in the Wrangell

Mountain district. Tuffs and lava flows make up the greater part of the known Permian deposits, forming the bottom and top of the section as well as a considerable portion of the intermediate sedimentary part, where they evidently represent material deposited in water. In places the pillow structure of some of the lava flows in the dominantly volcanic parts of the section suggests that they, too, were poured out on the sea bottom. This, however, may be only a local condition.

THICKNESS AND STRUCTURE

In the preceding pages sections of parts of the Permian series of bedded rocks in different localities are given, together with estimates of their thickness. It is not possible with present information to correlate these sections or to determine their exact relationships, and therefore it is likewise not possible to do more than suggest the order of magnitude of the thickness of the whole succession of volcanic and sedimentary beds. In a general way the Permian rocks consist of upper and lower parts that are dominantly of volcanic origin, separated by a middle part that is dominantly of sedimentary origin. The basal and middle parts are each thought to have a thickness of several thousand feet, and if the Nikolai greenstone is included with the Permian rocks a thickness of 5,000 to 6,000 feet of lava flows is added. Probably the estimate of 10,000 feet that Capps [12] suggested as the thickness of the Carboniferous rocks of the Chisana-White River district is not excessive, although his estimate was intended to include rocks that were then considered to be of Pennsylvanian age. At least it may be said that rocks of Permian age reach a thickness of many thousand feet in this area.

As is suggested by their age the Permian rocks have undergone greater change in form and other characters than the rocks that overlie them. The base of the section has not been recognized, and the rocks that lie beneath are not known within the area under consideration, although Middle (?) Devonian lavas, agglomerates, and tuffs, associated with considerable black shale and minor amounts of graywacke, underlie the Carboniferous volcanic rocks on Bonanza Creek, north of the White River district.[13]

The Permian rocks are much folded and faulted but are not schistose, although the limestone beds in places are recrystallized. Much of the folding occurred before the upper Triassic black shale of Skolai Creek was deposited on the upturned and eroded limestone of the mountains between Frederika and Nizina Glaciers, where it is shown that not only did folding take place but that there was an intervening period of elevation and erosion. This was followed by folding that involved the Lower Cretaceous sediments also, and finally came

[12] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, p. 39, 1916.
[13] Idem, p. 31.

movement that tilted the Tertiary lava flows together with all the older rocks.

AGE

The Permian sedimentary rocks are abundantly fossiliferous in places, and many good collections of fossils have been obtained from them, so that their late Carboniferous age was soon recognized. The fossils, however, are more closely related to forms found in Russia than to those of North America, and for this reason correlations were made with the Russian sections and the terms "Gschelian" and "Artinskian" came to be applied to the Carboniferous rocks of the upper White River.[14]

Some years after the work of Capps on Skolai Creek and the upper White River (1914), Girty came to the conclusion that the two Russian terms should be discarded in describing the rocks of these areas and that the term "Permian" should be used in place of "Artinskian" and "Pennsylvanian" in place of "Gschelian." This course is followed in the present report, although no Pennsylvanian rocks are known in this part of Alaska at present.

The accompanying list of Permian fossils from the upper Nizina and White River area is intended to include all the forms collected by different workers and contains a large number of species. Previously published lists have been revised where revision was needed, and a few names have been dropped where duplication occurred. The determinations were made by George H. Girty.

7098. North Fork of White River. Collector, Fred H. Moffit, 1908.

7099–7099c. White River, foot of Russell Glacier, on south side of river, 10 miles east of Skolai Glacier. Collector, Fred H. Moffit, 1908.

7100–7100s. White River, thick-bedded limestone south of the river. (Fossils not in place but from float below the limestone.) Collector, Fred H. Moffit, 1908.

7101–7101h. Kletsan Creek, on south side of White River near international boundary. (Fossils not in place.) Collector, Fred H. Moffit, 1908.

7102–7102h. Skolai Pass near east end of Russell Glacier and on north side. (Fossils in place.) Collector, Fred H. Moffit, 1908.

7105. Moraine Creek, at head of White River, east side of Russell Glacier. Collector, Adolph Knopf, 1908.

Lot 2, SRC. Moraine Creek. Collector, S. R. Capps, 1908.

7106. Middle Fork of White River. Collector, Adolph Knopf, 1908.

7107. Eureka Creek. Collector, Adolph Knopf, 1908.

7108–7108a. Lime Creek, at head of White River. Collector, Adolph Knopf, 1908.

7109. Skolai Pass, at head of White River. Collector, Adolph Knopf, 1908.

3995. Chitistone River, 2 miles below glacier. Collector, Fred H. Moffit, 1922.

3996–3996b. Chitistone River, 2 miles below glacier, small eastern tributary. Collector, Fred H. Moffit, 1922.

[14] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, p. 27, 1910. Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, p. 40, 1916.

Fossils from the Permian rocks

	7098	7099	7099a	7099b	7099c	7100	7100a	7100b	7100c	7100d	7100e	7100f	7100g	7100h	7100k	7100m	7100n	7100p	7100r	7100s	7101	7101a	7101b	7101c	7101d	7101e	7101f	7101g	7101h	7102	7102a	7102b	7102c	7102d	7102e	7102f	7102g	7102h	7105
Fusulina sp.																																							
Zaphrentis cf. Z. ovibos (Salter)																																							
Zaphrentis sp.																																							
Triplophyllum sp.																																							
Campophyllum sp.										×																													
Campophyllum? sp.											×																												
Clisiophyllum sp.																																							
Clisiophyllum? sp.																																							
Lophophyllum? sp.																×												×											×
Lithostrotion cf. L. irregulare (Phillips)																																							
Lithostrotion cf. L. portlocki (Bronn)																																							
Phillipsastraea? sp.																																							
Michelinia sp.																																							
Cladochonus sp.																																							
Chaetetes sp.																					×																		
Crinoid segments																																							
Platycrinus sp.																																							
Ceriocrinus sp.																																							
Cibolocrinus cf. C. texanus (Weller)																																							
Batostomella sp.																																							
Tabulipora cf. T. carbonaria (Worthen)																																							
Tabulipora sp.						×																																	
Tabulipora? sp.			×																																				
Fenestella sp.																																							
Phyllopora? sp.																																							
Polypora sp.																																							
Acanthocladia sp.																																							
Rhombopora cf. R. lepidodendroides (Meek)																																							
Rhombopora sp.			×																	×																			
Rhombopora? sp.																		×																					
Streblotrypa? sp.																																							
Cystodictya cf. C. pustulosa (Ulrich)																																							
Lingula sp.																																							
Rhipidomella cf. R. carbonaria (Swallow)																																							
Rhipidomella sp.																																							
Rhipidomella? sp.																																							
Schizophoria cf. S. resupinoides (Cox)																																							
Schizophoria cf. S. resupinoides (Cox?)																																							
Schizophoria? cf. S. supracarbonica (Tschernyschew)			×																				×																
Schizophoria sp.																																							
Schizophoria? sp.																																							
Enteletes hemiplicata (Hall)																									×														
Orthotichia? cf. O. morganiana (Derby)																																							
Orthotichia? n. sp.		×																																					
Derbya? sp.			×																																				
Streptorhynchus n. sp.																																							
Streptorhynchus? sp.																																							
Chonetes cf. C. geinitzianus (Waagen)																																							
Chonetes cf. C. granulifera (Owen)																																							
Chonetes cf. C. morahensis (Waagen)																																							
Chonetes cf. C. verneuilianus (Norwood and Pratten)		×	×																		×				×										×			×	
Chonetes sp.																																							
Chonetes? sp.																																							
Productus cora (D'Orbigny)																														×	×		×		×			×	
Productus cora (D'Orbigny?)																																							
Productus cf. P. cora (D'Orbigny)																																							
Productus cf. P. gruenewaldti (Krotow)																						×	×															×	
Productus cf. P. humboldti (D'Orbigny)																																						×	
Productus cf. P. konincksianus (De Verneuil)																																							
Productus cf. P. longispinus (Sowerby)																																×					×		
Productus cf. P. longus (Tschernyschew, not Meek)																																						×	
Productus cf. P. mammatus (Keyserling)																				×																			
Productus cf. P. multistriatus (Meek?)																																							
Productus cf. P. semireticulatus (Martin)																																							
Productus cf. P. tartaricus (Tschernyschew)																																							
Productus sp.		×												×			×		×		×								×					×	×				
Pustula cf. P. alternata (Norwood and Pratten)																																							
Pustula cf. P. fasciata (Kutorga)						×	×					×													×														
Pustula cf. P. horrida (Sowerby)																																							
Pustula cf. P. horrida (Sowerby?)																																							
Pustula cf. P. irginae (Stuckenberg)																																			×				
Pustula cf. P. juresanensis (Tschernyschew)																																							
Pustula cf. P. porrecta (Kutorga)																																							
Pustula cf. P. pseudaculeata (Krotow)						×																																	
Pustula cf. P. timanica (Stuckenberg)																																						×	
Pustula cf. P. tuberculata (Moeller)																																							
Pustula cf. P. tastubensis (Tschernyschew)																																							
Pustula cf. P. wallaciana (Derby)																																							
Pustula cf. P. wallaciana (Derby?)																		×							×														
Pustula n. sp.																																							
Marginifera cf. M. aagardi (Toula)																									×														
Marginifera? cf. M. clarkei (Tschernyschew)																																							
Marginifera cf. M. involuta (Tschernyschew)																																							
Marginifera cf. M. involuta (Tschernyschew?)																																							
Marginifera? cf. M. juresanensis (Tschernyschew)																																							
Marginifera cf. M. splendens (Norwood and Pratten)																																							
Marginifera? cf. M. splendens (Norwood and Pratten)																																							
Marginifera cf. M. typica (Waagen var. septentrionalis Tschernyschew)																																							
Marginifera? cf. M. typica (Waagen)																																							
Marginifera cf. M. wabashensis (Norwood and Pratten)																									×														
Marginifera? cf. M. wabashensis (Norwood and Pratten)			×											×								×																	
Marginifera sp.																																							
Marginifera? sp.																																							
Proboscidella? cf. P. genuina (Kutorga)																																							
Tegulifera? cf. T. uralica (Tschernyschew)																																							
Camarophoria cf. C. crumena (Martin)												×		×											×														
Camarophoria cf. C. kutorgae (Tschernyschew)						×																																×	
Camarophoria margaritovi (Tschernyschew)																																							
Camarophoria cf. C. sella (Kutorga)					×																																		
Camarophoria sp.																																							
Camarophoria? sp.																																							
Rhynchopora cf. R. illinoisensis (Worthen)																																							
Rhynchopora cf. R. nikitini (Tschernyschew)																																							
Rhynchopora sp.																					×																	×	
Dielasma cf. D. bovidens (Morton)																																			×			×	
Dielasma cf. D. timanicum (Tschernyschew)																																							
Dielasma sp.																																							
Spirifer cf. S. cameratus (Morton)																																							
Spirifer cf. S. cameratus (Tschernyschew, not Morton)																																						×	
Spirifer cf. S. condor (D'Orbigny)																																							
Spirifer cf. S. fasciger (Keyserling)																																						×	
Spirifer cf. S. fasciger (Keyserling?)																																							
Spirifer cf. S. interplicatus (Rothpletz)																																							
Spirifer cf. S. interplicatus (Rothpletz var. baschkirica Tschernyschew)																																							
Spirifer cf. S. keokuk (Hall)			×																																				
Spirifer cf. S. marcoui (Waagen)																																							
Spirifer cf. S. nikitini (Tschernyschew)			×										×						×																				
Spirifer cf. S. nikitini (Tschernyschew?)																										×	×												
Spirifer cf. S. rectangulus (Kutorga)																																							
Spirifer cf. S. ufensis (Tschernyschew)																																							
Spirifer sp.												×																											
Spiriferella arctica (Houghton)	×																	×																		×			×
Spiriferella arctica (Houghton?)														×	×																						×		
Spiriferella arctica var.																																							
Spiriferella? arctica																																							
Brachythyris sp.																																							
Martinia cf. M. semiglobosa (Tschernyschew)																																							
Martinia cf. M. triquetra (Gemmellaro)																																							
Martinia? sp.				×																																			
Reticularia cf. R. setigera (Hall)																																							
Reticularia sp.																																							
Squamularia cf. S. guadalupensis (Girty)																																							
Squamularia cf. S. perplexa (McChesney)			×						×																													×	
Squamularia? sp.							×																																
Spiriferina cf. S. cristata (Schlotheim)																																							
Spiriferina cf. S. laminosa (M'Coy)																																							
Spiriferina cf. S. pyramidata (Tschernyschew)																																						×	
Spiriferina cf. S. spinosa (Norwood and Pratten)																																							
Spiriferina sp.																																							
Hustedia cf. H. remota (Eichwald)																																							
Hustedia sp.																																							
Cleiothyridina cf. C. pectinifera (Sowerby)																																							
Cleiothyridina cf. C. roissyi (L'Eveille)																					×											×							
Cleiothyridina cf. C. roissyi (L'Eveille?)																									×										×				
Cleiothyridina? sp.																																							
Composita sp.																																							
Edmondia? n. sp.																																							
Sedgwickia? sp.		×																																					
Parallelodon sp.				×																																			
Aviculipecten cf. A. curticardinalis (Hall and Whitfield)																																			×				
Aviculipecten cf. A. herzeri (Meek)																																							
Aviculipecten sp.																																		×					
Deltopecten cf. D. occidentalis (Shumard)																																			×				
Deltopecten cf. D. tahlequahensis (Snider)																																							
Deltopecten cf. D. vanvleeti (Beede)																																							
Lima cf. L. retifera (Shumard)		×						×																															
Lima? sp.																																							
Pleurophorus sp.																																							
Euconospira sp.																																							
Pleurotomaria sp.			×	×																																			
Worthenia? sp.																																							
Bembexia? sp.																																							
Euomphalus cf. E. subquadratus (Meek and Worthen)																																							
Euomphalus sp.																																							
Omphalotrochus sp.																																							
Naticopsis? sp.																																							
Platyceras cf. P. occidens																																							
Platyceras cf. P. parvum (Swallow)																								×															
Platyceras sp.																																							
Platyceras n. sp.																																							
Platyceras? sp.																																						×	
Griffithides? sp.																																							

	Lot 2 SRC	7106	7107	7108	7108a	7109	3995	3996	3996a	3996b	3997	6429	6430	6431	6431a	6432	6433	6434	6435	6436	6437	6437a	6438	6439	6440	6440a	6441	6441a	6442	6442a	6442b	Lot 1 SRC
Fusulina sp.	×																															
Zaphrentis cf. Z. ovibos (Salter)	×																															
Zaphrentis sp.	×																															×
Triplophyllum sp.															×							×	×	×			×	×		×		
Campophyllum sp.																		×												×		
Campophyllum? sp.																																
Clisiophyllum sp.																																×
Clisiophyllum? sp.	×																															
Lophophyllum? sp.																																
Lithostrotion cf. L. irregulare (Phillips)	×																															
Lithostrotion cf. L. portlocki (Bronn)	×																															
Phillipsastraea? sp.	×																															
Michelinia sp.																															×	
Cladochonus sp.																								×								
Chaetetes sp.																																
Crinoid segments								×			×			×			×		×				×	×						×		×
Platycrinus sp.																											×					
Ceriocrinus sp.																		×														
Cibolocrinus cf. C. texanus (Weller)																											×					
Batostomella sp.	×											×						×		×												
Tabulipora cf. T. carbonaria (Worthen)	×																															
Tabulipora sp.																																
Tabulipora? sp.																																
Fenestella sp.	×													×				×														
Phyllopora? sp.									×																							
Polypora sp.	×													×				×														
Acanthocladia sp.														×				×														
Rhombopora cf. R. lepidodendroides (Meek)																	×															
Rhombopora sp.		×																														
Rhombopora? sp.																																
Streblotrypa? sp.														×																		
Cystodictya cf. C. pustulosa (Ulrich)							×																									
Lingula sp.	×																															
Rhipidomella cf. R. carbonaria (Swallow)																			×													
Rhipidomella sp.	×						×																									
Rhipidomella? sp.												×																				
Schizophoria cf. S. resupinoides (Cox)																	×		×													
Schizophoria cf. S. resupinoides (Cox?)																×																
Schizophoria? cf. S. supracarbonica (Tschernyschew)																																
Schizophoria sp.																		×														
Schizophoria? sp.								×						×																		
Enteletes hemiplicata (Hall)																																
Orthotichia? cf. O. morganiana (Derby)	×																															
Orthotichia? n. sp.																																
Derbya? sp.								×				×					×															
Streptorhynchus n. sp.							×																									
Streptorhynchus? sp.												×		×																		
Chonetes cf. C. geinitzianus (Waagen)	×																															
Chonetes cf. C. granulifera (Owen)	×						×					×																				
Chonetes cf. C. morahensis (Waagen)																																
Chonetes cf. C. verneuilianus (Norwood and Pratten)												×																				
Chonetes sp.																×		×								×						
Chonetes? sp.											×																					
Productus cora (D'Orbigny)								×									×									×				×		
Productus cora (D'Orbigny?)																				×												
Productus cf. P. cora (D'Orbigny)	×																															
Productus cf. P. gruenewaldti (Krotow)		×					×	×											×	×					×	×	×	×		×		
Productus cf. P. humboldti (D'Orbigny)				×																												
Productus cf. P. konincksianus (De Verneuil)	×			×			×																									
Productus cf. P. longispinus (Sowerby)																																
Productus cf. P. longus (Tschernyschew, not Meek)																																
Productus cf. P. mammatus (Keyserling)								×																								
Productus cf. P. multistriatus (Meek?)																								×								
Productus cf. P. semireticulatus (Martin)				×										×						×	×											
Productus cf. P. tartaricus (Tschernyschew)	×													×	×												×	×				
Productus sp.	×			×				×			×			×										×								
Pustula cf. P. alternata (Norwood and Pratten)			×																													
Pustula cf. P. fasciata (Kutorga)	×											×																				
Pustula cf. P. horrida (Sowerby)														×					×									×	×			×
Pustula cf. P. horrida (Sowerby?)								×				×																				
Pustula cf. P. irginae (Stuckenberg)	×																															
Pustula cf. P. juresanensis (Tschernyschew)							×					×																				
Pustula cf. P. porrecta (Kutorga)	×																															
Pustula cf. P. pseudaculeata (Krotow)																																
Pustula cf. P. timanica (Stuckenberg)							×					×																				
Pustula cf. P. tuberculata (Moeller)	×																															
Pustula cf. P. tastubensis (Tschernyschew)							×	×																								
Pustula cf. P. wallaciana (Derby)	×											×																				
Pustula cf. P. wallaciana (Derby?)						×																										
Pustula n. sp.								×																								
Marginifera cf. M. aagardi (Toula)							×	×	×		×	×													×							
Marginifera? cf. M. clarkei (Tschernyschew)	×																															
Marginifera cf. M. involuta (Tschernyschew)												×		×																		
Marginifera cf. M. involuta (Tschernyschew?)																×																
Marginifera? cf. M. juresanensis (Tschernyschew)																	×															
Marginifera cf. M. splendens (Norwood and Pratten)																				×												
Marginifera? cf. M. splendens (Norwood and Pratten)									×																							
Marginifera cf. M. typica (Waagen var. septentrionalis Tschernyschew)																					×				×							
Marginifera? cf. M. typica (Waagen)	×																									×						
Marginifera cf. M. wabashensis (Norwood and Pratten)																																
Marginifera? cf. M. wabashensis (Norwood and Pratten)																																
Marginifera sp.																												×				
Marginifera? sp.																																×
Proboscidella? cf. P. genuina (Kutorga)	×																															
Tegulifera? cf. T. uralica (Tschernyschew)	×																															
Camarophoria cf. C. crumena (Martin)				×																												
Camarophoria cf. C. kutorgae (Tschernyschew)																																
Camarophoria margaritovi (Tschernyschew)														×	×						×			×								
Camarophoria cf. C. sella (Kutorga)					×																											
Camarophoria sp.	×																															
Camarophoria? sp.							×																									
Rhynchopora cf. R. illinoisensis (Worthen)																											×					
Rhynchopora cf. R. nikitini (Tschernyschew)	×										×									×												
Rhynchopora sp.																																
Dielasma cf. D. bovidens (Morton)																																
Dielasma cf. D. timanicum (Tschernyschew)																			×													
Dielasma sp.							×																									
Spirifer cf. S. cameratus (Morton)																																×
Spirifer cf. S. cameratus (Tschernyschew, not Morton)	×																		×							×						
Spirifer cf. S. condor (D'Orbigny)																		×														
Spirifer cf. S. fasciger (Keyserling)							×					×		×															×			
Spirifer cf. S. fasciger (Keyserling?)																		×								×						
Spirifer cf. S. interplicatus (Rothpletz)	×																															
Spirifer cf. S. interplicatus (Rothpletz var. baschkirica Tschernyschew)	×																															
Spirifer cf. S. keokuk (Hall)																																
Spirifer cf. S. marcoui (Waagen)														×																		
Spirifer cf. S. nikitini (Tschernyschew)	×																						×	×								
Spirifer cf. S. nikitini (Tschernyschew?)																																
Spirifer cf. S. rectangulus (Kutorga)																											×		×			
Spirifer cf. S. ufensis (Tschernyschew)																																
Spirifer sp.									×			×						×														
Spiriferella arctica (Houghton)							×	×	×	×				×					×	×	×						×			×		
Spiriferella arctica (Houghton?)																						×	×									
Spiriferella arctica var.							×	×	×	×																						
Spiriferella? arctica																																×
Brachythyris sp.																														×		
Martinia cf. M. semiglobosa (Tschernyschew)					×	×																										
Martinia cf. M. triquetra (Gemmellaro)													×											×								
Martinia? sp.																																
Reticularia cf. R. setigera (Hall)			×																													
Reticularia sp.	×																															
Squamularia cf. S. guadalupensis (Girty)												×		×	×						×							×		×		
Squamularia cf. S. perplexa (McChesney)	×			×																						×						
Squamularia? sp.																																
Spiriferina cf. S. cristata (Schlotheim)							×																									
Spiriferina cf. S. laminosa (M'Coy)	×																															
Spiriferina cf. S. pyramidata (Tschernyschew)		×																														
Spiriferina cf. S. spinosa (Norwood and Pratten)																		×														
Spiriferina sp.																																
Hustedia cf. H. remota (Eichwald)	×																															
Hustedia sp.											×																					
Cleiothyridina cf. C. pectinifera (Sowerby)	×																															
Cleiothyridina cf. C. roissyi (L'Eveille)																																
Cleiothyridina cf. C. roissyi (L'Eveille?)																																
Cleiothyridina? sp.								×																								
Composita sp.																																
Edmondia? n. sp.																		×														
Sedgwickia? sp.																																
Parallelodon sp.																																
Aviculipecten cf. A. curticardinalis (Hall and Whitfield)																																
Aviculipecten cf. A. herzeri (Meek)																		×														
Aviculipecten sp.																		×								×						
Deltopecten cf. D. occidentalis (Shumard)																																
Deltopecten cf. D. tahlequahensis (Snider)																										×						
Deltopecten cf. D. vanvleeti (Beede)																		×														
Lima cf. L. retifera (Shumard)																																
Lima? sp.	×																															
Pleurophorus sp.																										×						
Euconospira sp.							×																									
Pleurotomaria sp.																																
Worthenia? sp.	×																															
Bembexia? sp.							×																									
Euomphalus cf. E. subquadratus (Meek and Worthen)								×						×																		
Euomphalus sp.												×																				
Omphalotrochus sp.	×																															
Naticopsis? sp.							×																									
Platyceras cf. P. occidens							×	×																								
Platyceras cf. P. parvum (Swallow)																																
Platyceras sp.	×											×																				
Platyceras n. sp.								×																								
Platyceras? sp.																																
Griffithides? sp.	×																															

3997. Chitistone River, 1 mile below glacier. Collector, Fred H. Moffit, 1922.

6429. Chitistone Valley, south side, 2 miles below glacier. Collector, Fred H. Moffit, 1927.

6430. Chitistone Valley, half a mile north of west end of Chitistone Glacier. Collector, Fred H. Moffit, 1927.

6431, 6431a. Skolai Creek Valley, south side, 1½ miles from Skolai Creek, on west side of small glacier opposite mouth of Frederika Creek. Collector, Fred H. Moffit, 1927.

6432. Frederika Valley, west side of glacier, 3 miles from its terminus. Collector, Fred H. Moffit, 1927.

6433. Frederika Valley, west side of glacier a few hundred yards north of locality 6432. Collector, Fred H. Moffit, 1927.

6434. Skolai Creek Valley, north side, 2 miles west of Frederika Glacier; altitude, 6,250 feet. Collector, Fred H. Moffit, 1927.

6435. Skolai Creek Valley, north side, 2½ miles west of Frederika Creek; altitude, 5,850 feet. Collector, Fred H. Moffit, 1927.

6436. Skolai Creek Valley, north side, 3 miles west of Frederika Creek; altitude, 4,850 feet. Collector, Fred H. Moffit, 1927.

6437, 6437a. Skolai Creek Valley, north side, a short distance north of locality 6436. Collector, Fred H. Moffit, 1927.

6438. Skolai Creek Valley, north side, north of localities 6436 and 6437; altitude, 6,000 feet. Collector, Fred H. Moffit, 1927.

6439. Nizina Glacier, ledges along glacier east of Chimney (Goat) Mountain. Collector, Fred H. Moffit, 1927.

6440, 6440a. Skolai Creek, 1½ miles from east end of lower lake. Collector, Fred H. Moffit, 1927.

6441, 6441a. Nizina Glacier Valley, east side, 2 miles south of Lower Skolai Lake. Collector, Fred H. Moffit, 1927.

6442–6442b. Nizina Glacier Valley, east side, 1½ miles south of Lower Skolai Lake. These fossils are lower in the section than collection 6441. Collector, Fred H. Moffit, 1927.

Lot 1, SRC. Skolai Creek, lower end. Collector, S. R. Capps, 1914.

NIKOLAI GREENSTONE (PERMIAN AND TRIASSIC?)

CHARACTER AND DISTRIBUTION

The Nikolai greenstone is a thick series of altered basaltic lava flows, which is exposed in many irregular areas on the north side of the Chitina Valley all the way from the Kotsina River to Chitina Glacier, a distance of 100 miles. Although the formation was originally continuous throughout this distance, much of it is now buried under younger rocks and hidden from view. For this reason also the northward extent of the flows is not known. The Nikolai greenstone is one of the formations that early received a name and has been of special interest to mining people because it gives indications of copper in a great many places and so has been looked on as a particularly favorable formation for prospecting.

The basalt flows have a marked similarity of appearance and general character throughout the area. Their color is prevailingly dark green but is locally reddish or reddish brown as a result of alteration. They are of fairly coarse texture and are commonly amygdaloidal, with the amygdules distributed throughout the individual flows and only rarely concentrated near their upper surfaces. As a rule individual flows are not readily recognized, and the bedded character is not distinct except in large exposures, where, however, it may be pronounced. The first general impression of the exposures is that of a massive intrusive rather than a succession of bedded lava flows.

Intercalated beds of tuff and sedimentary material have not been observed in the greenstone, and pillow structure within the flows has been recognized in only a few localities. The evidence for submarine extrusion of the lavas is therefore slight. On the other hand, the evidence for subaerial extrusion is no stronger, and the question whether most of the lavas were poured out on land or under water has not been decided.

PETROGRAPHY

The petrographic character of the lava flows that compose the Nikolai greenstone has been described many times in considerable detail, because of the association of the greenstone and copper minerals in the Chitina Valley. The most recent description is that by Moffit and Mertie,[15] which has been used as a source of material for most of the detailed petrographic description that follows.

Megascopic character.—Hand specimens of the Nikolai greenstone vary much in appearance. The color is commonly dark, but a greenish hue resulting from the development of secondary minerals is nearly always seen, although a reddish or reddish-brown color sometimes results from certain forms of alteration. The texture ranges from that of dense, fine-grained rocks in which the constituent minerals are all too small to be distinguished with the naked eye to that of medium-grained rocks in which some of the minerals, especially the feldspars, can be recognized. Some specimens are porphyritic, with phenocrysts of feldspar and pyroxene. This characteristic is usually seen best on a smooth weathered surface of the rock, where the contrast in color between the phenocrysts and groundmass is more pronounced. Much of the greenstone is amygdaloidal, the original gas cavities having been filled with calcite, chloritic and serpentinous material, quartz, epidote, and zeolites, and the white, green, or grayish spots produced by the secondary minerals are commonly much more conspicuous than the spots made by phenocrysts of feldspar or pyroxene. Ellipsoidal lavas have been found in the Nikolai greenstone at a few localities, but this structure is exceptional. The metamorphism of the greenstone has been chemical rather than dynamic.

Microscopic character.—An examination of a large number of thin sections of the Nikolai greenstone showed that much of it originally contained more or less glass, which was altered to serpentinous or chloritic material as a result of chemical changes that took place long after the rocks were cooled. At present only a little of the original glass remains. The alteration of other minerals besides the glass to serpentinous or chloritic material makes it difficult to determine what proportion of the lavas was originally glass. However, it probably did not exceed 10 or 15 percent, so that most of the greenstone may be considered to have been crystalline rather than glassy.

[15] Moffit, F. H., and Mertie, J. B., jr., The Kotsina-Kuskulana district, Alaska; U. S. Geol. Survey Bull. 745, pp. 62-67, 1923.

Most of the greenstone is porphyritic, but the porphyritic character is much more evident in some flows than in others. Feldspar is the most conspicuous phenocryst, in some specimens the only member of the first generation of crystals. Pyroxene also forms phenocrysts, but they are smaller and less common than the feldspar. As a rule the groundmass is found to have the diabasic or ophitic fabric, and the same fabric is seen where no phenocrysts are present.

The primary minerals of the lavas, named in order of abundance, are augite, labradorite, iron ores, apatite, olivine, and orthorhombic pyroxene. The estimated relative proportions of the principal minerals, neglecting original glass, is augite 50 percent, feldspar 40 percent, and iron oxides 10 percent. Apatite is an accessory constituent. Olivine and orthorhombic pyroxene were found in only a few of the thin sections.

The labradorite phenocrysts range in length from 0.5 millimeter to 6 millimeters. They show either a well-developed or in places less well-developed crystalline form, are of prismatic or equant habit, and are twinned polysynthetically by the albite law or rarely by the pericline law. Zonal growths are seen, and some crystals show magmatic resorption. The feldspar phenocrysts are always altered and have yielded sericite, kaolin, calcite, and chloritic material as alteration products. Epidote was found in some specimens.

The augite phenocrysts are much smaller than the labradorite and range in size from 0.3 to 1 millimeter, the larger crystals being exceptional. They have poorly developed crystal forms of approximately equal dimensions in the directions of their axes, are colorless, and many of them contain inclusions of labradorite. The augite of the groundmass was originally the most abundant constituent of the rock and occurred in two forms. It is present in the coarser-grained greenstone as large grains without crystal faces, including laths of plagioclase feldspar, the two giving the typical ophitic fabric. Where the greenstone is not coarse-grained and especially where glass is present the augite forms grains with crystal faces imperfectly developed. It is included between the feldspar crystals, but because of its smallness has developed its own crystal boundaries and has not yielded the ophitic structure. The augite is either colorless or light yellowish green, is nonpleochroic, and has its characteristic cleavage. Its alteration products are chlorite and serpentinous material and locally epidote.

The feldspar of the groundmass, labradorite, shows little variation in habit and is nearly always present as subhedral laths, twinned according to the albite law. The maximum length of crystals in the coarser greenstone is from 1 to 2 millimeters, but this is exceptional, and the average is less than half this size. The feldspar of the groundmass, like the phenocrysts, has been altered to sericite, kaolin, calcite, and chloritic material.

The iron ores, magnetite and ilmenite, occur as grains with or without crystal boundaries, which rarely exceed 0.2 millimeter in diameter. Like the other minerals described, they are chemically altered and yield secondary products, of which iron hydroxide and leucoxene are most common.

Apatite is not plentiful but occurs in most of the greenstone as tiny pale-green needles.

Olivine is relatively scarce in the greenstone. It alters readily to serpentine and is recognized usually by its alteration products or by pseudomorphs of these products after the six-sided olivine crystals from which the serpentine came. The presence of hematite, antigorite, or iddingsite along the irregular cracks of the original olivine now altered to serpentine is further evidence of the presence of olivine in the unaltered rock.

Only one occurrence of orthorhombic pyroxene was noted. The thin sections showed faintly pleochroic crystals of this mineral associated with the augite.

Secondary minerals.—A characteristic feature of the Nikolai greenstone is that the lavas have everywhere undergone a considerable degree of alteration, which, as has been stated, is chemical and not the recrystallization of minerals resulting from shearing and pressure. This alteration is more evident in thin sections than in hand specimens. The feldspar yielded sericite, kaolin, calcite, and chloritic and serpentinous products; the augite gave chlorite and serpentines. These alteration products occupy the places of the original minerals. Secondary minerals, however, occur in other ways. The original lava flows in many places contained gas cavities, which are now filled with secondary minerals introduced through the agency of mineral-bearing solutions that circulated through the rocks, thus forming the amygdules so frequently seen. Two or more such minerals may occur in the same amygdule, arranged concentrically. A common association is yellow serpentinous material which lines the original cavity and green pleochroic chlorite which lies within the serpentinous material and grades into it. The center of the cavity may be colorless serpentine or calcite or both. Some cavities were filled with only one of several chloritic or serpentinous materials. The two outer linings are regarded as evidence of chemical reaction between the mineral-bearing solutions and the walls of the cavities, which may have resulted in some enlargement of the cavities. As evidence is cited the irregular shapes of such cavities, as compared with cavities filled by only one mineral, and the common occurrence of rock-forming minerals projecting into the cavities, such minerals having the same double lining as the rest of the cavity and showing various degrees of chloritization. The central filling of calcite and serpentinous or chloritic material is regarded as due wholly to deposition by the circulating ground water.

Another occurrence of secondary minerals is that of epidote and quartz as alteration products of pyroxene and feldspar and as cavity fillings. As an alteration product of the rock-forming minerals epidote is more common than quartz. The epidote-quartz mineralization was a later process than that which produced some of the chloritic material and calcite, and as it has been observed chiefly in association with or in the near vicinity of copper deposits it is believed to have had a genetic connection with the copper mineralization.

A third process of chemical alteration is the development of zeolites and prehnite as vein and cavity fillings. Analcite, heulandite, and a third zeolite that is probably thompsonite, although its identification is not complete, were noted. These zeolites and their associated prehnite appear not to have replaced the green stone but are confined mainly to veinlets and amygdules.

THICKNESS AND STRUCTURE

The thickness of the individual flows that make up the Nikolai greenstone ranges from a few feet to many tens of feet. Probably the flows are lenticular and overlap one another, for it seems highly improbable that the individual flows should be continuous over the whole extent of the formation. The thickness of the formation as a whole probably varies at different places and can be stated only approximately. In the Kotsina-Kuskulana district [16] the thickness was estimated to be not less than 6,500 feet. In the Nizina district [17] the thickness is not less than 4,500 feet. This estimate represents an incomplete section, for the base of the greenstone is not exposed at the

[16] Moffit, F. H., and Mertie, J. B., Jr., *The Kotsina-Kuskulana district, Alaska:* U. S. Geol. Survey Bull. 745, p. 59, 1923.

[17] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, p. 62, 1911.

place where the measurement was made. No complete section of the Nikolai greenstone has been recognized. Both the top and the bottom are exposed in the vicinity of Nizina Glacier, but the intervening part is concealed either by ice or by Cretaceous rocks, so that measurements and observations of dip and strike by which the thickness could be calculated cannot be made. It seems probable, however, that the thickness is not less than 5,000 feet and may be as great as that of the Kotsina-Kuskulana district, or even greater.

The structural relations of the greenstone to the rocks beneath and above it offer several problems. In the Nizina district the basal beds rest conformably on limy tuff beds, interstratified with thin flows of basalt, and evidently belong to the sequence of volcanic and sedimentary deposits that make up the Permian formations. These relations are best shown near the lower end of Nizina Glacier and in the Chitistone Valley. The relation of the greenstone to the Strelna formation is less clear. No well-defined boundary line between the two formations is recognized, and the separation [18] was made largely on lithologic evidence. The difference in age and the supposed absence of Pennsylvanian rocks between the two formations suggests the probability of an erosion interval before the Nikolai lavas were erupted.

The relation of the greenstone to the overlying Chitistone limestone appears to be one of structural conformity wherever the contact has been examined. A thin shale bed commonly intervenes, but the beds of limestone and the lava flows appear to be parallel to one another. In seeming contradiction to this relation of conformity is the occurrence of Triassic shale unconformably overlying the massive Permian limestone north of lower Skolai Creek. This suggests either that the greenstone was present and has been eroded off or that the limestone there was never covered by the Nikolai lava flows. Although the northward extent of the lava flows is not known, the first alternative would seem the more probable and if true furnishes evidence that strong deformation of the Permian rocks took place before the shale was deposited.

The Nikolai greenstone is composed of hard, resistant lava flows but has yielded in two ways to the deforming pressures that have been applied to it. The flows have been bent into broad folds and in addition have yielded by fracture and by movement within the flows. Because of its brittleness and this fracturing the greenstone is everywhere cut by joints and by fracture planes on which movement has taken place, as is made evident by the abundance of slickensided surfaces. The fracture planes divide the rock into angular blocks of all shapes and sizes and give rise to a rugged topography. Because of the resistance of the lavas to decomposition and the relative ease of

[18] Moffit, F. H., and Mertie, J. B., Jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745, p. 22, 1923.

breaking down that results from the fracturing, the bases of greenstone cliffs are commonly hidden by great accumulations of blocks that fell from above.

AGE

The age of the Nikolai greenstone was long a confusing problem and even now can be stated only within wide limits. Little doubt remains that the lava flows at the base of the formation are the product of the period of volcanic activity that characterized Permian time in this region. This conclusion is based on the evidence of fossils collected from tuff and limestone beds at the base of the greenstone. However, it is not known whether the outpouring of the Nikolai lavas was completed in Permian time or whether it continued into the Triassic period, although it had ended before the Chitistone limestone was deposited, in Upper Triassic time. That event fixes an upper limiting age for the greenstone, and it may therefore be stated that the earlier lava flows are definitely Permian, and the later flows are either Permian or possibly Triassic.

MESOZOIC BEDDED ROCKS

The Mesozoic bedded rocks of the Chitina Valley and the adjoining area include chiefly marine sediments, limestone, shale, sandstone, conglomerate, and tuff, with a total thickness of at least 10,000 feet. In addition a great thickness of slate and graywacke exposed in the Chugach Mountains is now regarded as partly if not wholly of Mesozoic age. These Mesozoic rocks include formations of Upper Triassic, Middle and Upper Jurassic, and Lower Cretaceous age. The following table illustrates the dominant character and relation of these formations:

	Feet
Lower Cretaceous: Black shale or slate, sandstone, graywacke, conglomerate	6, 000
Upper Jurassic: Black shale.	
Middle Jurassic: Tuffaceous shale.	
Upper Triassic:	
Black shale (McCarthy)	1, 500–2, 500
Limestone (Nizina)	1, 100
Limestone (Chitistone)	1, 900

Although Mesozoic rocks are widespread in the Chitina Valley, knowledge of their identity and distribution has accumulated only gradually and is still incomplete. This condition results from the fact that although fossils are fairly plentiful in some formations or parts of formations, they are nevertheless scarce and difficult to find throughout great thicknesses of the deposits, and from the further fact that many of the collections were made from isolated areas of beds whose mutual stratigraphic relations were unknown in the field. In addition no thoroughgoing comparative study of the faunas has ever been made, and the paleontologist is therefore not in possession of the facts needed to solve some of the problems that have arisen. Because of their lithologic character and more abundant fossils the Upper Triassic limestones and the overlying McCarthy shale have been easier to recognize, and their distribution throughout most of the Chitina Valley is well established, yet knowledge even of these rocks is incomplete in important details. The top of the McCarthy shale has never been recognized, and the maximum thickness of the formation is in doubt. The Middle Jurassic tuff beds are known only in one small area with indefinite boundaries near the mouth of the Chitina River, yet they have afforded a small distinctive fauna and arouse little doubt regarding their age, although their structure is not known. The Upper Jurassic and Cretaceous sedimentary beds, however, present such difficulties to differentiation in the present state of knowledge concerning them that it has seemed best not to attempt to distinguish them on parts of the geologic map. Upper Jurassic rocks are recognized north of the Chitina River in the Kotsina-Kuskulana district and eastward on McCarthy Creek. The Cretaceous sedimentary rocks, on the other hand, have their greatest development in the Nizina district, although they are recognized as far west as the eastern tributaries of the Kuskulana River and extend eastward into the upper Chitina Valley. They consist chiefly of sandstone and shale and reach a thickness of several thousand feet, much greater than that of known Jurassic deposits in this district, yet notwithstanding their wide distribution and thickness the Cretaceous rocks were not recognized as such in the earlier work and were regarded as belonging to the Upper Triassic McCarthy shale or the Upper Jurassic formation. Their identity could not be determined till larger collections and more helpfully diagnostic fossils were available for study.

The Mesozoic rocks are described below at greater length, but first the writer wishes to acknowledge his indebtedness for the assistance and stimulating ideas he has gained from a study of Martin's excellent work on the Mesozoic stratigraphy of Alaska,[19] in which all the information available at the time he wrote it was collected and correlated.

UPPER TRIASSIC ROCKS

As has been stated by Martin,[20] the most complete known section of Triassic rocks in Alaska is in the Chitina Valley. The section includes about 5,000 feet of marine deposits, consisting of a lower part about 3,000 feet thick, made up of limestone and representing two formations, and an upper part whose thickness is unknown but approximates 2,000 feet, made up of black shale, calcareous argillite, and a few small limestone beds. This sequence of sedimentary deposits finds its best or most typical development in the mountains

[19] Martin, G. C., U. S. Geol. Survey Bull. 776, 1926.

[20] Idem, p. 6.

between McCarthy Creek and the Chitistone River, where the whole succession is shown in natural sections with diagrammatic clearness. The general section in this district is as follows:

General section of Triassic rocks in the Nizina district

	Feet
Upper Triassic:	
McCarthy formation: Above, a black shale member with a few thin beds of limestone. Below, interbedded black shale and hard calcareous argillite in beds commonly less than 3 feet thick; this member is of variable thickness and in places exceeds 1,000 feet	2, 000?
Conformity.	
Nizina limestone: Thin-bedded dark-gray limestone, commonly with shale partings that increase in thickness toward the top	1, 100
Structural conformity.	
Chitistone limestone: Bluish-gray limestone, prevailingly in thicker beds and with fewer and thinner shale partings than the overlying Nizina limestone. Black chert bodies of irregular form are numerous in the Chitistone limestone in places	1, 900
Structural conformity.	
Permian or Triassic (?): Nikolai greenstone: Basaltic lava flows.	

This section may be considered the standard section of the Nizina district. It is not displayed everywhere in full development, especially in the western part of the Chitina Valley. Variations from the typical form are discussed below in the appropriate places.

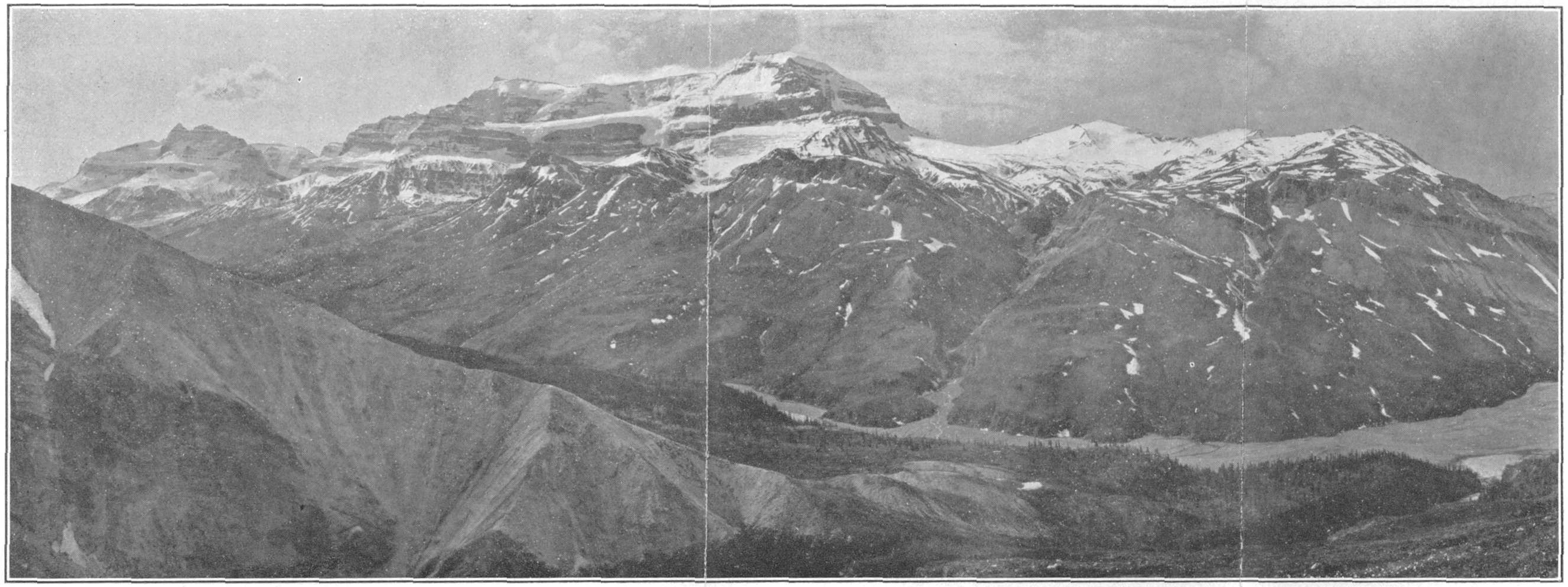
Chitistone and Nizina limestones

CHARACTER AND DISTRIBUTION

The two Upper Triassic limestone formations were not distinguished from each other in most of the field work that has been done in the Chitina Valley, and the distinction is not made on the geologic map (pl. 2) accompanying this report. Formerly the name "Chitistone" was applied to the whole thickness of Upper Triassic limestone in the Nizina district, although lithologic differences between the upper and lower parts were noted. Later these differences were recognized in Martin's proposal to restrict the name "Chitistone" to the lower part and apply the new name "Nizina" to the upper part.[21]

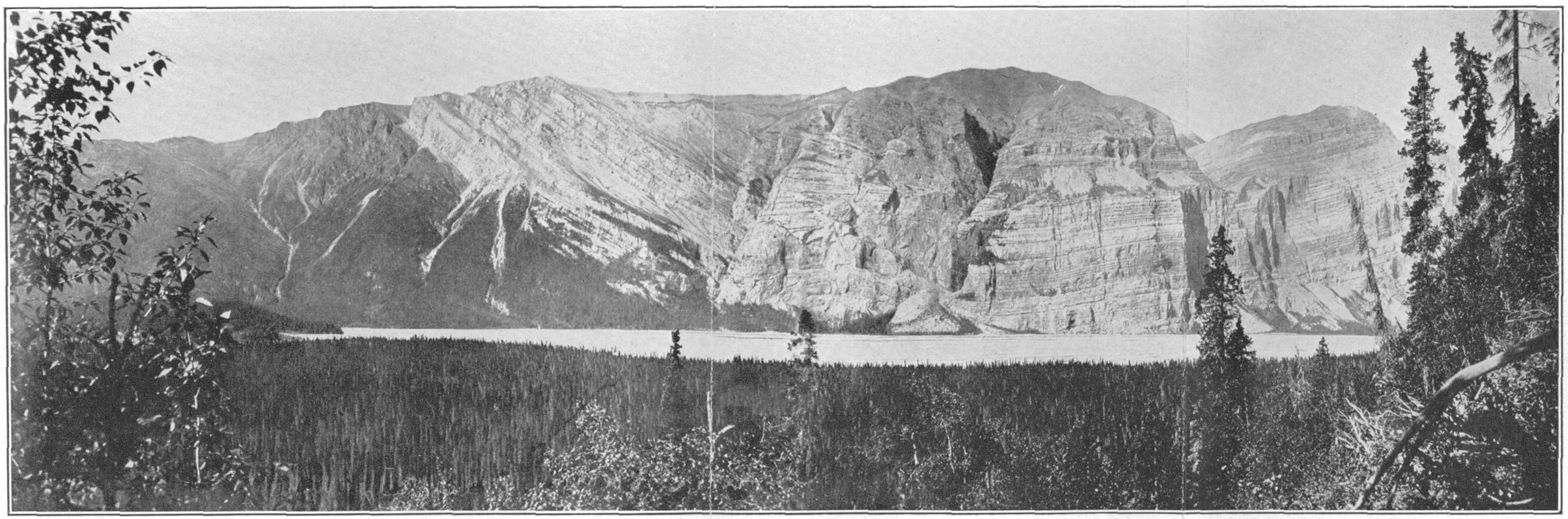
The two formations in the type locality comprise an uninterrupted succession of limestone beds that were deposited on a gradually sinking sea bottom. Probably the lowest beds were laid down in an arm of the sea that increased somewhat in area as subsidence continued, so that the later beds overlap the older. The basal part of the Chitistone limestone is bluish-gray limestone that, so far as is known, lies with structural conformity above the Nikolai greenstone and is

[21] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 37, pp. 690-694, 1916.



A. THE MOUNTAINS NORTH OF LOWER SKOLAI CREEK.

View to the southeast. On the left is the valley of Skolai Creek. On the extreme right is the Nizina River Valley. The horizontally bedded rocks on the left are Tertiary volcanics. Below them and on the right are Permian volcanics and limestone.

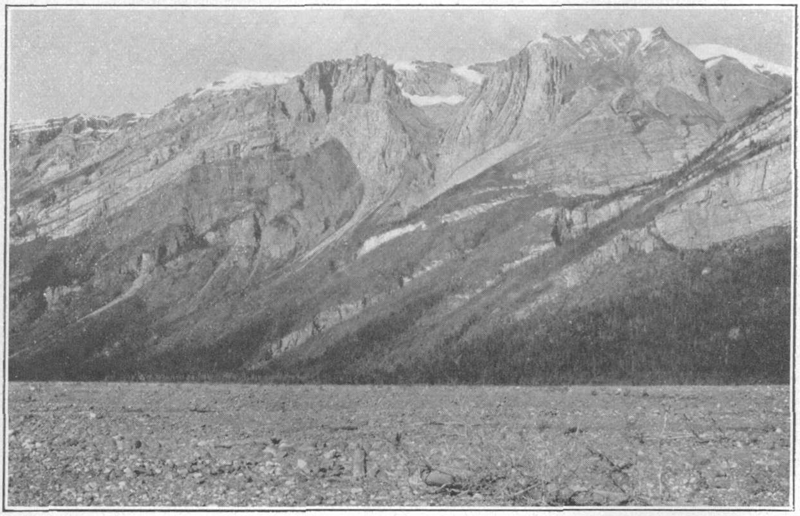


B. VIEW OF THE WEST SIDE OF NIZINA VALLEY FROM A POINT ABOUT 1 MILE NORTH OF THE CHITISTONE RIVER.

On the left is the Nikolai greenstone. This is overlain by the Chitistone and Nizina limestones, on which is the McCarthy shale forming the highest part of the mountain. To the left of the center the horizontal Lower Cretaceous sandstone rests unconformably on the Triassic limestone.

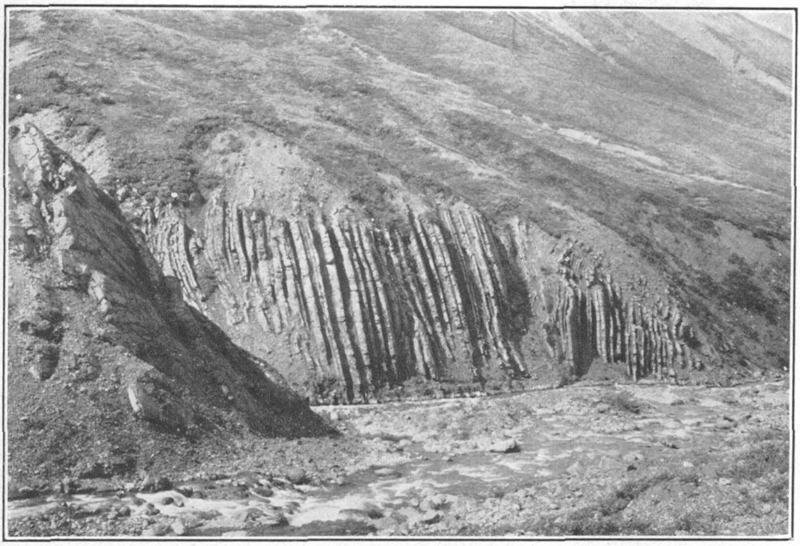
SECTION OF THE UPPER TRIASSIC ROCKS ON THE EAST SIDE OF McCARTHY CREEK.

The Chitistone and Nizina limestones rest on the Nikolai greenstone, seen on the lower right. The top of the section, in the center of the picture, is the base of the McCarthy shale. On the extreme right, near the limestone-greenstone contact, are the buildings of the Green Butte mine.



A. THE GREAT OVERTHRUST FAULT AS IT APPEARS ON THE NORTH SIDE OF THE CHITISTONE RIVER BELOW THE MOUTH OF GLACIER CREEK.

The dark rocks on the lower left are Nikolai greenstone. Above and to the right are the Chitistone and Nizina limestones.



B. THIN-BEDDED UPPER TRIASSIC ARGILLITE AND SHALE BEDS ON ROCK CREEK, IN THE KOTSINA VALLEY.

separated from it in places if not everywhere by a bed of gray or reddish shale from a few inches to 5 feet thick. Commonly but not invariably the basal beds are massive, to be measured in tens of feet, and show little evidence of stratification, but where bedding planes are recognized thin shaly partings between limestone beds may often be seen. Locally, however, the basal beds are 18 inches or less in thickness, although the bedding lines are not distinct at close view. In the higher beds the composition of the limestone is somewhat different. The freshly broken surface is darker gray, thin beds are more numerous, and shale partings are more noticeable. Evidently the sea was depositing more mud, the limestone was becoming less pure, and the conditions of deposition were less stable. A fine section of the limestone on the east fork of McCarthy Creek shows a fairly regular succession of massive beds with indistinct or discontinuous lines of stratification, alternating with zones of thin beds, the whole assemblage having a thickness of at least 1,000 feet.

In some localities, as at the Kennecott mines, the lower beds of the Chitistone limestone are dolomitic. In part at least the dolomitization was a secondary process that was brought about after the original limestone was deposited, for the boundary surface between the dolomitic and the purer limestone crosses the beds irregularly without regard to bedding planes. The dolomitic rock, however, is not known to extend more than a few hundred feet above the base of the formation. How widespread this altered phase of the Chitistone limestone may be in the Chitina Valley has not been determined. Probably it is a local feature.

Another feature of the Chitistone limestone that is evident wherever the formation occurs, yet is more characteristic of some parts of it than of others, is the occurrence of black or brownish-black chert. The chert may take the form of thin beds or stout lens-shaped bodies in the bedding planes, such lenses reaching a thickness of 10 or 12 inches. Commonly the bodies are tuberous, with stout knobby branches, and are distributed through the limestone with no apparent dependence on the bedding planes. Fantastic shapes that resemble cucumbers, dumbbells, and branching, twisting rods are plentiful. In general the forms are chunky and range in size from less than an inch to a foot or more. These chert bodies are particularly noticeable in limestone on the head of Nikolai Creek, where irregular masses of the adjacent limestone have been silicified, an alteration that makes the rock harder than the normal rock and prevents it from taking the usual light-gray weathering on the surface.

The Chitistone limestone is cut here and there by dikes of quartz diorite or a closely related light-colored igneous rock. Most of the dikes have been considerably altered, so that their character is not easily determined. Furthermore the dikes themselves blend so well with the limestone in the surface exposures that they escape casual notice. Several such intrusive bodies were encountered in the mines at Kennecott. They are probably more numerous in that part of the area than elsewhere.

The Nizina limestone includes approximately the upper two-fifths of the original Chitistone limestone as exposed in the Nizina district. No distinct stratigraphic break is recognized between the Chitistone and Nizina formations. The two are structurally conformable in the type locality, and there is difficulty in determining where to place the boundary line separating them. The Nizina is distinctly bedded, and on the average the beds are thinner than those of the Chitistone, commonly measuring from a few inches to 2 feet, although much thicker beds are present. It is a darker gray, and the shale partings between the beds are thicker and more noticeable, yet they constitute only a minor proportion of the whole. In large exposures viewed from a distance the weathered surface of the Nizina limestone shows a brownish-yellow color that serves to distinguish it from the underlying Chitistone. This distinction, however, is less pronounced in hand specimens, and in isolated exposures it is practically impossible to distinguish the Nizina limestone from the Chitistone by lithologic differences.

No sharp line of separation exists between the Nizina limestone and the overlying McCarthy shale, for the two merge into each other by a gradual change in the character of the sediments that continued through many scores of feet and finally resulted in the substitution of argillaceous and fine sandy material for lime.

The Upper Triassic limestone formations are exposed in the mountains on the north side of the Chitina Valley from the Kotsina River on the west to the divide between the heads of Glacier and Canyon Creeks on the east. They do not form a continuous belt of limestone throughout this distance. Their continuity was interrupted through faulting and erosion, and they are covered in places by younger rock formations and stream-gravel deposits that lie on them unconformably. Their finest exposures are on McCarthy Creek (pl. 7) and the Nizina River (pl. 6, *B*), where the whole sequence of Upper Triassic limestone from the base to the overlying McCarthy shale is displayed in natural sections of diagrammatic clearness. Between Kennicott Glacier and the Kuskulana River the limestone formations are much less in evidence than at the extremities of the basin, and exposures have not been examined with thoroughness, for they extend into a district of very rugged mountains and are difficult of access. It is not known whether the limestone is continuous through this section or occurs in disconnected areas. West of the Kuskulana River the limestone is repeatedly folded, with the result that through the accidents of erosion and faulting it is exposed in several distinct nearly parallel belts.

The length of the area in which the Chitistone and Nizina limestones are known to occur is about 65 miles from east to west, and the width at the widest place on Nizina River is 14 miles. How far the limestones may extend northward beneath the Tertiary lava flows of the Wrangell Mountains is impossible to determine. They are not known to occur south of the Chitina River.

THICKNESS AND STRUCTURE

The Chitistone and Nizina limestones are exposed in their full development in at least three localities where conditions afford favorable opportunities to calculate their thickness—on the Nizina River opposite the mouth of the Chitistone, on the east side of McCarthy Creek, and on the east side of the Lakina River near the foot of the glacier. At each locality fine natural sections were produced by stream and ice erosion, but the valley walls are so high and precipitous that direct measurements are impracticable. It is therefore necessary to calculate the thickness, making use of the topographic map and the known dips and strikes. In this way the limestone on McCarthy Creek was found to be about 3,000 feet thick.[22] This computation involves an exercise of judgment in placing the boundary between the Nizina limestone and the McCarthy shale, for, as has been stated, no sharply marked boundary exists. It is thus possible that some difference of opinion as to the correctness of the computations may easily arise.

The section on McCarthy Creek is much more accessible than the type section of the Chitistone on the Nizina River and has been given special study. It was first estimated that the total thickness of 3,000 feet should be apportioned between the Chitistone and Nizina formations in the ratio of about 3 to 2. It was later found that the thickness of the Chitistone limestone at this place is about 1,900 feet and that of the Nizina limestone is 1,100 feet. Although these figures are admittedly not exact, the percentage of error is probably not great.

The section on the Nizina River is less accessible for direct measurement than that on McCarthy Creek. A great open synclinal fold is exposed, but the lowest point of the fold dips slightly below the bars of the Nizina River, and the top of the limestone is no more distinctly shown than on McCarthy Creek. By reconstructing the section, however, a measurement agreeing well with the thickness on McCarthy Creek is obtained.

A calculation of the thickness on the Lakina River was not made, as the topographic map of that vicinity is on a smaller scale and is

[22] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, p. 23, 1911.

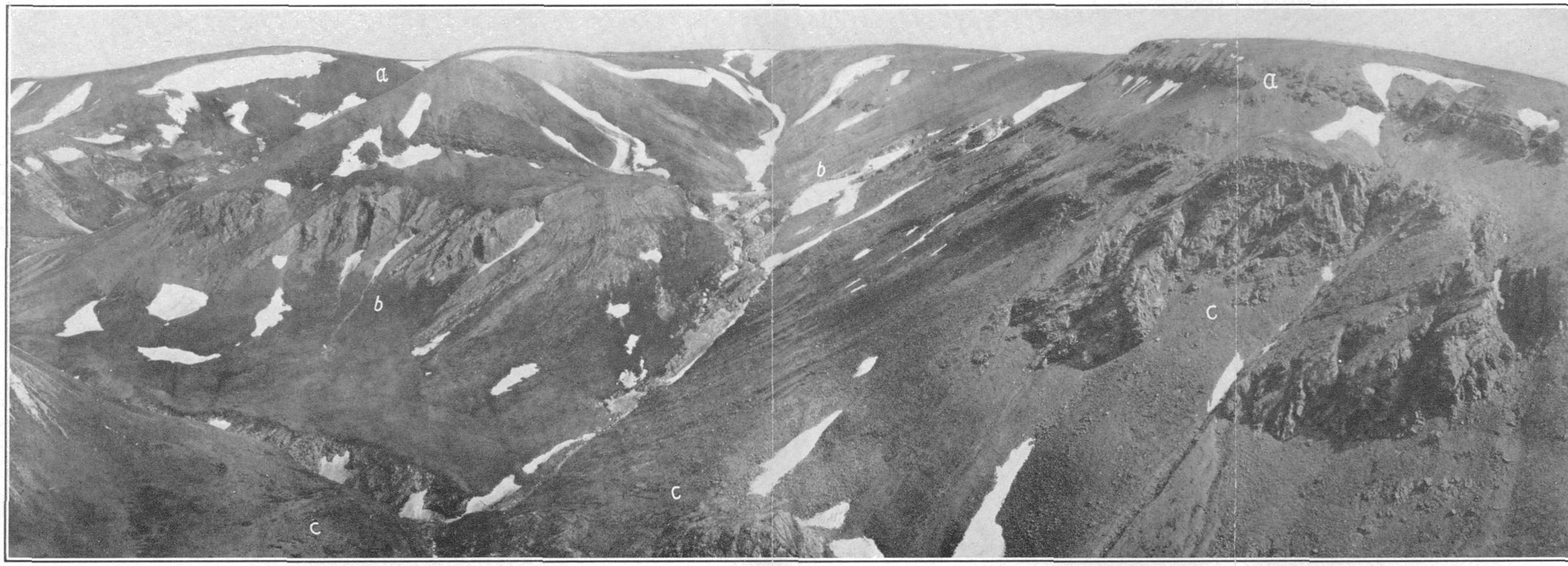
less accurate. It is probable that the thickness there is not greatly different from that of the two sections already given.

The Triassic limestone is well exposed on the Chitistone River and appears to be somewhat thicker in that vicinity, but measurements there are made uncertain by folding of the beds and the occurrence of a great overthrust fault.

In the Kotsina-Kuskulana district the opportunities for measurement are less favorable than in the east end of the limestone basin, as the limestone is extensively faulted and in places is hidden by younger unconformable beds. The limestone on the north side of Elliott Creek ranges from 75 to 200 feet in thickness. This great reduction in thickness is considered below in connection with the structure. Nearby on the north fork of Strelna Creek the thickness is 400 feet. On Clear Creek, a tributary of the Kuskulana River, it is 700 feet, and on Lime Creek it is from 700 to possibly 1,000 feet. These measurements apply only to the Chitistone limestone, for in mapping this area an attempt was made to differentiate the Chitistone from the Nizina. The Nizina limestone, however, was considered a part of the Kuskulana formation—an undifferentiated succession of Upper Triassic limestone and shale beds that were believed to represent the Nizina limestone and the McCarthy shale.

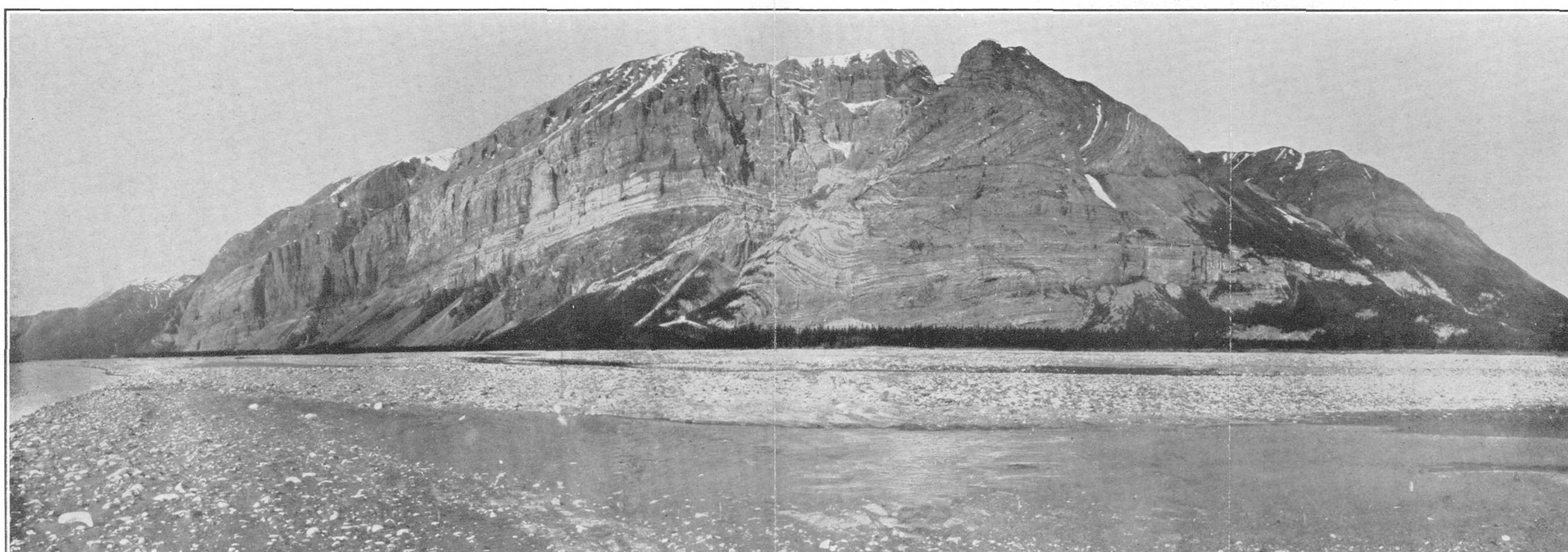
It appears probable that neither the Chitistone nor the Nizina limestone is as thick in the Kotsina-Kuskulana district as in the Nizina district. On the other hand, the overlying Upper Triassic shale may be thicker.

The Chitistone limestone appears to have been deposited on the Nikolai greenstone with structural conformity. The contact of the two formations in the large exposures is commonly covered with talus, for differential weathering tends to produce at the contact a slight bench, which is favorable for the accumulation of loose material. A thin bed of shale between the lava flows and limestone has been noted in many places where the talus is absent or has been removed or where the contact of the limestone and greenstone has been exposed in mining operations, but the bedding planes of the lava and the limestone are conformable wherever they have been studied. Nevertheless it seems probable that some time break must be represented by the contact, for most of the recently collected evidence points to a Permian age for the lava flows, and no sedimentary rocks other than the shale are present to represent the probable long interval of Triassic time between the pouring out of the lavas and the deposition of the limestone. Black shale that resembles the McCarthy shale lithologically yet carries a fauna that Martin regards as typical of the Chitistone limestone lies unconformably on Permian limestone north of lower Skolai Creek. As the limestone occurs in the middle of the Permian stratigraphic section it is evident that a great uncon-



A. UNCONFORMITY BETWEEN PERMIAN AND TRIASSIC, AND LOWER CRETACEOUS FORMATIONS AT THE HEAD OF NIKOLAI CREEK.

a, Lower Cretaceous sandstone and shale. *b*, Chitistone limestone. *c*, Nikolai greenstone. View southward from point near the Nikolai "mine."



B. THE OVERTHRUST FAULT ON THE WEST SIDE OF THE NIZINA RIVER BELOW THE MOUTH OF THE WEST FORK.

In the center of the picture a wedge-shaped mass of Nikolai greenstone is thrust over the lower part of the Chitistone and Nizina limestones. The drag folds of the limestone above the fault are seen in the upper right. The direction of the view is southwesterly, and the strike of the fault is about west-northwest.

formity exists between the Permian and Upper Triassic rocks in this locality.

The Chitistone and Nizina limestones are folded and much faulted. Along the southern boundary of the limestone belt, from the head of Young Creek to the Lakina River, the dip of the basal beds is north-northeast at varying angles up to 35°. The beds dip less steeply farther north, and in places, as on the Nizina River and McCarthy Creek, they evidently have a general synclinal structure complicated by minor folds. In the Kotsina-Kuskulana district the major folds are repeated, the tops of the anticlines were eroded off, and a succession of belts of limestone with radial arrangement, diverging toward the west, was produced. This folding, however, was accompanied or followed by profound faulting, so that the structure is complex.

Faults are pronounced throughout the area where the limestone occurs. Commonly the major faults cut the limestone with strikes that approximate the strike or the dip of the beds. Faulting on the bedding planes is widespread. Evidently the limestone beds moved on one another much like the leaves of a book that is folded. Such bed faulting occurred throughout the formation and also at its base, so that probably there are few places on the flanks of the folds where movement of the Chitistone limestone on the Nikolai greenstone has not taken place. Some of the bedding-plane faults pass from one bedding plane to another, cutting the intermediate bed or beds at acute angles. They also merge into the dip faults in many places, and the resulting striations and grooves on the walls of the dip faults are parallel to the bedding planes. The faults in the Chitistone limestone of the Kennecott mines are of so great importance in the mining operations that they are mapped and studied with much care. All classes of faults are met, but the bedding-plane and dip faults are of particular concern because of their controlling influence in the formation of the ore bodies.

A fine example of a gently southward-dipping thrust fault cutting the limestone and greenstone contact is seen on the west side of the Nizina River a short distance below the mouth of the West Fork (pl. 9, *B*). This fault extends northwestward into the West Fork Valley and southeastward across the Nizina and Chitistone Rivers (pl. 8, *A*) into the valley of Glacier Creek. It has a known length of at least 10 miles and a displacement of many hundreds of feet. The fault originated by the rupture of an unsymmetrical fold in the limestone and resulted in the thrusting of a wedge of greenstone northward over the basal beds of the limestone. The relative motion of the masses of rock above and below the fault is plainly shown by the drag folds of the limestone.

Another conspicuous fault occurs in Donahoe Peak between the forks of Kennicott Glacier, west of the Erie mine. This is a bedding-plane fault between the limestone and greenstone, dipping north-northeast, and would be difficult to recognize if it were not for the wedge of limestone and greenstone cut off by the fault at the south side of the peak.

Vertical faults crossing the limestone-greenstone contact are numerous. The displacement may range from practically nothing to many feet but is commonly too small to indicate in reconnaissance mapping. In many places, as on the north side of Dan Creek, faulting of this kind produced a noticeable stepping up or down of the boundary line between the limestone and greenstone.

Faulting is highly developed in the Kotsina-Kuskulana district, and faults having the same strike as the trend of the formations are particularly prominent, as may be seen from the geologic map. In most places strike faults between the limestone of the several limestone belts and one of the adjoining formations were definitely recognized. Martin [23] has presented evidence in support of a belief that a marked unconformity exists within the Upper Triassic formations of the Chitina Valley, as well as those of southeastern Alaska and British Columbia, and suggested that the apparent thinning of the limestone toward the west in the Chitina Valley may be due to the erosion represented by this unconformity and the consequent nondeposition of beds representing all or part of the Nizina formation. This possibility is discussed in connection with the description of the McCarthy formation (p. 60), but it may be stated here that although the possibility is recognized by the writer he has been inclined, in the absence of evidence for structural unconformity in the sections that are most favorable for examination, to attribute the irregularities in thickness of the Upper Triassic limestone formations in this area to variation in the amount and character of the deposits, to faulting, and to post-Triassic unconformities rather than to a period of erosion that interrupted the deposition of sediments.

AGE AND CORRELATION

The Chitistone and Nizina limestones are of Upper Triassic age. According to Martin [24] the Chitistone limestone "probably belongs to the middle or Karnic stage of the Upper Triassic, being the equivalent of at least a part of the Hosselkus limestone of California." The Nizina limestone is overlain by the McCarthy shale, which, as stated by Martin,[25] "probably belongs to the Upper Noric, near the top of the Upper Triassic."

The age determinations are based on the evidence of fossils and are not open to doubt so far as the Upper Triassic assignment is concerned. Fossils are not abundant in the limestones at any place but are more

[23] Martin, G. C., The Mesozoic stratigraphy of Alaska: U. S. Geol. Survey Bull. 776, p. 124, 1926.

[24] Idem, p. 18.

[25] Idem, p. 22.

numerous in the lower part than in the upper thin-bedded part. The failure to obtain fossils for determination during the earlier field work led to the correlation of the Chitistone limestone with the Carboniferous limestone of the White River district, a correlation that was quite natural in view of the appearance of the rocks and their occurrence in neighboring localities but that was found in error when fossil collections became available for study. The fauna of the Chitistone formation is of the marine Mediterranean type[26] and probably indicates a warm-water environment. The fauna of the McCarthy shale, on the other hand, is of the boreal type, indicative of colder water. The cold-water fauna is abundant in a zone that includes the base of the McCarthy shale and at least the upper beds of the limestone—that is, in thin limestone beds that form the top of the Nizina limestone, if the Nizina limestone is defined on the basis of its lithologic character rather than its fauna. The Nizina limestone of the type locality has not yielded diagnostic fossils, but the thin-bedded limestone of the Kotsina-Kuskulana district, which is believed to be the equivalent of the Nizina limestone, contains a fauna that "appears to be essentially the same as that of the Chitistone limestone."[27] It is the belief of the writer that the change from a warm to a cold sea occurred during the deposition of the Nizina limestone but not till most of the formation had been laid down. Such a change might signify an elevation of the sea bottom and a period of erosion that interrupted deposition for a time but was followed by subsidence and the establishment of a new and different fauna. It might signify equally well merely the incursion of colder waters in a restricted warm-water sea during a period of continued subsidence of the land. Such an incursion could bring about conditions under which the cold-water fauna of the McCarthy formation would flourish. Not having seen evidence of structural unconformity within the different Upper Triassic formations of the Chitina Valley, the writer was led to regard the latter interpretation of the change of faunas as the more probable for this area. Martin,[28] however, has given evidence showing the occurrence of an unconformity within the Upper Triassic deposits of southeastern Alaska and British Columbia and has presented facts to support his belief that a similar unconformity exists between the Nizina limestone and the McCarthy shale. It is the writer's belief that we do not yet have all the information needed to determine which interpretation is correct, so far as an unconformity within the Upper Triassic deposits of the Chitina Valley is concerned. Upper Triassic fossils from more than 150 localities in the Chitina Valley have been collected and submitted to the paleontologists for identification. The number of localities where fossils have been found, however, is much greater than that, because at many

[26] Idem, p. 18.
[27] Idem, p. 22.
[28] Idem, p. 124.

times in the course of reconnaissance mapping it was not felt necessary to collect forms that were easily recognized and duplicated collections already made.

In the accompanying table is given a list of fossils arranged biologically, and below is a description of the localities from which they came. This list contains all the species collected from the Upper Triassic formations, including the McCarthy shale as well as the Chitistone and Nizina limestones. The fossils were identified by T. W. Stanton and John B. Reeside, Jr., as is indicated by the initials S. and R. at the tops of the columns representing different localities. The most common fossil collected from the limestone, at least in all but the highest beds, is the pelecypod *Halobia* cf. *H. superba* Mojsisovics (pl. 10, figs. 1, 2), which is widespread in distribution and is regarded as characteristic of the Chitistone and Nizina formations.[29]

4810. South side of Chitistone River at Houghton-Alaska Co.'s prospect. Talus. Collector, Fred H. Moffit, 1907.

6319. South side of Chitistone River on east side of lowest large tributary, about 4 miles above Nizina River. Near base of Chitistone limestone. Collector, Fred H. Moffit, 1909.

6320. South side of Chitistone River on west side of lowest large tributary, about 4 miles above Nizina River. Near base of Chitistone limestone. Collector, Fred H. Moffit, 1909.

6333. South side of Chitistone River at Houghton-Alaska prospect, about 4½ miles above Nizina River. Near base of Chitistone limestone. Collector, S. R. Capps, 1909.

6306. Valley of Nikolai Creek about two-thirds of a mile northeast of Nikolai mine. Collector, Fred H. Moffit, 1909.

6300. Jumbo Creek on spur 0.4 mile southwest of Bonanza Peak. Base of Chitistone limestone. Collector, Fred H. Moffit, 1909.

6303. Boulder of limestone in Nikolai Creek. Collector, Fred H. Moffit, 1909.

6311. Top of mountain north of headwaters of Nikolai Creek, about 1⅔ miles N. 20° E. of Nikolai mine; altitude 6,000 feet. Near locality and horizon of lot 8889. Collector, Fred H. Moffit, 1909.

6312. Head of Nikolai Creek, 4,400 feet N. 35° E. of Nikolai mine. Collector, Fred H. Moffit, 1909.

8882. Valley of Nikolai Creek about two-thirds of a mile east of Nikolai mine. About 1,000 feet above base of Chitistone limestone. Collector, G. C. Martin, 1914.

8883. Valley of Nikolai Creek about two-thirds of a mile east of Nikolai mine, 200 or 300 yards northwest of locality 8882. 1,200 feet above base of Chitistone limestone. Collector, G. C. Martin, 1914.

8884. Valley of Nikolai Creek about 0.3 mile N. 70° E. of Nikolai mine. About 800 feet above base of Chitistone limestone. Collector, G. C. Martin, 1914.

8885. Valley of Nikolai Creek about a quarter of a mile east of Nikolai mine. About 500 feet above base of Chitistone limestone. Collector, G. C. Martin, 1914.

8886. Valley of Nikolai Creek, small gulch 0.56 mile N. 50° E. of Nikolai mine. Boulder probably near horizon of lot 6306. Collector, G. C. Martin, 1914.

[29] Idem, pp. 18, 22, 120–122.

Fossils from the Upper Triassic rocks

	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	R	R	S	S	R	R	R	R
	4810	6319	6320	6333	6306	8886	6303	6311	8889	6312	8882	8883	8884	8885	8887	8890	8891	14507	14509	6314	6330	11379	11381	11382	11384
Sponge																									
Corals											X														
Thecosmilia sp																									
Thamnastraea sp																									X
Spongiomorpha sp																									
Crinoid stems, probably *Isocrinus* sp																									X
Pentacrinus sp																									
Pelecypod						X	X																		
Pelecypod, possibly a *Myophoria*												X													
Terebratula sp																					X				
Spiriferina sp	X																								
Nemodon sp																									
Avicula sp																									
Pteria sp																									
Cassianella sp																									
Halobia cf. *H. austriaca* Mojsisovics						X							X	X											
Halobia cf. *H. septentrionalis* Smith?																									
Halobia superba Mojsisovics			?	?			?																		
Halobia sp	X								X						X							X			X
Halobia sp. with broad ribs																									
Halobia sp. with fine ribs																									
Halobia sp. nearly smooth																									
Pseudomonotis subcircularis (Gabb)										X								X		X					
Gryphea sp																									
Cardinia sp																									
Megalodus																									
Myophoria sp																									X
Pecten sp																							X	?	
Hinnites sp																									
Hinnites sp. cf. *Halobia occidentalis* (Whiteaves)																									
Lima (*Plagiostoma*) sp., possibly n. sp																									
Lima n. sp																									
Pleuromya sp																									
Gastropod																									X
Pleurotomaria (Sisenna) sp																									
Turbo sp						?																			
Pseudomelania sp																									
Natica sp																									
Arpadites sp																									
Orthoceras sp										X															
Orthoceras cf. *O. shastense* (Hyatt and Smith)																									X
Pleuronautilus sp																									
Ammonite						X		X																	
Tropigastrites sp																									
Tropites sp	?	X																							
Tropites cf. *T. subbullatus* Hauer																									
Tropites more compressed than *T. subbullatus* (Hauer)																									X
Discotropites cf. *D. sandlingensis* (Hauer)																									X
Halorites sp																		X							
Halorites sp. aff. *H. americanus* Hyatt but distinct																									
Juvavites (*Anatomites*) sp. aff. *J. intermittens* (Hyatt and Smith)																									
Juvavites sp					?					?															
Arniotites sp									?							?	?								
Arcestes sp	?	X	X	X	X	?				X			?	?	?				?						X
Ceratites sp																									
Clionites sp																									
Clionites (*Neanites*) sp																									
Trachyceras (*Protrachyceras*)																									
Trachyceras sp																									?
Phylloceras sp																									
Atractites sp						X									X										
Barnacle (plates) of family Lepadidae																									

	R	R	R	R	R	R	R	R		R	R	R	S	S	S	S	S					S	S	S	R
	11385	11386	11388	14026	14027	14030	14493	14494	13	14036	14037	14513	6317	6318	6321	6323	6335	9482	7	8	2200	4808	4809	6300	13749
Sponge												X													
Corals																						X		?	
Thecosmilia sp	?																								
Thamnastraea sp	X																								
Spongiomorpha sp	?																								
Crinoid stems, probably *Isocrinus* sp																									
Pentacrinus sp																							X		
Pelecypod																									X
Pelecypod, possibly a *Myophoria*																									X
Terebratula sp	X																					X	X		
Spiriferina sp	X																					X			
Nemodon sp																									
Avicula sp																							?		
Pteria sp																									
Cassianella sp																								?	?
Halobia cf. *H. austriaca* Mojsisovics		X								X															
Halobia cf. *H. septentrionalis* Smith?																									
Halobia superba Mojsisovics										X				?	?										
Halobia sp							X				X														
Halobia sp. with broad ribs																									
Halobia sp. with fine ribs																									
Halobia sp. nearly smooth																									
Pseudomonotis subcircularis (Gabb)			X					X	X			X	X			X	X	X	X	X		X			
Gryphea sp																									
Cardinia sp																									
Megalodus																									?
Myophoria sp	X																								
Pecten sp								X																	
Hinnites sp																						?			
Hinnites sp. cf. *Halobia occidentalis* (Whiteaves)																									
Lima (*Plagiostoma*) sp., possibly n. sp																									
Lima n. sp				X	X	X																			
Pleuromya sp	?																								?
Gastropod	X																								X
Pleurotomaria (Sisenna) sp	X																								
Turbo sp	X																								
Pseudomelania sp	?																								
Natica sp	?																								
Arpadites sp																									
Orthoceras sp																									
Orthoceras cf. *O. shastense* (Hyatt and Smith)																									
Pleuronautilus sp																									X
Ammonite						X		X																	
Tropigastrites sp						?																			
Tropites sp																									
Tropites cf. *T. subbullatus* Hauer																									
Tropites more compressed than *T. subbullatus* (Hauer)																									
Discotropites cf. *D. sandlingensis* (Hauer)																									
Halorites sp																									
Halorites sp. aff. *H. americanus* Hyatt but distinct																									
Juvavites (*Anatomites*) sp. aff. *J. intermittens* (Hyatt and Smith)																									
Juvavites sp																							?		X
Arniotites sp	?																								
Arcestes sp	X																						?		
Ceratites sp																									
Clionites sp						?																			
Clionites (*Neanites*) sp																									
Trachyceras (*Protrachyceras*)																									
Trachyceras sp																									
Phylloceras sp																									
Atractites sp																									
Barnacle (plates) of family Lepadidae																									

	S		R	R	S	S	S		S	S	S	S	R	R	R	R	R	R	S	S	S	S	S	S	R
	8881	14463	14469	14470	9968	9974	9979	2209	9961	9962	9963	9964	11365	11366	11367	11368	14472	14482	9953	9956	9957	9958	9959	9960	14473
Sponge																									
Corals																									
Thecosmilia sp																									
Thamnastraea sp																									
Spongiomorpha sp																									
Crinoid stems, probably *Isocrinus* sp																									
Pentacrinus sp								X																	
Pelecypod								X																	
Pelecypod, possibly a *Myophoria*																									
Terebratula sp																									
Spiriferina sp																									
Nemodon sp																									
Avicula sp								?																	
Pteria sp																				?					
Cassianella sp																									
Halobia cf. *H. austriaca* Mojsisovics																									
Halobia cf. *H. septentrionalis* Smith?																	?								
Halobia superba Mojsisovics														X											
Halobia sp																		X							
Halobia sp. with broad ribs																				X					
Halobia sp. with fine ribs																									
Halobia sp. nearly smooth																									
Pseudomonotis subcircularis (Gabb)	X		X	X	X	X	X		X	X		X	X		X	X						X	X		X
Gryphea sp								X																	
Cardinia sp																									
Megalodus																									
Myophoria sp																									
Pecten sp																					X				
Hinnites sp									?																
Hinnites sp. cf. *Halobia occidentalis* (Whiteaves)																									
Lima (*Plagiostoma*) sp., possibly n. sp																									
Lima n. sp																									
Pleuromya sp																									
Gastropod																									
Pleurotomaria (Sisenna) sp																									
Turbo sp																									
Pseudomelania sp																									
Natica sp																									
Arpadites sp																									
Orthoceras sp																									
Orthoceras cf. *O. shastense* (Hyatt and Smith)																									
Pleuronautilus sp																									
Ammonite									X		X									X					
Tropigastrites sp																									
Tropites sp																									
Tropites cf. *T. subbullatus* Hauer																									
Tropites more compressed than *T. subbullatus* (Hauer)																									
Discotropites cf. *D. sandlingensis* (Hauer)																									
Halorites sp																									
Halorites sp. aff. *H. americanus* Hyatt but distinct																									
Juvavites (*Anatomites*) sp. aff. *J. intermittens* (Hyatt and Smith)																									
Juvavites sp																									
Arniotites sp																									
Arcestes sp																									
Ceratites sp																									
Clionites sp																									
Clionites (*Neanites*) sp																	?								
Trachyceras (*Protrachyceras*)																								?	
Trachyceras sp																									
Phylloceras sp					X																				
Atractites sp																									
Barnacle (plates) of family Lepadidae																					X				

	R		R	R	R				S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
	14474	14475	14476	14479	14481	1	2	2202	8165	8166	8167	8169	8152	8153	8154	8156	8157	8158	8159	8160	8162	8164	9948	9932	9947
Sponge																									
Corals																									
Thecosmilia sp																									
Thamnastraea sp																									
Spongiomorpha sp																									
Crinoid stems, probably *Isocrinus* sp																									
Pentacrinus sp																									
Pelecypod																X									
Pelecypod, possibly a *Myophoria*																									
Terebratula sp																									
Spiriferina sp																									
Nemodon sp		?																							
Avicula sp																									
Pteria sp																									
Cassianella sp																									
Halobia cf. *H. austriaca* Mojsisovics																									
Halobia cf. *H. septentrionalis* Smith?																									
Halobia superba Mojsisovics															?										
Halobia sp									?	?		X	?	X	X		?	X	?			?			
Halobia sp. with broad ribs																									
Halobia sp. with fine ribs																							X		
Halobia sp. nearly smooth																									
Pseudomonotis subcircularis (Gabb)	X	X	X	X	X	X	X	X												X	X			X	X
Gryphea sp											?								?						
Cardinia sp	?																								
Megalodus																									
Myophoria sp															?										
Pecten sp																				X					
Hinnites sp																									
Hinnites sp. cf. *Halobia occidentalis* (Whiteaves)																									
Lima (*Plagiostoma*) sp., possibly n. sp																									
Lima n. sp																									
Pleuromya sp																									
Gastropod													X												
Pleurotomaria (Sisenna) sp																									
Turbo sp																									
Pseudomelania sp																									
Natica sp																									
Arpadites sp																									
Orthoceras sp																									
Orthoceras cf. *O. shastense* (Hyatt and Smith)																									
Pleuronautilus sp																									
Ammonite																		X							
Tropigastrites sp																									
Tropites sp																									
Tropites cf. *T. subbullatus* Hauer																									
Tropites more compressed than *T. subbullatus* (Hauer)																									
Discotropites cf. *D. sandlingensis* (Hauer)																									
Halorites sp																									
Halorites sp. aff. *H. americanus* Hyatt but distinct																									
Juvavites (*Anatomites*) sp. aff. *J. intermittens* (Hyatt and Smith)																									
Juvavites sp																									
Arniotites sp																									
Arcestes sp													X												
Ceratites sp															?		?	?							
Clionites sp																									
Clionites (*Neanites*) sp																									
Trachyceras (*Protrachyceras*)																									
Trachyceras sp																									
Phylloceras sp																									
Atractites sp																									
Barnacle (plates) of family Lepadidae																									

	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
	9946	8147	8148	8149	8150	8151	8925	8928	8929	8930	8931	9919	9920	9921	9922	9923	9924	9925	9926	9927	9928	9929	9930	9931	9945
Sponge																									
Corals													X												
Thecosmilia sp																									
Thamnastraea sp																									
Spongiomorpha sp																									
Crinoid stems, probably *Isocrinus* sp																									
Pentacrinus sp																									
Pelecypod																									
Pelecypod, possibly a *Myophoria*																									
Terebratula sp																									
Spiriferina sp																									
Nemodon sp																									
Avicula sp																									
Pteria sp																									
Cassianella sp																									
Halobia cf. *H. austriaca* Mojsisovics																									
Halobia cf. *H. septentrionalis* Smith?																									
Halobia superba Mojsisovics	?	?		?								?		?		?	?	?		?	?	?	?		?
Halobia sp					X	X				X	?														
Halobia sp. with broad ribs																					X	X			
Halobia sp. with fine ribs																									
Halobia sp. nearly smooth												X													
Pseudomonotis subcircularis (Gabb)													X						X					X	
Gryphea sp																									
Cardinia sp																									
Megalodus																									
Myophoria sp																									
Pecten sp											?														
Hinnites sp																									
Hinnites sp. cf. *Halobia occidentalis* (Whiteaves)																									
Lima (*Plagiostoma*) sp., possibly n. sp																									
Lima n. sp																									
Pleuromya sp																									
Gastropod																									
Pleurotomaria (Sisenna) sp																									
Turbo sp																									
Pseudomelania sp																									
Natica sp											?														
Arpadites sp																									
Orthoceras sp																									
Orthoceras cf. *O. shastense* (Hyatt and Smith)																									
Pleuronautilus sp																									
Ammonite								X				X													
Tropigastrites sp																									
Tropites sp			?						X																
Tropites cf. *T. subbullatus* Hauer																									
Tropites more compressed than *T. subbullatus* (Hauer)																									
Discotropites cf. *D. sandlingensis* (Hauer)																									
Halorites sp																									
Halorites sp. aff. *H. americanus* Hyatt but distinct																									
Juvavites (*Anatomites*) sp. aff. *J. intermittens* (Hyatt and Smith)																									
Juvavites sp																									
Arniotites sp																									
Arcestes sp							?		?						?			X							
Ceratites sp																									
Clionites sp																									
Clionites (*Neanites*) sp																									
Trachyceras (*Protrachyceras*)																									
Trachyceras sp																									
Phylloceras sp																									
Atractites sp																									
Barnacle (plates) of family Lepadidae																									

		S	S	S	S	S	S	S	S	S	S	S	S	S	S		S	S	S	S	S	S			
	2194	8945	8946	9934	9935	9936	9937	9938	9939	9940	9941	9942	9943	9944	8923	4806	8932	8941	8942	8943	8914	8938	4804	4805 (2, 23)	4805 (3-6)
Sponge																									
Corals			X																						
Thecosmilia sp																									
Thamnastraea sp																									
Spongiomorpha sp																									
Crinoid stems, probably *Isocrinus* sp																									
Pentacrinus sp																									
Pelecypod																									
Pelecypod, possibly a *Myophoria*																									
Terebratula sp			X																						X
Spiriferina sp																									X
Nemodon sp																									
Avicula sp			X																						
Pteria sp																									
Cassianella sp																									
Halobia cf. *H. austriaca* Mojsisovics																									
Halobia cf. *H. septentrionalis* Smith?																									
Halobia superba Mojsisovics																	?	?			?				
Halobia sp			?										X		?		?		X			?			
Halobia sp. with broad ribs				X	X						X														
Halobia sp. with fine ribs																									
Halobia sp. nearly smooth																									
Pseudomonotis subcircularis (Gabb)		X				X	X	X	X	X				X								X			
Gryphea sp			?												?										
Cardinia sp																									
Megalodus																									
Myophoria sp			X																			?			
Pecten sp															X										
Hinnites sp																								?	?
Hinnites sp. cf. *Halobia occidentalis* (Whiteaves)	X																								
Lima (*Plagiostoma*) sp., possibly n. sp							X																		
Lima n. sp																									
Pleuromya sp			?																						?
Gastropod					X																	X			
Pleurotomaria (Sisenna) sp																									
Turbo sp			?																						
Pseudomelania sp			?																						
Natica sp																?									
Arpadites sp					?																				
Orthoceras sp																									
Orthoceras cf. *O. shastense* (Hyatt and Smith)																									
Pleuronautilus sp																									
Ammonite													X		X									X	
Tropigastrites sp																									
Tropites sp																									
Tropites cf. *T. subbullatus* Hauer					X																				
Tropites more compressed than *T. subbullatus* (Hauer)																									
Discotropites cf. *D. sandlingensis* (Hauer)					X																				
Halorites sp																									
Halorites sp. aff. *H. americanus* Hyatt but distinct														X											
Juvavites (*Anatomites*) sp. aff. *J. intermittens* (Hyatt and Smith)					X																				
Juvavites sp					?									?					?	?					
Arniotites sp																									
Arcestes sp					X														?	?					
Ceratites sp																									
Clionites sp																									
Clionites (*Neanites*) sp																									
Trachyceras (*Protrachyceras*)																									
Trachyceras sp																									
Phylloceras sp																									
Atractites sp																									
Barnacle (plates) of family Lepadidae																									

8887. Valley of Nikolai Creek about 0.6 mile N. 48° E. of Nikolai mine. Boulder probably from about same horizon as lot 6306. Collector, G. C. Martin, 1914.

8889. About 100 feet southwest of summit of 6,550-foot peak north of headwaters of Nikolai Creek. Probably 1,500 or 2,000 feet above base of McCarthy formation. Collector, G. C. Martin, 1914.

8890. About 0.3 mile southeast of summit of 6,550-foot peak north of headwaters of Nikolai Creek. Nearly same horizon as 8889. Collector, G. C. Martin, 1914.

8891. About 0.2 mile south-southwest of summit of 6,550-foot peak north of headwaters of Nikolai Creek. Nearly same horizon as 8889. Collector, G. C. Martin, 1914.

14507. Nikolai Creek, 1¼ miles northeast of Nikolai mine; altitude 5,100 feet. Collector, Fred H. Moffit, 1928.

14509. A quarter of a mile northeast of Nikolai mine. Collector, Fred H. Moffit, 1928.

6314. McCarthy Creek, forks of Dimond Creek, an eastern tributary, 4 miles north of the mouth of East Fork. Collector, Fred H. Moffit, 1909.

6330. McCarthy Creek. Said to be 10 feet above base of Chitistone limestone. Given to Fred H. Moffit, 1909.

11379. McCarthy Creek, mouth of third eastern tributary below west glacier. Collector, Fred H. Moffit, 1922.

11381. McCarthy Creek, eastern tributary 6 miles north of East Fork, 2 miles above Dimond Creek, near mouth of creek. Collector, Fred H. Moffit, 1922.

11382. McCarthy Creek, eastern tributary 6 miles north of East Fork, almost 1½ miles north of Mother Lode camp on Dimond Creek, south of and 500 feet higher than locality 11381. Collector, Fred H. Moffit, 1922.

11384. Ridge between McCarthy Creek and East Fork; altitude 5,000 feet. Upper part of Chitistone limestone. Collector, Fred H. Moffit, 1922.

11385. Ridge between McCarthy Creek and East Fork; altitude about 5,100 feet. Collector, Fred H. Moffit, 1922.

11386. Same as locality 11385. Float that could not have traveled more than 50 feet. Collector, Fred H. Moffit, 1922.

11388. Ridge between McCarthy Creek and East Fork, altitude 5,900 feet. Collector, Fred H. Moffit, 1922.

14026. McCarthy Creek Valley 2½ miles north-northeast of Bonanza Peak; altitude 4,400 feet. Collector, Fred H. Moffit, 1927.

14027. McCarthy Creek Valley 3 miles northeast of Bonanza Peak; altitude 4,650 feet. Collector, Fred H. Moffit, 1927.

14030. McCarthy Creek Valley near creek on east side, 2½ miles from west glacier. Collector, Fred H. Moffit, 1927.

14493. Ridge east of McCarthy Creek and south of Lubbe Creek (5½ miles north of East Fork), 1 mile north of Dimond Creek (4 miles north of East Fork). Collector, Fred H. Moffit, 1928.

14494. Lubbe Creek, an eastern tributary of McCarthy Creek 5½ miles north of East Fork. Collector, Fred H. Moffit, 1928.

13. Boulder on flood plain of Nizina River. Collector, Oscar Rohn, 1899.

14036. Skolai Creek Valley, north side, 3 miles west of Frederika Glacier; altitude 6,000 feet. Collector, Fred H. Moffit, 1927.

14037. Skolai Creek Valley north of locality 14036; altitude 6,100 feet. Collector, Fred H. Moffit, 1927.

14513. West side of Nizina Glacier 1 mile from lower end. Collector, Fred H. Moffit, 1928.

6317. West end of canyon of Dan Creek, 1¼ miles below Copper Creek. Collector, Fred H. Moffit, 1909.

6318. Same locality as 6317; boulder in Cretaceous (?) conglomerate. Collector, Fred H. Moffit, 1909.

6321. Copper Creek Valley, ridge north of Texas Creek. Collector, Fred H. Moffit, 1909.

6323. Copper Creek Valley, mouth of Idaho Gulch. Collector, Fred H. Moffit, 1909.

6335. Copper Creek Valley, Idaho Gulch, one-third mile above mouth. Collector, S. R. Capps, 1909.

9482. Stream 2 miles east of Canyon Creek, joining the Hawkins Glacier stream 1 mile north-northwest of Gibraltar Hill. Collector, Fred H. Moffit, 1915.

7. West lateral moraine of Kennicott Glacier. Collector, Oscar Rohn, 1899.

8. Kennicott Glacier. Collector, Oscar Rohn, 1899.

2200. Float along edge of Kennicott Glacier, 7 miles above the Pot Hole. Collectors, F. C. Schrader and A. C. Spencer, 1900.

4808. Near Bonanza mine, on Bonanza Creek. Collector, Fred H. Moffit, 1907.

4809. Jumbo Creek near Bonanza mine. Talus. Collector, Fred H. Moffit, 1907.

13749. East side of Kennicott Glacier, 5 miles north of Kennecott. Float at base of cliff of Chitistone limestone. Collector, Fred H. Moffit, 1926.

8881. Southeast side of mountain north of Fourth of July Pass, altitude 4,300 feet. Thin-bedded shaly limestone. Collector, G. C. Martin, 1914.

14463. Boulder on west side of Kennicott Glacier, 1 mile south of Hidden Creek. Collector, Fred H. Moffit, 1928.

14469. Just below forks of tributary on north side of Fourth of July creek, 1½ miles from Kennicott Glacier. Collector, Fred H. Moffit, 1928.

14470. Forks of Fourth of July Creek. Collector, Fred H. Moffit, 1928.

9968. First northern tributary of Bear Creek east of Fohlin Creek, near falls, half a mile from Bear Creek; altitude 3,200 feet. Float. Collector, Fred H. Moffit, 1916.

9974. Bear Creek a quarter of a mile west of Fourth of July Pass and 200 feet higher. Collector, Fred H. Moffit, 1916.

9979. Fohlin Creek 2.3 miles north of mouth of Bear Creek. Talus below cliff of thin shale and limy argillite. Collector, Fred H. Moffit, 1916.

2209. East side of Lakina Glacier. Collector, A. C. Spencer, 1900.

9961. Mill Creek, western tributary of Lakina River, at forks of creek, 2½ miles from Lakina River. Float. Collector, Fred H. Moffit, 1916.

9962. Same locality as 9961. Fossils in place. Collector, Fred H. Moffit, 1916.

9963. Mill Creek, north side, half a mile from glacier on west fork. Collector, Fred H. Moffit, 1916.

9964. Mill Creek, north fork, 1 mile from mouth. Collector, Fred H. Moffit, 1916.

11365. Ridge south of west branch of Lakina River, 800 feet higher than little lake south of trail. Collector, Fred H. Moffit, 1922.

11366. Top of ridge between west headwater branch of Gilahina River and west fork of Lakina River. Collector, Fred H. Moffit, 1922.

11367. S. 50° W. from mouth of Fohlin Creek and 1,000 feet above Lakina River. Collector, Fred H. Moffit, 1922.

11368. S. 50° W. from mouth of Fohlin Creek and 1,600 feet above Lakina River. Collector, Fred H. Moffit, 1922.

14472. Head of easternmost northern tributary of Mill Creek, tributary of Lakina River. Collector, Fred H. Moffit, 1928.

14482. Same as locality 14472.

9953. 1 mile south of mouth of creek that comes down from Kuskulana Pass to Chokosna River. Collector, Fred H. Moffit, 1916.

9956. Ridge northeast of northern tributary of Chokosna River, half a mile above creek that comes down from Kuskulana Pass. Collector, Fred H. Moffit, 1916.

9957. Ridge east of locality 9956. Collector, Fred H. Moffit, 1916.

9958. Chokosna River 1 mile southeast of mouth of creek flowing from Kuskulana Pass. Collector, Fred H. Moffit, 1916.

9959. Chokosna River about 1½ miles southeast of mouth of creek flowing from Kuskulana Pass. Collector, Fred H. Moffit, 1916.

9960. Chokosna River, limestone bluff three-quarters of a mile S. 35° E. from mouth of creek flowing from Kuskulana Pass. Collector, Fred H. Moffit, 1916.

14473. Headwaters of Chokosna River, 1 mile from river, on east branch of third tributary below its head. Collector, Fred H. Moffit, 1928.

14474. Ridge on north side of head of Chokosna River. Collector, Fred H. Moffit, 1928.

14475. Headwaters of Chokosna River, 1 mile north of old Nizina trail, on first tributary of river east of point where trail from Kuskulana Pass reaches the river. Collector, Fred H. Moffit, 1928.

14476. Same as locality 14475.

14479. Head of Chokosna River, 1½ miles northeast of point where trail from Kuskulana Pass joins the river. Collector, Fred H. Moffit, 1928.

14481. Divide between Chokosna River and Slatka Creek. Collector, Fred H. Moffit, 1928.

1. West side of Kuskulana River. Collector, Oscar Rohn, 1899.

2. West side of Kuskulana River a short distance north of locality 1. Collector, Oscar Rohn, 1899.

2202. Creek on north side of Kuskulana River near camp 16. Collector, A. C. Spencer, 1900.

8165. Nugget Creek near forks. Fault block of Chitistone limestone. Collector, Theodore Chapin, 1912.

8166. Divide between Nugget and Roaring Creeks. Limestone, probably Chitistone or thin-bedded Triassic formation. Collector, Theodore Chapin, 1912.

8167. Same as locality 8166.

8169. Divide between Nugget and Roaring Creeks. Thin-bedded shale. Collector, Theodore Chapin, 1912.

8152. Clear Creek. Blue limestone above roadhouse. Collector, Theodore Chapin, 1912.

8153. Clear Creek. Thin-bedded Triassic limestone, corresponding to McCarthy shale. Collector, Theodore Chapin, 1912.

8154. Ridge south of Clear Creek. Black slate and gray limestone. Collector, Theodore Chapin, 1912.

8156. First creek south of Clear Creek (Sheep Creek). Black calcareous shale. Collector, Theodore Chapin, 1912.

8157. First creek south of Clear Creek (Sheep Creek). Gray limestone, either Chitistone or thin-bedded Triassic. Collector, Theodore Chapin, 1912.

8158. Clear Creek. Thin-bedded limestone and shale. Collector, Theodore Chapin, 1912.

8159. Clear Creek. Talus slope below Chitistone limestone and overlying thin-bedded limestone. Collector, Theodore Chapin, 1912.

8160. Divide between Clear and Rock Creeks, ridge east of Dixie Pass; altitude 6,100 feet. Black shale of Triassic thin-bedded formation. Collector, Theodore Chapin, 1912.

8162. Divide between Clear and Rock Creeks, near locality 8160. Collector, Theodore Chapin, 1912.

8164. Clear Creek. Chitistone limestone. Collector, Theodore Chapin, 1912.

9948. North fork of Sheep Creek between Squaw and Clear Creeks. Collector, Fred H. Moffit, 1916.

9932. South brow of round-topped hill on ridge between east fork of Strelna Creek and small creek between Squaw and Clear Creeks. Collector, Fred H. Moffit, 1916.

9947. Squaw Creek; altitude 3,100 feet. Collector, Fred H. Moffit, 1916.

9946. Gulch tributary of Dry Creek from east; altitude 3,400 feet. Chitistone limestone in the gulch at about altitude 3,700 feet. Collector, Fred H. Moffit, 1916.

8147. Strelna Creek 1⅓ miles from Dixie Pass. Collector, Fred H. Moffit, 1912.

8148. North fork of Strelna Creek near mouth of first large creek on east side. Upper part of Chitistone limestone (?). Collector, Fred H. Moffit, 1912.

8149. North fork of Strelna Creek. Shale area 600 feet south of first large branch on east. Collector, Fred H. Moffit, 1912.

8150. North fork of Strelna Creek 2,000 feet north of first large branch from east. Collector, Fred H. Moffit, 1912.

8151. Near mouth of first branch of north fork of Strelna Creek. Collector, Fred H. Moffit, 1912.

8925. 8,200 feet S. 67° E. from forks of east fork of Strelna Creek; altitude 4,500 feet. Collector, Fred H. Moffit, 1914.

8928. North fork of Strelna Creek; altitude 3,000 feet. Collector, Fred H. Moffit, 1914.

8929. 4,700 feet N. 57° E. from forks of north fork of Strelna Creek; altitude 4,000 feet. Collector, Fred H. Moffit, 1914.

8930. West fork of north fork of Strelna Creek, mouth of gulch about 1,400 feet above forks. Collector, Fred H. Moffit, 1914.

8931. 6,600 feet N. 44° E. of Dixie Pass; altitude 5,500 feet. Collector, Fred H. Moffit, 1914.

9919. North fork of Strelna Creek near benchmark 3664. Collector, Fred H. Moffit, 1916.

9920. Head of north fork of Strelna Creek; altitude 3,700 feet. Collector, Fred H. Moffit, 1916.

9921. Head of north fork of Strelna Creek; altitude 4,000 feet. Collector, Fred H. Moffit, 1916.

9922. Head of north fork of Strelna Creek, 400 feet east of locality 9921; altitude 4,000 feet. Collector, Fred H. Moffit, 1916.

9923. East branch of east fork of Strelna Creek; altitude 4,300 feet. Collector, Fred H. Moffit, 1916.

9924. East branch of east fork of Strelna Creek; altitude 4,400 feet. Collector, Fred H. Moffit, 1916.

9925. East branch of east fork of Strelna Creek; altitude 5,000 feet. Talus. Collector, Fred H. Moffit, 1916.

9926. East branch of east fork of Strelna Creek about 1,000 feet northeast of locality 9924; altitude 5,000 feet. Collector, Fred H. Moffit, 1916.

9927. East branch of east fork of Strelna Creek 600 feet north of locality 9926. Collector, Fred H. Moffit, 1916.

9928. North branch of east fork of Strelna Creek 0.8 mile south of Dixie Pass; altitude 4,200 feet. Collector, Fred H. Moffit, 1916.

9929. North branch of east fork of Strelna Creek 800 feet east-northeast of locality 9928; altitude 4,500 feet. Collector, Fred H. Moffit, 1916.

9930. Ridge between Dixie Pass branch of Strelna Creek and Clear Creek, 1.1 miles southeast of Dixie Pass. Collector, Fred H. Moffit, 1916.

9931. Ridge between Dixie Pass branch of Strelna Creek and Clear Creek, 200 feet north of locality 9930. Collector, Fred H. Moffit, 1916.

9945. Dixie Pass branch of Strelna Creek, 1 mile from pass; altitude 3,900 feet. Collector, Fred H. Moffit, 1916.

2194. Near pass between head of Pass Creek and Rock Creek. Talus just under reef of thick-bedded limestone. Collector, F. C. Schrader, 1900.

8945. Rock Creek; altitude 3,475 feet. Collector, G. C. Martin, 1914.

8946. South fork of Rock Creek, on trail leading to west fork of Strelna Creek; altitude 4,800 feet. Probably thin plate of Chitistone limestone. Collector, G. C. Martin, 1914.

9934. West branch of Rock Creek about one-fifth mile east of trail to Strelna Creek; altitude 4,900 feet. Collector, Fred H. Moffit, 1916.

9935. Ridge between branches of Rock Creek, 1.1 miles south of point where branches join. Collector, Fred H. Moffit, 1916.

9936. Gulch leading from west branch of Rock Creek to saddle between Rock Creek and East Fork of Copper Creek; altitude 5,200 feet. Collector, Fred H. Moffit, 1916.

9937. Highest point of ridge between East Fork of Copper Creek, Pass Creek, and Rock Creek, about 0.6 mile northwest of locality 9936. Collector, Fred H. Moffit, 1916.

9938. West branch of Rock Creek one-third mile from forks; altitude 3,900 feet. Collector, Fred H. Moffit, 1916.

9939. West branch of Rock Creek 400 feet from forks. Collector, Fred H. Moffit, 1916.

9940. 3,000 feet N. 21° W. of Dixie Pass; altitude 4,700 feet. Collector, Fred H. Moffit, 1916.

9941. 0.2 mile northwest of locality 9940, three-fourths mile N. 28° W. of Dixie Pass. Collector, Fred H. Moffit, 1916.

9942. Saddle on ridge between Rock and Lime Creeks, 0.3 mile north of 6,685-foot peak. Collector, Fred H. Moffit, 1916.

9943. Gulch tributary to east fork of Rock Creek from east side, 1.2 miles from Dixie Pass; altitude 4,500 feet. Collector, Fred H. Moffit, 1916.

9944. Same gulch as locality 9943 but only 200 feet from Rock Creek. Collector, Fred H. Moffit, 1916.

8923. West side of Lime Creek opposite east glacier. Collectors, Fred H. Moffit and J. B. Mertie, Jr., 1914.

4806. Skyscraper claim on Roaring Creek, north side of Skyscraper Peak. Collector, Fred H. Moffit, 1907.

8932. 5,850 feet N. 31° W. from Ammann's cabin, on north side of Kluvesna River about 1½ miles above mouth of river; altitude 3,700 feet. Collector, Fred H. Moffit, 1914.

8941. Gulch on north side of Kotsina River about 0.4 mile below Kluvesna River, 100 feet above trail. Collector, G. C. Martin, 1914.

8942. About 10 feet above trail at locality 8941. Collector, G. C. Martin, 1914.

8943. Outcrop by side of trail at locality 8941. Collector, G. C. Martin, 1914.

8944. Float from Kuskulana (?) limestone at locality 8941. Collector, G. C. Martin, 1914.

8938. Head of Middle Fork of Copper Creek, 11,800 feet S. 80° E. from Alice Peak; altitude 4,800 feet. Collector, Fred H. Moffit, 1914.

4804. Elliott Creek Valley, on Magpie Creek 1 mile above mouth; altitude 3,500 feet. Collector, Fred H. Moffit, 1907.

4805 (2, 23). Head of Copper Creek, Mullen claim. Collector, Fred H. Moffit, 1907.

4805 (3–6). Head of Copper Creek, Talus. Collector, Fred H. Moffit, 1907.

McCarthy shale

CHARACTER AND DISTRIBUTION

The McCarthy shale is typically a black shale or slate, which, as represented on the geologic map, includes at its base a considerable but variable thickness of alternating beds of shale and hard, cherty calcareous argillite. Here and there a thin bed of bluish limestone is interbedded with the shale and helps to indicate the structure. In many places the shale is cut by dikes and sills of light-gray quartz diorite, which stand in strong contrast to the dark enclosing sedimentary beds and are thus more readily distinguished than intrusive rocks of the same kind in the Chitistone and Nizina limestones.

The alternating beds of shale and argillite at the base of the McCarthy shale are a constant feature of the formation in the Chitina Valley. As these beds and the overlying shale were less able to resist deformation than the limestone and the Nikolai greenstone, they are strongly folded in nearly all exposures. The hard argillite beds range from a few inches to 3 or 4 feet in thickness, but commonly are less than 2 feet. They predominate over the interbedded shale and probably make up more than three-fourths of the total thickness. They also are much more resistant to weathering than the shale, and in consequence the argillite stands out in strong relief in many exposures and forms most intricate patterns where the folding is intense (pl. 8, *B*).

Martin [30] has described these argillite beds, or at least some of them, as cherts. They vary in texture and in composition, both from bed to bed and in different localities, but those that most resemble chert are dense dark-gray or black, very hard rocks that break with a conchoidal or subconchoidal fracture, so that they possess characteristics commonly found in cherts. On the other hand, the beds, almost without exception, are calcareous and effervesce readily when dilute hydrochloric acid is applied to a fresh surface. The writer tested in the field many scores of samples from Fohlin Creek, Fourth of July Creek, Nikolai Creek, and other localities and found practically no beds that did not respond positively to this test except in a few small areas where the beds were silicified, probably as a result of intrusion by igneous rocks. Both the McCarthy shale and the Nizina limestone show this kind of silicification, which is readily recognized at a distance by the white surface weathering of the altered rocks. The thin-bedded shale and argillite zone between the Nizina limestone and the upper or shale member of the McCarthy shale is too conspicuous to escape observation even in hasty geologic exploration and doubtless has been noted by all workers in the region, although it has been described by different terms, with emphasis on the limy,

[30] Martin, G. C., op. cit., pp. 25, 28.

cherty, or argillaceous character in different places. These beds were regarded by Moffit and Capps [31] as occupying a transition zone between the limestone and the shale and marking a period of changing sedimentation. The writer is of the opinion that neither the term "argillite" nor the term "chert" describes accurately the hard beds in the lower part of the McCarthy shale. They are siliceous or cherty limy argillites, or possibly cherty argillaceous limestones, and differ from the interbedded shale through the deposition of additional lime and silica. It may be that the silica was introduced after the beds were formed, as is believed to be true of the silicified or cherty limestone and argillite previously mentioned, but no positive evidence of this silicification was recognized. These beds are included in the McCarthy formation, for reasons given in the discussion of their age.

The McCarthy shale occurs throughout the area of the Chitistone and Nizina limestones and extends beyond the limits of these formations into the valleys of the upper Chitina River, Skolai Creek, and the White River within the area represented on plate 2.

On the geologic map of the Kotsina-Kuskulana district [32] the McCarthy shale and the Nizina limestone were included in an undifferentiated formation called the Kuskulana formation. It was recognized at the time that this formation was too inclusive,[33] but the formation was adopted as a mapping unit because there was neither time nor opportunity to undertake further field work on the problems that were involved. On the geologic map accompanying this report (pl. 2) the Kuskulana formation unit is not used, and an attempt is made to differentiate as well as may be the limestone from the thin-bedded shale and argillite. This involves some errors in boundary lines, but these errors are of less moment on the much smaller scale of the map here given than they would be on the original detailed map.

THICKNESS AND STRUCTURE

The thickness of the McCarthy shale is not known with accuracy and can be given only within wide limits. Much of the shale was removed by erosion during a period of land elevation before the deposition of the unconformably overlying Cretaceous beds, so that the full original thickness may never be determined. Distortion of the beds introduces another uncertainty, for the soft shale and the underlying thin-bedded shale and argillite were unable to resist pressure to the same degree as the limestone and greenstone and are compressed and highly folded. They yielded in places almost like a plastic material, and individual beds are not only intricately folded

[31] Moffit, F. H., and Capps, S. R., Geologic and mineral resources of the Nizina district, Alaska; U. S. Geol. Survey Bull. 448, pp. 28, 29, 1911.

[32] Moffit, F. H., and Mertie, J. B., Jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745, pl. 3, 1928.

[33] Idem, p. 35.

but are thickened in some places and made thinner in others. Finally the McCarthy shale is infolded with black Cretaceous shale in its type locality on McCarthy Creek, and the two formations cannot be differentiated except where fossils are found, for they are lithologically similar.

The lower or thin-bedded shale and limy argillite member of the McCarthy formation is about 1,000 feet thick at the head of Nikolai Creek. It is at least that thick at the head of the Chokosna River, although in this vicinity it is so closely folded that direct measurements give misleading results. These localities probably include the sections of greatest thickness. At other places the thickness is considerably less, but it seems necessary to assume that the variation is an original condition and not the result of folding or faulting.

Evidence for the thickness of the upper or strictly shale member of the McCarthy formation is less definite than that for the lower part. Moffit and Capps,[34] using data obtained on the East Fork of McCarthy Creek, estimated the total thickness of the McCarthy shale in that vicinity as about 2,500 feet. This estimate admits a thickness of 1,500 feet or a little more for the shale member in this vicinity, but from other evidence it has since been concluded that the total thickness of the McCarthy shale in the Nizina district may be as great as that of the Chitistone and Nizina limestones, or about 3,000 feet.

The Kuskulana formation of the Kotsina-Kuskulana district shows a minimum thickness of 2,000 feet. This measurement includes an uncertain amount of the Nizina limestone as well as some of the McCarthy shale and is not directly comparable with the section of McCarthy shale in the Nizina district. The shale member, however, is well developed in the mountains between Elliott Creek and Lime Creek and is probably thicker there than in the Nizina district.

The McCarthy shale rests with structural conformity on the Nizina limestone in its type locality on McCarthy Creek but possibly lies unconformably on older rocks in the Kotsina-Kuskulana district. Hayes [35] collected Triassic fossils (*Pseudomonotis subcircularis*) from black shale overlying the Permian limestone "in the walls of Skolai Pass." A small area of black shale and siliceous cherty shale that rests unconformably on Permian limestone on the mountain top north of Skolai Creek and 3 miles west of Frederika Creek yielded two species of *Halobia*, one of which, *Halobia superba*, is common to the Chitistone and Nizina limestones and the other, *Halobia austriaca*, has been previously reported only from Nikolai and McCarthy Creeks. If *Halobia superba* is characteristic of the warm-water limestone deposits, this shale should be correlated with the limestone rather than the McCarthy shale. In either event the Upper Triassic shale

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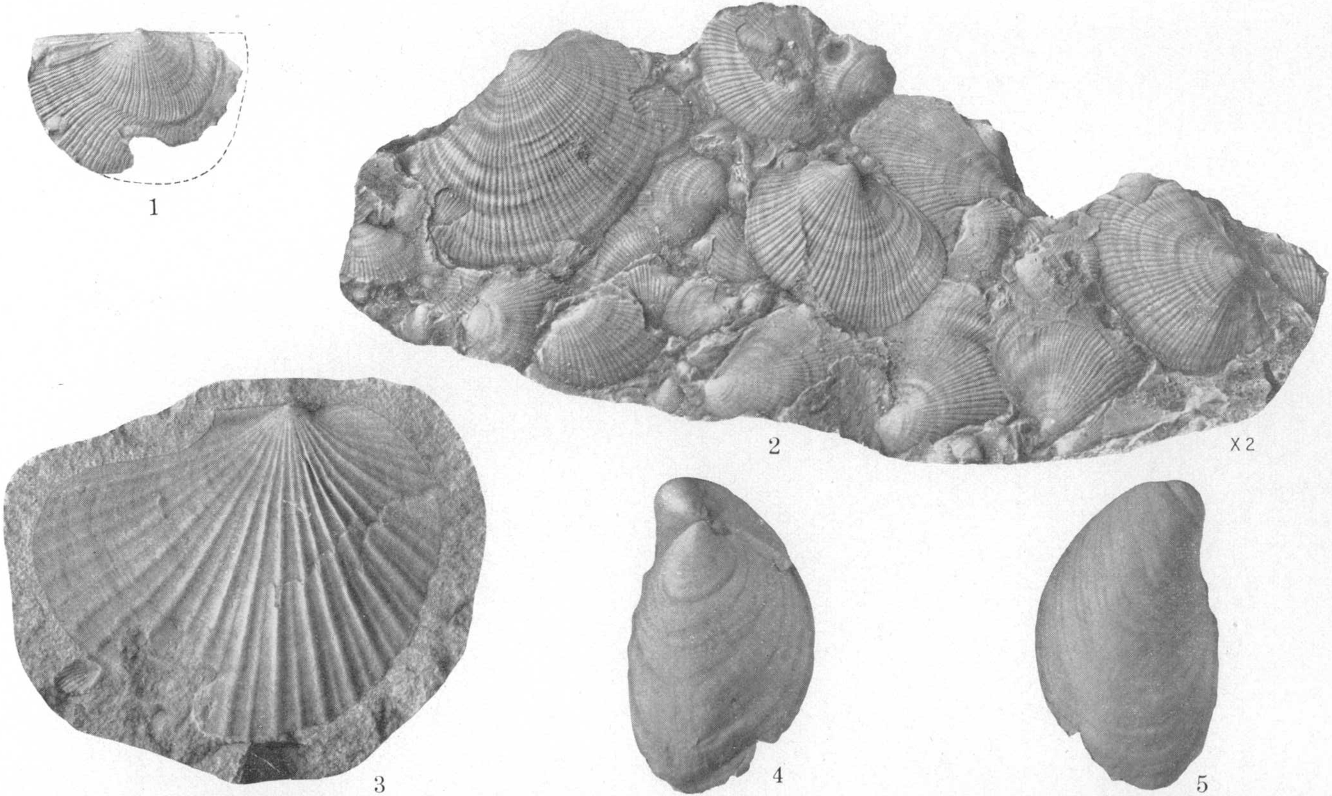
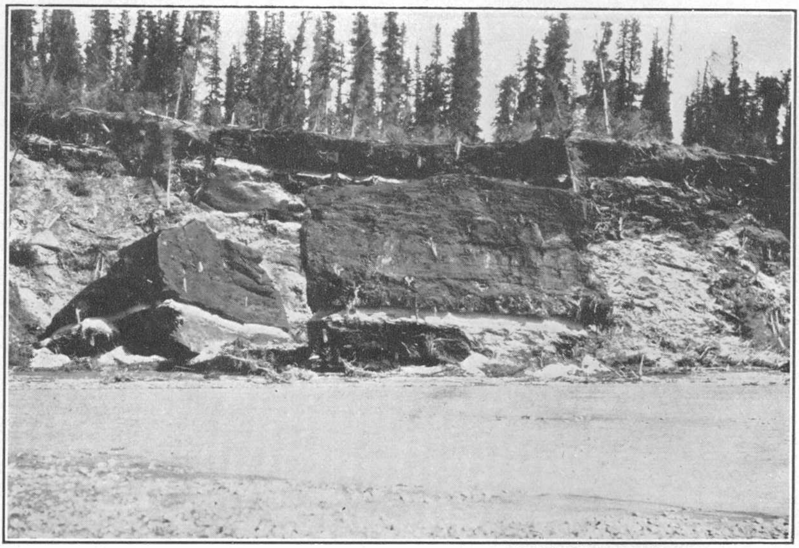
34 Moffit, F. H., and Capps, S. R., op. cit., p. 29.

35 Hayes, C. W., An expedition through the Yukon district: Nat. Geog. Mag., vol. 4, p. 140, 1892.



FOSSILS FROM CHITINA VALLEY.

1, 2, *Halobia* cf. *H. superba* Mojsisovics; found in the Chitistone and Nizina limestones. 3, *Pseudomonotis subcircularis* Gabb; abundant in the lower part of the McCarthy shale and the top of the Nizina limestone. 4, 5, *Aucella* cf. *A. crassicollis* Keyserling; a common Lower Cretaceous fossil.



A. VOLCANIC ASH INTERBEDDED WITH PEAT ON UPPER WHITE RIVER.

In the foreground are overturned blocks of peat and ash that rolled down fron the gravel bank behind. Shows spruce stumps in the peat.

B. FOLDED TRIASSIC LIMESTONE AND SHALE BEDS AT THE TOP OF THE NIZINA LIMESTONE OR BASE OF THE McCARTHY SHALE ON COPPER CREEK.

of Skolai Pass and lower Skolai Creek rests unconformably on older rocks.

The top of the McCarthy shale is marked by a distinct unconformity which separates it from the overlying Cretaceous and younger deposits. This unconformity is shown beautifully on Nikolai Creek (pl. 9, *A*), where the nearly horizontal Cretaceous sandstone rests on the eroded, upturned edges of greenstone, limestone, and shale.

The McCarthy shale is more strongly folded than any of the other Mesozoic rocks of the district. This condition is most apparent in the thin-bedded shale and limy argillite beds and is conspicuous in many large exposures (pl. 11, *B*). The shale member was doubtless compressed and folded as much as the lower part of the formation, but the folding is less evident, for the shale is of a more homogeneous character and lacks the conspicuous bedding lines.

Faulting took place in the McCarthy shale, but faults are hard to distinguish where contrasting beds are lacking, and many strong faults that are plainly seen in the limestone or other adjacent formations are lost as they pass from the harder rocks to the shale. The great overthrust fault on the Nizina River extends into the McCarthy shale but either ends within a short distance or is concealed by younger Cretaceous deposits.

AGE AND CORRELATION

The McCarthy shale is of Upper Triassic age. This determination is based on the presence of a fauna that is poor in number of species but rich in number of individuals of a single species. The characteristic fossil is *Pseudomonotis subcircularis*, a form stated by Martin[36] to be "very closely related to if not identical with *Pseudomonotis ochotica*, which is the characteristic fossil of the boreal facies of the Noric of Europe and Asia." This fossil mollusk (pl. 10, fig. 3) is present in vast numbers in certain parts of the McCarthy formation and is particularly abundant in a zone that includes the transition beds at its base. It has been collected by the writer from both the limestone and the shale partings between limestone beds that lithologically form the top of the Nizina limestone and from beds that range practically through the whole thickness of the thin-bedded shale and limy argillite member of the McCarthy shale. It is less common or possibly absent from much of the overlying shale member, either because the conditions of the sea were not favorable for the growth of the organism or because its remains were destroyed by the folding and shearing of the shale.

The fauna of the McCarthy shale contains much fewer species than are found in the Chitistone and Nizina limestones, although the fos-

[36] Martin, G. C., op. cit. (Bull. 776), p. 29.

sils themselves are vastly more numerous in some parts of the shale. This is because *Pseudomonotis subcircularis* (Gabb) occurs in such enormous numbers in places that the rock cannot be broken without revealing it. The different species are listed in the table facing page 52 but for the sake of comparison are segregated in the following list:

Coral?
Pelecypods.
Pseudomonotis subcircularis (Gabb).
Halobia.
Cardinia? sp.
Pecten, several species.
Hinnites? sp.
Lima (Plagiostoma).
Lima n. sp.
Clionites? sp.
Ammonites.
Tropigastrites? sp.
Halorites cf. H. americanus Hyatt.
Juvavites? sp.
Arniotites? sp.

Upper Triassic sediments containing the *Pseudomonotis* fauna have been found in many places in Alaska, showing clearly that deposits regarded as equivalent stratigraphically to the McCarthy shale are much more widespread than the warmer-water deposits correlated with the Chitistone and Nizina limestones.

JURASSIC SYSTEM

The bedded rocks in this area that are known to belong to the Jurassic system or have been doubtfully referred to the Jurassic comprise a variety of marine deposits that were laid down in water, yet are partly of volcanic origin. The rocks included in this group are widely distributed in the Chitina Valley, occurring in many small disconnected areas, but they occupy only a relatively small part of the area. They include tuff, shale, limestone, sandstone, and conglomerate, part of which were formed in Middle Jurassic time and part in Upper Jurassic or possibly post-Jurassic time. Although the age assignment of some of these sedimentary beds is well established, that of others has not been fixed beyond doubt, for the determinations are based on collections of fossils that have not been exhaustively studied or that have a considerable range in time and are not fully diagnostic. It is possible that Lower Jurassic sedimentary rocks are present in the area, and probably some rocks that have heretofore been regarded as Jurassic are in fact Cretaceous.

The Middle Jurassic rocks are assigned to that epoch on the evidence of fossils that leave no doubt of the correctness of the assignment. The exact areal extent of these rocks is unknown, and this is also true of marine sedimentary beds in the McCarthy Creek Valley that have yielded several small collections of fossils containing forms that are definitely of Upper Jurassic age. These collections were obtained from black shale that is intimately associated with and is not easily distinguishable from black shale of Upper Triassic age and black shale of Cretaceous age. Supposedly the Upper Jurassic black shale occupies only a small area, but it was not differentiated from the Cretaceous black shale, the prevailing rock of the locality, as the fossils were not recognized in the field investigation, and their significance was not understood till after they had been identified in the office.

A considerable number of fossils, mostly from the Kotsina-Kuskulana district, have been referred doubtfully to the Jurassic or Cretaceous, and as the rocks yielding them differ lithologically and stratigraphically from any possibly equivalent beds in the middle and eastern part of the Chitina Valley, the proper age assignment is not aided by a comparison and is still in doubt.

In view of all these conditions, some of the Jurassic and Cretaceous rocks of the Chitina Valley cannot be differentiated at present, and they are therefore represented on plate 2 with no attempt to separate them. Furthermore, it is necessary until further evidence is obtained to designate some beds as either Jurassic or Cretaceous. It has become evident that a more extended field investigation, supplemented by a thorough comparative study of the fossils, will be required before much further progress can be made in solving the problems of the Jurassic and Cretaceous deposits of the Chitina Valley.

Middle Jurassic rocks

CHARACTER AND DISTRIBUTION

Rocks that are known to be of Middle Jurassic age have been recognized at only one locality in the Chitina Valley—on the south side of the Chitina River near its mouth. Their occurrence has been described by the writer [37] and is perplexing.

A narrow belt of schist, forming a bench with irregular surface 100 to 300 feet above the river, extends along the east side of the Copper from the Chitina River to Canyon Creek. This bench is limited on the east by a line of cliffs that forms the front of a second, much higher bench. The cliffs are composed of massive conglomerate containing well-rounded pebbles and cobbles of argillite, diorite, greenstone, and quartz in a tuffaceous matrix. The conglomerate is associated with tuffaceous beds deposited in water and containing fossils. Both the conglomerate and the tuffaceous beds are cut by intrusive masses of greenstone and by light-gray diorite and are extensively faulted. Furthermore, the conglomerate is highly fractured, as if it had been crushed, and it contains numberless veinlets of white chalky alteration products. Not less than 500 or 600 feet of the conglomerate is exposed in this locality, but its thickness is not known with accuracy.

[37] Moffit, F. H., Geology of the Hanagita-Bremner region, Alaska: U. S. Geol. Survey Bull. 576, pp. 25-37, 1914.

This conglomerate is regarded by Martin [38] as possibly of Lower Jurassic age, as it does not resemble Middle Jurassic rocks of other parts of Alaska.

Evidence indicating a fault contact between the conglomerate and the schist was obtained at several places, though no good exposure of the contact was seen, and strong evidence for an unconformity of deposition between the conglomerate and schist appears at other localities.

The fossil-bearing tuffaceous beds here grouped with the conglomerate are exposed on the south side of the Chitina River near its mouth and form prominent cliffs along the river. They lie immediately east of the conglomerate and are thought to overlie it. The beds are composed of a dark fine-grained sandstone-like, slightly calcareous rock, showing numerous small flakes of mica on the cleavage surface. The rock is much jointed and slightly altered and breaks down readily under the influence of the weather, forming talus slopes of angular platy fragments. A considerable amount of this rock is exposed along the Chitina River, but it was not recognized farther south along the Copper River, although its presence there was expected. Several small areas of unaltered brownish-gray sandstone found east of Taral, however, may represent a phase of the tuffaceous beds, now largely removed by erosion. On the ridge south of Taral Creek this sandstone contains much quartz, numerous grains of clear unaltered feldspar, flakes of biotite in a calcareous cement, and some small black spots, which are thought to be organic remains but are too imperfect for identification.

AGE AND CORRELATION

Fossils were collected from the tuffaceous beds along the Chitina River but were not found in the conglomerate. All the fossils were collected from one locality—at the edge of the Chitina River flood plain a short distance east of the little creek that drains Taral Lake. They were identified by T. W. Stanton and are listed in the following table:

Middle Jurassic fossils from Chitina Valley

	7231	7232	7233
Leda?	×		
Inoceramus ambiguus Eichwald?		×	×
Inoceramus (shell fragments)	×		
Ostrea	×		
Stephanoceras?	×		×
Perisphinctes?	×		

7231. South bank of the Chitina River about 1½ miles above its mouth. Collector, Theodore Chapin, 1911.

7232, 7233. Same locality as 7231. Collector, Fred H. Moffit, 1911.

[38] Martin, G. C., op. cit. (Bull. 776), p. 238.

In commenting on the fossils of lot 7231, Stanton says:

The general character of this little collection seems to justify its reference to the Jurassic and to about the horizon of the lower half of the Enochkin formation. * * * The lower half of the Enochkin formation referred to under specimen 7231 is the Middle Jurassic Tuxedni sandstone exposed on the west side of Cook Inlet, and described by Martin and Katz.[39]

Rocks of similar character or age have not been found on the north side of Chitina Valley and are not known to occur at any place nearer than the upper Matanuska Valley, where Paige and Knopf[40] found sandstone and shale that Stanton correlated with the lower part of the †Enochkin formation.[40a] Lava flows are associated with the sediments in Matanuska Valley, giving evidence that volcanic forces were active there as well as on the Chitina River. The Chitina locality is therefore the only place in this part of Alaska where rocks to be correlated with the Middle Jurassic Tuxedni formation are known.

Upper Jurassic rocks

The Upper Jurassic rocks have been briefly described in the introductory statement (p. 62) and will be referred to again in connection with the Lower Cretaceous rocks. The only occurrences in the Chitina Valley of sedimentary rocks that are definitely determined to be of Upper Jurassic age are two small areas of soft black shale associated with black shale of the McCarthy formation and the overlying black Cretaceous shale. Little is known of these two occurrences except that they have yielded fossils that are characteristic of the Naknek formation of the Alaska Peninsula. The shale appears to be folded into the McCarthy shale and is probably overlain unconformably by the basal beds of the Lower Cretaceous. At least this appears to be the relation of these rocks on the tributary of McCarthy Creek 1¼ miles north of Dimond Creek, where fossils were collected from the mountain slope south of the creek. At the head of McCarthy Creek near the front of the west glacier, the black Upper Jurassic shale is associated with black Lower Cretaceous shale. No Triassic shale is known in this vicinity. The extent of the area here occupied by the Upper Jurassic shale is unknown but must be small, for Cretaceous fossils have been collected from nearby rocks on all sides within less than a mile. No evidence bearing on the thickness of the shale was obtained. The two localities are shown with indefinite boundaries on the geologic map.

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[39] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 59–64, 1912.

[40] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna Basins, Alaska: U. S. Geol. Survey Bull. 327, p. 19, 1907.

[40a] A dagger (†) preceding a geologic name indicates that the name has been abandoned or rejected for use in classification in publications of the U. S. Geological Survey. Quotation marks, which were formerly used to indicate abandoned or rejected names, are now used only in the ordinary sense.

The diagnostic fossil of the Upper Jurassic shale in this locality is *Amoeboceras* sp., which is associated with an *Aucella* like *A. pallasi* Keyserling. The *Amoeboceras* has not been collected elsewhere in the Chitina Valley.

Jurassic or Cretaceous rocks

The bedded rocks that are described as Jurassic or Cretaceous occur chiefly in the Kotsina and Kuskulana drainage areas and present one of the most confusing geologic problems of the Chitina Valley. The confusion arises principally from two causes. First, the beds include a variety of marine sedimentary deposits, occurring in many disconnected areas, that are difficult to correlate with one another and to refer on lithologic grounds to their proper places in the stratigraphic sequence. Second, although the deposits are fossiliferous in most places and abundantly so in some places, the fossils so far collected at some localities are not sufficiently diagnostic to determine definitely the age of the deposits at those places, although elsewhere they are diagnostic. It appears that the faunas are unusual in some respects if compared with other American occurrences of possible equivalent age. There is doubt concerning the true range of some of the species, and there is a question as to the identity of some closely related species that may have different ranges.

It is probably true that if certain key localities were studied in detail with the aid of topographic maps of larger scale than those now available, many doubtful points relating to stratigraphy and correlation could be cleared up in the field without the aid of the fossils, and, incidentally, questions concerning the meaning of the fossils could be settled also. Such a study has not been possible.

In view of these considerations it seems best to treat as a group several sedimentary formations that on the evidence of fossils have been determined by the paleontologists doubtfully as either Jurassic or Cretaceous and some others that are certainly Cretaceous. This course is further justified by the fact that in places the field evidence suggests the probable identity of at least part of the two groups.

CHARACTER AND DISTRIBUTION

In the Kotsina and Kuskulana Valleys and in the valleys of Trail Creek and the upper Chokosna River a group of rocks crop out in widely separated areas and are evidently the remnants of beds that were once widespread but have been almost wholly removed by erosion. They include conglomerate, grit, sandstone, sandy shale, and limestone but do not present the same sequence and thickness of beds in the different areas and cannot everywhere be correlated with certainty on lithologic grounds, even in areas that are near each other. They were deposited unconformably on the older rocks—the Nikolai greenstone, the Upper Triassic shale and limestone, and the intrusive granodiorite—and are folded into them in many of the exposures.

The most extensively developed and by far the thickest member of the group is the Kotsina conglomerate, which is known only within the drainage area of the Kotsina River and Strelna Creek and was described by Moffit and Mertie,[41] who applied to it the formation name previously used by Rohn.[42]

The Kotsina conglomerate is a massive conglomerate that crops out in a belt extending northwest from the head of the easternmost tributaries of Strelna Creek to the Kotsina River and thence northward into the mountains north of the river. The conglomerate shows conspicuously in the mountains about the head of Strelna Creek and north of Elliott Creek, forming the summit of the ridge throughout most of that distance and reaching its greatest width of about 2 miles at the Kotsina River.

The formation is a massive dark conglomerate, almost without lines of bedding, yet containing a little black shale. It is composed largely of water-worn pebbles and cobbles or boulders, most of which are plainly of local origin and are derived from the underlying formations. Pebbles of greenstone, limestone, the light-colored granodiorite intrusives, and quartz are most common. It was noticed repeatedly that in the vicinity of areas of the Chitistone limestone the limestone pebbles in the conglomerate increase greatly in number and form a large proportion of the rock. A similar relationship is doubtless true of other constituents of the conglomerate and their parent rocks but is not so readily seen.

The pebbles are enclosed in a shaly or arkosic matrix which disintegrates rather easily and breaks down rapidly under the influence of weathering. In consequence the outcrops are rough, and the talus slopes consist largely of pebbles freed from their matrix. The conglomerate mountains are rugged, with precipitous cliffs and a ragged sky line. Their dark color and rough surface give them a forbidding aspect, and in fact many of the ridges are practically impassable. The few thin beds of black shale interstratified with the conglomerate form but an insignificant part of the whole.

On the mountain between Clear Creek, tributary to the Kotsina River, and the Kluvesna River the conglomerate shows a much finer structure than in its southeasterly extension, changing first to a grit made up of tiny flattened pebbles of fairly uniform size and then to a soft yellowish-brown fossiliferous sandstone. About 50 feet of massive light-gray limestone with a slightly sugary texture and surface peppered over with tiny black specks rests on the brown sandstone,

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[41] Moffit, F. H., and Mertie, J. B., Jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745, pp. 44–45, 1923.

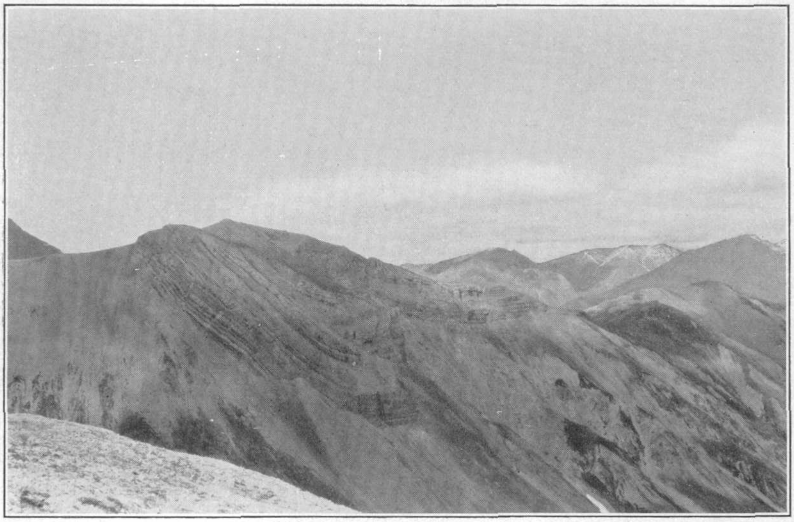
[42] Rohn, Oscar, A reconnaissance of the Chitina River and the Skolai Mountains, Alaska: U. S. Geol. Survey 21st Ann. Rept., pt. 2, p. 431, pl. 52, 1900.

which presumably corresponds to the base of the Kotsina formation, and is overlain in turn by a small thickness of gray limy sandstone. Both the limestone and the sandstone beds above and beneath it are fossiliferous. These limestone and sandstone beds cap the high part of the mountain north of the mouth of the Kluvesna River, but the sandstone below the limestone is not continuous with the sandstone exposed half a mile to the south-southwest, which is mapped as part of the Kotsina conglomerate, and therefore may possibly not be equivalent to it. Furthermore, two other small areas of limestone are exposed in this vicinity, one of which rests on the Nikolai greenstone and the other on the Upper Triassic shale. If the three limestone areas are equivalent to one another, as they appear to be, then either progressive overlapping of sediments on a sinking sea floor or an unconformity below the limestone is indicated. This relation will be referred to again.

The maximum thickness of the Kotsina conglomerate in the mountains north of Elliott Creek is not less than 1,500 feet and in all probability is much more, possibly reaching 2,000 or 2,500 feet. This conglomerate has not yielded fossils except Upper Triassic forms that came from boulders derived from the underlying rocks. Its age is therefore not definitely known, and it cannot be definitely correlated with any other conglomerate in the Chitina Valley, although it may possibly be the equivalent of a massive conglomerate on McCarthy Creek, in the Nizina district.

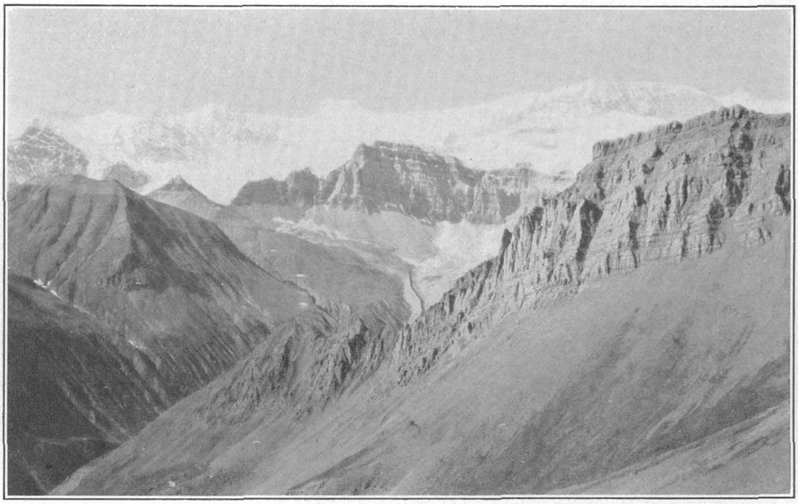
At many localities scattered throughout the Kotsina and Kuskulana Valleys are small areas of clastic deposits that overlie or are folded and faulted into the older, more strongly deformed rocks and have been identified with some degree of uncertainty as of Jurassic or Cretaceous age. Nearly all these deposits include conglomerate, sandstone, and sandy shale. In most places a speckled limestone resembling that on the mountain top north of the Kotsina River or a brownish sugary-textured limestone is also present. In a few places limestone occurs without the conglomerate or the sandstone. The field relations and proximity to one another of many of these areas suggests strongly that they belong to one group of sedimentary rocks, but the difficulty of correlating them on stratigraphic grounds is well illustrated on Sheep Creek. This locality, however, is not the only one to offer difficulties.

Near the head of Sheep Creek is a small area showing a basal member of conglomerate, 200 feet thick, overlain by sandstone with intercalated conglomerate. The beds have a total thickness of 880 feet and are folded and faulted into Upper Triassic limestone and shale, which they overlie unconformably. A mile to the south, on the same (east) side of a prominent north-south fault, is a second small area that shows 75 feet of limestone overlying sandstone that rests on and



A. FOLDED JURASSIC AND CRETACEOUS SEDIMENTS AT THE HEAD OF MacDOUGALL CREEK.

They rest unconformably on Upper Triassic sediments and associated granitic rocks. View looking westward.



B. VIEW AT THE HEAD OF McCARTHY CREEK.

The bedded rocks and high mountains of the background are Tertiary lava flows and tuff beds. The dark rocks in the left foreground are Lower Cretaceous shale. In the right foreground is a massive conglomerate, probably Cretaceous also.

is folded into Upper Triassic shale. A quarter of a mile west of the first area limestone rests directly on the Upper Triassic shale. The limestone and sandstone of these three localities contain fossils that indicate equivalence in age, but the succession of beds is entirely different, notwithstanding the short distance from one area to the others.

On the north side of the Trail Creek Valley, east of the Kuskulana River, about 100 feet of fossiliferous speckled limestone, slightly sandy in the upper part, rests on a mass of older quartz latite. This limestone is in strike with and probably was once continuous with a small area of limestone half a mile south of Trail Creek, which also rests on the intrusive rock.

On MacDougall Creek, 2 miles southwest of Trail Creek, the following section is exposed:

Section on MacDougall Creek

	Feet
Black crumbly shale with a few thin hard beds	75
Light-gray hard limestone with sugary texture	150
Dark-gray sandstone with fragments of *Inoceramus* shells	75
Conglomerate	25
	325
Unconformity.	
Upper Triassic shale and intruded diorite.	

Still farther east, on a tributary of the Chokosna River near Kuskulana Pass, is a fine exposure that shows about 250 feet of sugary limestone, containing *Inoceramus* shells and having numerous tiny pebbles scattered through it, lying on Upper Triassic limestone. It is overlain by sandstone estimated to be about 500 feet thick.

AGE

The beds of conglomerate, sandstone, limestone, and sandy shale of these various localities contain a fauna that has been difficult to interpret. Most of the collections have been regarded as Jurassic or as "probably Jurassic," but some suggest a Cretaceous age. The beds lie unconformably on the older rocks, yet the succession of beds is not the same in any two localities. The limestone, if it is the same limestone throughout, increases in thickness toward the east but is not known to occur east of the Chokosna River. In places it rests directly on rocks belonging to an earlier epoch, but in most places it lies on Jurassic or Cretaceous conglomerate or sandstone of variable thickness, which on MacDougall Creek (pl. 12, *A*) reaches a maximum of at least 100 feet. No deposits that can be definitely correlated with these beds are recognized elsewhere in the Chitina Valley. The fauna which they contain has not been exhaustively studied, but it suggests a probability that even if the Jurassic age determination of these deposits in the Kotsina-Kuskulana district should prove to be incorrect, the Mesozoic conglomerate and sandstone that rest unconformably on Upper Triassic and older rocks there are somewhat older than Mesozoic rocks of the same kind and in the same relative position with relation to the older rocks farther east in the Chitina Valley. The beds in the Kotsina and Kuskulana districts that are in question have yielded the species included under the first 27 localities of the table of Jurassic or Cretaceous fossils facing page 80 (lots 8924 to 14478). The age determinations offering the most difficulty are chiefly those of localities east of the Kuskulana River.

Rocks that have been described as of Jurassic age are exposed in the Nizina district and in the upper Chitina Valley. They include the Kennicott formation, which was originally called the Kennicott "series" by Rohn [43]—a name that was used by him to describe the "light-colored arkoses, shales, and limestones" that he found on Bear and Fourth of July Creeks between Fohlin Creek and the Kennicott Glacier and was later extended by Moffit and Capps [44] to designate all the supposedly Jurassic sedimentary rocks of the Nizina district. They also include several areas of sandstone north of the upper Chitina River that have been mapped and described as Jurassic by Moffit and Overbeck.[45] These areas, together with the various rocks included in the Kennicott formation by Moffit and Capps, are now regarded by Reeside as Cretaceous rather than Jurassic and are therefore described in the section on Cretaceous rocks.

CRETACEOUS SYSTEM

Cretaceous rocks are now known to occupy a large area in the Chitina Valley and adjacent districts, although it was formerly supposed that they had only a subordinate place in the stratigraphic column of the region. Included in the group of sedimentary beds to be considered are some whose Cretaceous age is regarded as established beyond doubt, although their position within the Cretaceous system is in part open to question. Rocks of this kind are especially well developed in the Nizina district. Also included in this group are beds that are regarded as probably in part Cretaceous, although their Cretaceous age is only inferred from their field relations, and possibly, if not probably, they include older Mesozoic rocks and even Paleozoic rocks. In this doubtful group is a great thickness of beds that make up a large part of the Chugach Mountains.

The Cretaceous sedimentary rocks show much variety in their lithologic character but are noticeably lacking in beds of limestone. Those of established Cretaceous age are chiefly black shale, sandstone, conglomerate, grit, and gray sandy shale, among which the black

[43] Rohn, Oscar, A reconnaissance of the Chitina River and the Skolai Mountains, Alaska: U. S. Geol. Survey 21st Ann. Rept., pt. 2, pp. 424, 428, 431–433, 439–440, pl. 52, 1900.

[44] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 31–43, 1911.

[45] Moffit, F. H., and Overbeck, R. M., The upper Chitina Valley, Alaska: U. S. Geol. Survey Bull. 675, pp. 27–28, 1918.

shale and sandstone are dominant. These rocks are all less folded and otherwise disturbed than the pre-Cretaceous rocks that lie beneath them. The rocks referred with much less assurance to the Cretaceous are chiefly slate and graywacke—rocks that differ from those first mentioned not only in lithology but in degree of metamorphism, for they show greater folding and more alteration than the definitely Cretaceous rocks.

Although the variety of sedimentary rocks to be considered may raise a question as to whether more than one epoch of the Cretaceous may be represented, the fossils do not make possible a conclusive answer. Furthermore, the field studies have not revealed structural unconformities or other definite evidence of interrupted sedimentation during the time when the various beds were being deposited. The Cretaceous rocks of the Chitina Valley have been described as including both Lower and Upper Cretaceous formations,[46] but an increased number of fossil collections and a reexamination of the older collections by the paleontologists have raised serious doubt as to the presence of Upper Cretaceous sedimentary rocks. (See p. 80.)

The Cretaceous rocks of the Nizina district and localities north of the Chitina River will be described first.

Lower Cretaceous rocks

CHARACTER AND DISTRIBUTION

The Cretaceous rocks of the north side of the Chitina Valley present two contrasting aspects. In a large way they consist of two groups—black argillaceous shale, which is extensively developed and reaches a thickness of several thousand feet, and sandstone, conglomerate, and sandy shale, only a little less thick and less widely distributed. The exact stratigraphic relationships of these two groups are in doubt.

The rocks of the type locality of Rohn's Kennicott formation in Fourth of July Pass are now considered to be Lower Cretaceous. Those that overlie the Upper Triassic rocks and, on paleontologic grounds, properly belong to the Kennicott formation include conglomerate, brown sandstone, crumbly gray shale, and black shale. A somewhat generalized section on Fourth of July Creek shows the following beds:

Section on Fourth of July Creek

	Feet
Black shale or slate intruded by numerous light-colored porphyry dikes	Possibly 3,000
Crumbly gray shale with concretions	50?
Massive brown sandstone	100–200
Conglomerate with angular and subangular fragments	Variable but only a few feet
Unconformity.	
Upper Triassic shale.	

[46] Moffit, F. H., and Overbeck, R. M., op. cit., p. 41. Martin, G. C., op. cit., p. 327.

The basal conglomerate, sandstone, and gray shale of this section are exposed on the lower north slopes of the valleys of Bear and Fourth of July Creeks and along the creek channels. They overlap the Upper Triassic rocks, are not much folded, dip at a moderate angle to the south, and pass beneath the black shale that forms the mountains south of the two creeks. Whether the black shale rests with normal contact on the gray shale is not definitely established, but seemingly the two grade into each other. No limestone was seen in this vicinity, and the section quite evidently differs from the Jurassic or Cretaceous rocks of Trail Creek.

Although the conglomerate and sandstone are conspicuous only between Fohlin Creek and Kennicott Glacier, the black shale extends westward beyond the Lakina River and is continuous with the black shale near the town of McCarthy and on Dan and Chititu Creeks, east of the Nizina River. On upper McCarthy Creek the black Cretaceous shale overlies brown-weathering sandy beds with a thickness between 200 and 300 feet. The basal beds are best seen on an unnamed eastern tributary of McCarthy Creek 1¼ miles north of Dimond Creek. They extend up this tributary from its mouth to the divide at its head and across into the valley of the West Fork of the Nizina River and are believed to mark the boundary between the Cretaceous black shale to the north and the Upper Triassic and Upper Jurassic black shale to the south. The black Cretaceous shale extends northward from the small tributary to the head of McCarthy Creek, where it is overlain by conglomerate and fossiliferous sandy beds, also of Cretaceous age. These in turn are overlain by the Tertiary volcanic beds exposed in the upper walls of the cirques about the two small glaciers at the head of McCarthy Creek (pl. 12, *B*). However, an element of uncertainty in connection with the extent of the black shale arose with the discovery that the area that was supposed to be made up entirely of Cretaceous black shale contains also an unknown amount of Upper Jurassic (Naknek) black shale. This fact was not evident from the field examinations but was brought out later by a study of the collections of fossils. Rocks of Naknek age are not known elsewhere in the Chitina Valley.

The Cretaceous black shale is highly developed on Dan, Rex, White, and Young Creeks. On Eagle Creek, an upper tributary of Copper Creek, the black shale overlies nearly 200 feet of grit and sandstone that rest unconformably on the McCarthy shale. On Idaho Gulch, another tributary of Copper Creek, the following succession of beds, forming the lower part of the shale formation, was observed:

Section on Idaho Gulch

	Feet
Black shale	Several thousand
Soft gray shale	100
Limestone conglomerate with boulders 12–18 inches in diameter	30–40
Soft black shale	5
Fine grit	10–15
Unconformity.	
McCarthy shale.	

The black shale at the head of Copper Creek is overlain by the succession of nearly horizontal beds of sandstone, shale, and conglomerate that caps Pyramid Peak.

Young Creek shows a variety of features in the shale and associated beds that were not noticed elsewhere. The Cretaceous rocks of this vicinity may be divided into three members, which, designated in ascending order, are sandstone, black and red shale, and a succession of beds that include coarse- and fine-grained conglomerate, sandstone, arkose, and sandy shale. The basal beds are in view at several places, and although there is no complete correspondence in composition and thickness of beds at these places they are nevertheless to be correlated with each other. No complete continuous section of all the Cretaceous beds has been found. A section near the mouth of Canyon Creek gives a general idea of the character of the basal beds.

Section near mouth of Canyon Creek

	Feet
Shaly, crumbling, brown-weathering sandstone with fossiliferous limy concretions as much as 3 feet in diameter	250
Greenish-gray sandstone	100
Conglomerate and fine grit	2
Unconformity.	
Tuffs and chert beds.	

Near the head of Canyon Creek are beds of sandstone and sandy shale that are overlain by the black shale. The black shale is essentially homogeneous in aspect but contains a few thin limestone beds and many limy concretions as much as 2 or even 3 feet in diameter. It also contains hard cherty beds in its lower part. The black shale and associated red shale form most of the country rock of the Young Creek Valley. The black shale is overlain in Pyramid and Andrus Peaks, at the head of Young Creek, by about 2,500 feet of nearly horizontal beds of sandstone and shale with subordinate conglomerate.

The ridge south of Young Creek, when seen from the north, appears to be made up of black shale capped by a succession of nearly horizontal beds of conglomerate and sandstone. These beds, however, form not only the top of the ridge but also most of the precipitous south slope, on the Chitina River side. They occupy an area about 15 miles in length and 3 miles in maximum width and are distinctly indicated by the topography of the ridge. This topographic expression is seen in the tablelike summits along the ridge and in the cliffs facing the Chitina River.

The beds consist of conglomerate, sandstone, sandy shale, and arkose. Although the conglomerate is at first sight the most noticeable component of the whole mass, the sandstone, shale, and arkose predominate. These rocks are well exposed at the heads of the gulches that come into Young Creek from the south. In the first gulch above Calamity Gulch the contact of the shale and the overlying conglomerate, arkose, and shale succession is seen in the creek bed about 1,200 feet above Young Creek, where it is a fault contact. A massive conglomerate dipping about 40° S. and consisting of cobbles and boulders as much as a foot in diameter, set in a matrix of rather coarse greenish sandstone, rests on much-folded black shale. The fault plane is nearly parallel with the bedding of the conglomerate, crossing it at a slight angle. The conglomerate is made up chiefly of igneous rocks—granite and greenstone—in well-rounded pebbles and cobbles, most of which do not exceed 6 inches in diameter. Beds of greenish sandstone are included in the conglomerate.

Above this lower, coarse conglomerate are beds of finer conglomerate, associated with sandstone, included between beds of shale. In the following section the thicknesses given are only approximate:

Section of Cretaceous conglomerate, arkose, and shale on Young Creek

	Feet
Sandstone, coarse, green and gray, interbedded with dark shale containing imperfect plant remains	700
Shale, brown and gray, with subordinate dark beds	700
Sandstone, greenish or greenish gray	100
Shale, fine-grained, brown, gray, or greenish gray	700
Conglomerate and sandstone	300
	2, 500

The total thickness of the beds was confirmed by measurements made at other places, but it does not necessarily represent the original thickness of the deposits, for part of them have been removed by erosion. The coarse sandstone near the top of the series was thought in the field to be tuff but on further study was found to be a sandstone consisting chiefly of fairly fresh angular grains of feldspar and quartz set in a fine-grained greenish groundmass. It probably represents the material produced by rapid erosion of a neighboring land mass consisting chiefly of igneous rocks like those in the conglomerate. Imperfect plant remains were obtained from the sandstone, but they were too poor to be of use in determining the age of the rocks.

The sandstone, shale, and conglomerate on the ridge south of Young Creek overlie the shale, but the exact nature of the contact is not fully determined. In places it is a fault contact.

The Cretaceous rocks of the upper Chitina Valley include three or more small areas of clastic beds that were described by Moffit and Overbeck [47] as Upper Jurassic. They include only soft brownish or pinkish sandstone and gray sandstone, both of which contain concretions, the largest 2 feet or more in diameter, some of them abundantly fossiliferous. The principal known exposures are in the lower slopes of the Chitina Valley west of Canyon Creek and on the tops of the high mountains north and south of Barnard Glacier. In the first locality a hard gray sandstone overlying soft brownish sandstone is faulted against greenstone, but the base of the section is not exposed. Sandstone in nearly horizontal beds forms isolated areas on both sides of Barnard Glacier, where it overlies the older formations and accounts for the flat summits of the mountains. About 500 feet of sandstone is exposed. It is rather uniform in character, so far as is now known, but it contains two prominent thick beds, one at the base and the other near the middle, that are clearly distinguished from the rest of the mass. These isolated areas are doubtless the remnants of a widespread and continuous formation that once extended over much of the Chitina Valley but is now almost entirely removed by erosion.

Some marked differences between the Cretaceous deposits of the Nizina district and those of Young Creek may be noted. On the high flat-topped ridge between the Nizina River and the head of Nikolai Creek, an eastern tributary of McCarthy Creek, nearly horizontal beds of sandstone and sandy shale lie on an old erosion surface of the Nikolai greenstone, Chitistone limestone, and McCarthy shale, affording a fine example of unconformable structure. The following section was observed south of Nikolai Creek in the vicinity of the limestone-greenstone contact:

Section south of Nikolai Creek

	Feet
Greenish-gray sandy beds	50
Sandy beds with limy phases, weathering brown; fossils fairly numerous	50
Dark-gray shale, weathering brown and grading into shale below	50
Light-gray shale, weathering brown	50
Dark-gray grit or fine conglomerate of variable thickness, not exceeding 50 feet; contains beds of ground-up shells and is highly calcareous	50
Unconformity.	——
Nikolai greenstone and Chitistone limestone.	250

The basal bed fills the depressions in an old land surface. Its character varies from exposure to exposure, and in places it is practically absent. On the brow of the ridge overlooking the Nizina River the basal bed contains boulders of the Nikolai greenstone and ranges in thickness from 20 to 50 feet.

[47] Moffit, F. H., and Overbeck, R. M., op. cit. (Bull. 675), p. 27.

The upper part of the ridge between the Nizina River and the West Fork is made up in part of Cretaceous rocks that overlie the McCarthy shale unconformably and are in turn overlain unconformably by the Tertiary volcanic rocks. Beginning on the ridge at an altitude of 4,600 feet and extending northward up the ridge the following section is exposed:

Section on ridge between Nizina River and West Fork

	Feet
Volcanic beds.	
Unconformity.	
Brown sandstone	(?)
Black and gray shale	575
Limy sandstone and gray sandstone Gray sandstone	50–75
Thin-bedded green sandy shale and dirty limy beds	100
Base not exposed.	

The Cretaceous beds slope down to the level of Nizina Glacier and, near the starting point of the trail across the glacier to Skolai Creek, rest on Upper Triassic beds and the Nikolai greenstone. At the base, locally, is conglomerate that reaches a thickness of 10 feet and contains boulders as much as 18 inches in diameter. Above the conglomerate are massive brown grit or sandstone with cross-bedding, sandy shale, and black shale, with a few conglomerate or sandstone beds, that reach a total thickness of at least 3,000 feet. The top of the section is black shale, on which at one place rests 75 feet of Tertiary conglomerate overlain by lava flows. Some of the lower sandstone beds contain numerous spherical or subspherical sandstone concretions, which are locally known as "cannonballs." The section of Cretaceous beds on the West Fork and on the west side of Nizina Glacier resembles that of McCarthy Creek but has not been studied or mapped in other than a reconnaissance way.

Cretaceous rocks are well exposed east of Nizina Glacier. About 3 miles south of Skolai Lake they overlie the Nikolai greenstone. They extend southward along the glacier for a mile or more but find their greatest development in the mountains to the east, where at least 3,000 feet is exposed. The basal beds include a conglomerate of no great thickness, with scattered pebbles 3 inches or less in diameter, 75 feet of gray sandstone, overlain by 20 feet of coarse black grit and then brown-weathering sandstone that dips gently south. A mile south of this locality, on the north side of Moonshine Creek, the brown Cretaceous sandstone and sandy shale contain numerous round concretions as much as 3 feet in diameter. These beds, which are overlain by about 600 feet of horizontally bedded soft gray shale that contains thin sandstone beds and concretions, form the lower slopes of the flat-topped mountain south of Moonshine Creek. The gray shale weathers easily to form soft mud. The top of the mountain has an altitude of a little more than 6,000 feet, and its precipitous north side gives a fine exposure of nearly horizontal beds that are the basis of the following highly generalized section. The thicknesses given are based on estimates of the proportionate parts of the section made up by the different members and viewed from a distance.

Generalized section on north side of mountain south of Moonshine Creek

	Feet
Brown-weathering sandstone	400
Brown-weathering shale and sandy shale with sandstone beds	800
Brown-weathering sandstone	800
Soft gray shale with local sandstone beds and concretions	100
Conglomerate	(?)

A vast amount of Cretaceous shale and sandstone has been removed by erosion, and areas that once were certainly occupied by such rocks show no evidence of them now. On the other hand, little patches of sandstone appear unexpectedly in many places as a thin veneer on ridges and capping on mountain tops.

The Cretaceous rocks were intruded by large masses of granite and quartz diorite and are cut by light-colored porphyritic dikes and sills that are offshoots of the large bodies or were injected at the same time. These intrusive bodies appear to be most numerous in the black shale, where they are certainly more conspicuous than in the sandstone and associated beds. In large exposures the contrast of the light dikes and sills, seen against the background of dark shale, makes their presence easier to discover than in the sandstone or in the older light-colored rocks such as the Triassic limestones. Although the older rocks were necessarily cut by the intrusives that invaded the overlying Cretaceous shale, they give less evidence of their presence, and even the dark McCarthy shale seems to contain fewer of the intrusives.

Some of the intrusive bodies are of large size and occupy extensive areas. Porphyry and Sourdough Peaks are such intrusive bodies that are composed dominantly of granite and quartz diorite but have masses of the black shale caught up in them.

The dikes vary in size, form, and regularity of distribution. They are numerous in the mountain west of Kennicott Glacier and are a conspicuous feature of the landscape there, as they top the mountain and under the influence of the weather provide an abundance of light-colored debris that streams down over the black shale. They are widely scattered on Dan and Copper Creeks and the head of Rex Creek but are also found in many other places. One dike on Copper Creek is practically continuous for a distance of about 5 miles.

The dikes and sills are more resistant to weathering than the enclosing shale and tend to stand out in relief, although this tendency is neutralized in part by the numerous joints and fracture planes that permit them to break down in blocks as fast as the shale is eroded away from them.

THICKNESS AND STRUCTURE

A consideration of the composition of the Cretaceous deposits and the succession of beds that have been described as occurring in the Chitina Valley eastward from the Lakina River suggests that they may be represented by the following generalized statement. At the base in most places is conglomerate or grit that fills the depressions of an old land surface and is irregular in thickness or in places absent. Overlying the conglomerate are beds of sandstone and sandy shale that are highly calcareous in places, although beds of limestone are not known. These sandy beds may reach a thickness of 500 feet or more but in most places are not over 300 feet thick. They are overlain by a black shale member that reaches a maximum thickness of not less than 3,000 feet and is somewhat variable in character, being fairly homogeneous in its westward extension but including much red shale and thin beds of limestone, sandstone, and conglomerate, together with numerous concretions, in the more easterly exposures. The black shale is capped by at least 2,500 feet, possibly 3,000 feet, of conglomerate, sandstone, and sandy shale. The three groups of Cretaceous sediments in the Nizina district therefore appear to have a total thickness of at least 6,000 feet.

The Cretaceous sediments show marked differences in the character of the material that was being laid down in contemporaneous deposits at different localities. This is illustrated by the change from the almost homogeneous black shale of McCarthy Creek to the sandstone and sandy shale east of Nizina Glacier, for although it has not been proved that these deposits are contemporaneous, their relation to the underlying rocks makes it appear probable that they are. A different sedimentation is seen in the red shale and limestone of Young Creek. The conglomerate, sandstone, and shale beds of Pyramid Peak are believed to be the equivalent of the conglomerate, sandstone, and arkose beds south of Young Creek, yet here again the differences of sedimentation are seen, for the thick basal conglomerate of the Young Creek ridge is not present in Pyramid Peak.

No beds that can be certainly correlated with the beds of Pyramid Peak and Young Creek are known on the Nizina River, although the highest beds of the Cretaceous in the McCarthy Creek Valley give evidence of a change from mud to sand deposits.

A distinct unconformity marks the beginning of Cretaceous sedimentation in the Chitina Valley. The preexisting rocks had already been deformed and had been subjected to a long period of erosion before the subsidence that brought about renewed sedimentation took place, so that Cretaceous deposits rest on all the older rocks from the Strelna formation to the McCarthy shale. Although the unconformity can be seen in many localities, one of its best examples is found near the head of Nikolai Creek, where the nearly horizontal sandstone beds lie across the tilted contact plane of the Nikolai greenstone and the Chitistone limestone.

Where the Cretaceous beds are overlain by Tertiary fresh-water sedimentary and volcanic deposits the contact shows structural unconformity, but the folding and tilting of the Cretaceous beds is less than that of the rocks beneath them.

Folding and faulting have affected the different Cretaceous sedimentary rocks in different ways. The soft shales were distorted by deforming forces more than the sandstones and show much greater folding and other evidence of disturbing pressure. The sandstone, on the other hand, rarely shows severe folding and in many places lies horizontal or is only slightly tilted. Faults, however, are more easily discovered in the sandstone and conglomerate than in the homogeneous black shale. Faulting of very considerable degree occurred after the Cretaceous rocks were formed, as may be seen in the great break that extends from Nikolai Creek to the head of Copper Creek and in smaller faults in the ridge south of Young Creek.

The Cretaceous sediments show less folding than the Upper Triassic limestone and shale but more than the overlying Tertiary volcanic rocks, although in places the parallelism between the bedding planes of the sandstone and of the Tertiary tuff beds and lava flows is practically perfect.

AGE AND CORRELATION

The Cretaceous marine sediments of the Chitina Valley are abundantly fossiliferous in places, especially in the lower sandstone beds, yet great thicknesses of both the shale and the sandstone seem to be almost lacking in evidences of former life. Many collections of invertebrate fossil remains, including a considerable number of species among which an *Aucella* like *A. crassicollis* Keyserling (pl. 10, figs. 4, 5) is common, have been made, and in addition a small number of fossil-plant collections. These collections were made from time to time throughout a period of more than 30 years and were taken from widely scattered localities, some of which are isolated and cannot be correlated with accuracy either on lithologic and stratigraphic grounds or on the evidence of the fossils. Moreover, the collections of fossils have not yet been studied in a thorough systematic way and have not been compared in connection with all the field evidence now available. It was, therefore, almost inevitable that some confusion and contradiction of opinion as to the interpretation of the fossils should arise. Doubtless the most satisfactory way of attacking the problem is for the paleontologist himself to study the field sections and make additional collections and comparisons, but this course has not been possible.

Although some collections of fossils from the Chitina Valley have been determined as Lower Cretaceous and a small number as Upper Cretaceous, Reeside,[48] who has identified the forms contained in the later collections and has compared them with previous determinations, is inclined to the belief that all the Cretaceous fossils collected from the north side of the valley are probably Lower Cretaceous. This conclusion, if it is correct, does not eliminate the possibility that Upper Cretaceous sediments are present, yet until definite knowledge of their presence is obtained it seems best to designate all the deposits as Cretaceous, with the understanding that Lower Cretaceous deposits are dominant but that Upper Cretaceous deposits may be present although they are not recognized. On this assumption the accompanying table of Cretaceous fossils and list of localities has been prepared. The determinations were made by T. W. Stanton and John B. Reeside, Jr., as indicated by the initials S and R at the tops of the columns. The list is arranged approximately in geographic order.

8924. 2,000 feet S. 12° W. from 6,005-foot limestone point west of Kluvesna River. Collector, J. B. Mertie, Jr., 1914.

8934. Float, 9,000 feet N. 47° W. from Ammann's cabin, on Kluvesna River; altitude 5,200 feet. Collector, Fred H. Moffit, 1914.

8935. Same locality as 8934 but fossils found in place. Collector, Fred H. Moffit, 1914.

8936. 9,950 feet N. 40½° W. from Ammann's cabin, on Kluvesna River; altitude 5,800 feet. Collector, Fred H. Moffit, 1914.

8937. Same locality as 8936 but an overlying bed. Collector, Fred H. Moffit, 1914.

8940. Boulders in Limestone Creek near mouth. Collector, G. C. Martin, 1914.

2196. Chitty (Clear) Creek, Kotsina Valley; altitude 3,290 feet. Collector, F. C. Schrader, 1900.

2198. About 6 miles up Chitty (Clear) Creek, Kotsina Valley. Collector, F. C. Schrader, 1900.

2210. Chitty (Clear) Creek, Kotsina Valley. Collector, F. C. Schrader, 1900.

2211. North fork of Kuskulana River. Collector, F. C. Schrader, 1900.

8168. Divide between Nugget and Roaring Creeks. Collector, Theodore Chapin, 1912.

9942. Saddle on ridge between Rock and Lime Creeks. Collector, Fred H. Moffit, 1916.

9933. Ridge between east fork of Strelna Creek and Clear Creek. Collector, Fred H. Moffit, 1916.

8155. First creek south of Clear Creek, tributary of Kuskulana River. Collector, Theodore Chapin, 1912.

8939. 5,800 feet S. 39° E. from mouth of Slatka Creek; altitude, 3,500 feet. Collector, Fred H. Moffit, 1914.

9949. Creek 1½ miles southwest of Trail Creek, a tributary of Kuskulana River. Collector, Fred H. Moffit, 1916.

9950. West side of Trail Creek. Collector, Fred H. Moffit, 1916.

[48] Reeside, J. B., Jr., oral cummunication.

Fossils from the Jurassic or Cretaceous rocks

	8924 S	8934 S	8935 S	8936 S	
Coral					[illegible]
Hydrozoan					[illegible]
Worm trails					[illegible]
Serpula sp				×	[illegible]
Pentacrinus sp					[illegible]
Echinoid					[illegible]
Thyasira sp					[illegible]
Aviculid pelecypod					[illegible]
Venerid pelecypod					[illegible]
Pelecypod sp., large ribbed form					[illegible]
Pelecypod sp					[illegible]
Brachiopod sp					[illegible]
Rhynchonella sp	×				[illegible]
Terebratula sp	×				[illegible]
Spiriferina sp	?				[illegible]
Venerid					[illegible]
Solemya sp					[illegible]
Nucula sp				?	[illegible]
Grammatodon sp					[illegible]
Leda sp					[illegible]
Cucullaea sp., undescribed?					[illegible]
Cucullaea sp					[illegible]
Nemodon sp					[illegible]
Arca sp					[illegible]
Pinna sp				?	[illegible]
Pteria sp					[illegible]
Inoceramus cf. *I. concentricus* (Parkinson)					[illegible]
Inoceramus sulcatus (Parkinson)					[illegible]
Inoceramus sp., large form	×				[illegible]
Inoceramus sp., with thick shell					[illegible]
Inoceramus sp., small, finely ribbed					[illegible]
Inoceramus sp., fine radial and coarser concentric striations					[illegible]
Inoceramus sp		×	×	×	[illegible]
Aucella cf. *A. crassicollis* (Keyserling)					[illegible]
Aucella cf. *A. pallasi* (Keyserling)					[illegible]
Aucella cf. *A. piochi*, concentrically ribbed					[illegible]
Aucella sp., a broad form suggesting *A. crassicollis* (Keyserling)					[illegible]
Aucella sp., a form with concentric ribs and fine radial striations between					[illegible]
Aucella sp., a concentrically ribbed form					[illegible]
Aucella sp					[illegible]
Exogyra sp					[illegible]
Ostraea sp					[illegible]
Pecten (*Camptonectes*) sp., undescribed					[illegible]
Pecten (*Syncyclonema?*) sp., undescribed					[illegible]
Pecten sp	×			×	[illegible]
Pecten sp., smooth					[illegible]
Pecten (*Vola*) sp					[illegible]
Trigonia sp					[illegible]
Spondylus sp					[illegible]
Plicatula sp					[illegible]
Lima sp					[illegible]
Anomia sp					[illegible]
Pleuromya sp					[illegible]
Thracia cf. *T. semiplicata* (Whiteaves)					[illegible]
Thracia sp					[illegible]
Astarte sp				?	[illegible]
Cyprina occidentalis (Whiteaves)					[illegible]
Cyprina sp					[illegible]
Tancredia sp					[illegible]
Lucina sp					[illegible]
Protocardia sp					[illegible]
Clisocolus sp					[illegible]
Isocardia sp					[illegible]
Dosinia sp					[illegible]
Solen sp					[illegible]
Corbula sp					[illegible]
Teredo borings					[illegible]
Turnus sp					[illegible]

	8924 S	8934 S	8935 S	8936 S	
Dentalium sp					[illegible]
Trichotropsis sp. cf. *T. konincki* (Muller) as figured by Stoliczka					[illegible]
Gastropod					[illegible]
Pleurotomaria sp					[illegible]
Turbo sp					[illegible]
Chemnitzia sp					[illegible]
Natica sp					[illegible]
Amauropsis tenuistriata (Whiteaves)					[illegible]
Anchura or *Aporrhais* sp					[illegible]
Aporrhais sp					[illegible]
Tessarolax sp					[illegible]
Fusus sp					[illegible]
Actaeon sp					[illegible]
Cylichna sp					[illegible]
Cinulia sp					[illegible]
Nautilus sp					[illegible]
Ammonite (*Pachydiscus?*)					[illegible]
Ammonite sp					[illegible]
Aptıcus of an ammonite					[illegible]
Lytoceras (*Gaudryceras*) sp					[illegible]
Lytoceras (*Gaudryceras*) sacya (Forbes)					[illegible]
Lytoceras (*Tetragonites*) cf. *L. timotheanum* (Major)					[illegible]
Lytoceras sp			?		[illegible]
Phylloceras cf. *P. ramosum* (Meek)					[illegible]
Phylloceras sp					[illegible]
Hamites sp					[illegible]
Ptychoceras sp					[illegible]
Baculites cf. *B. tares* (Forbes)					[illegible]
Baculites sp					[illegible]
Oppelia (*Neumayria*) sp. or *Hoplites* sp					[illegible]
Oppelia sp					[illegible]
Olcostephanus sp					[illegible]
Idoceras sp					[illegible]
Perisphinctes sp				?	[illegible]
Amoeboceras sp. unnamed					[illegible]
Aspidoceras sp. cf. a bulbous form like *A. cyclotus* (Steyer?)					[illegible]
Desmoceras breweri (Gabb)					[illegible]
Desmoceras haydeni (Gabb)					[illegible]
Desmoceras (*Puzosia*) sp					[illegible]
Desmoceras sp					[illegible]
Haueriiceras sp					[illegible]
Holcodiscus cf. *H. cumshewaensis* (Whiteaves)					[illegible]
Holcodiscus (*Spitidiscus*) sp					[illegible]
Holcodiscus sp					[illegible]
Pachydiscus sp					[illegible]
Puzosia sp					[illegible]
Hoplites sp					[illegible]
Crioceras sp					[illegible]
Anisoceras sp. cf. *A. armatum* (Sowerby)					[illegible]
Anisoceras sp					[illegible]
Belemnites (*Belemnopsis*) sp. of the canaliculati type					[illegible]
Belemnites sp					[illegible]
Belemnites or *Belemnitella* sp					[illegible]
Decapod crustacean					[illegible]
Crustacean claw					[illegible]
Barnacle (plates) of Lepadidae family					[illegible]
Fish scales					[illegible]
Shark teeth					[illegible]

8926. Southwest side of Trail Creek, near trail; altitude 3,300 feet. Collector, Fred H. Moffit, 1914.

8927. Southwest side of Trail Creek, near trail and locality 8926; altitude 3,500 feet. Collector, Fred H. Moffit, 1914.

2195. Bed of stream near trail east of Kuskulana River; altitude 3,350 feet. Collector, A. C. Spencer, 1900.

9951. Small gulch 100 yards above forks of Trail Creek. Collector, Fred H. Moffit, 1916.

9952. Float on ridge half a mile south of Kuskulana Pass. Collector, Fred H. Moffit, 1916.

9954. Northern tributary of Chokosna River half a mile above mouth of gulch that leads to Kuskulana Pass. Collector, Fred H. Moffit, 1916.

9955. Chokosna River Valley near locality 9954. Collector, Fred H. Moffit, 1916.

9957. Chokosna River Valley, ridge east of locality 9954. Collector, Fred H. Moffit, 1916.

14477. Head of Chokosna River, 1 mile up southern tributary that joins the river at Kuskulana Trail. (Compare locality 9954.) Collector, Fred H. Moffit, 1928.

14478. Head of Chokosna River, near locality 14477. Collector, Fred H. Moffit, 1928.

9963. Mill Creek, north side, half a mile from glacier on west fork. Collector, Fred H. Moffit, 1916.

14480. Near divide between head of Slatka Creek and Chokosna River. Collector, Fred H. Moffit, 1928.

2191. Creek tributary to Lakina River half a mile above crossing of old trail between Lakina and Kennicott Rivers. Collector, A. C. Spencer, 1900.

11369. Fall Creek, first tributary of Lakina River east of Fohlin Creek, 1,000 feet higher than mouth of Fohlin Creek. Collector, Fred H. Moffit, 1922.

11370. Fall Creek 1,200 feet higher than mouth of Fohlin Creek. Collector, Fred H. Moffit, 1922.

3. Boulder in creek between Lakina River and Fohlin Creek at camp 9. Collector, Oscar Rohn, 1899.

4. East side of Fohlin Creek. Collector, Oscar Rohn, 1899.

9976. Fohlin Creek 125 feet above mouth of Bear Creek. Collector, Fred H. Moffit, 1916.

9977. Fohlin Creek 300 feet north of locality 9976. Collector, Fred H. Moffit, 1916.

9978. Fohlin Creek 1,300 feet north of locality 9976. Collector, Fred H. Moffit, 1916.

8873. East bank of Fohlin Creek, 4,900 feet north of mouth of Bear Creek. Collector, G. C. Martin, 1914.

8875. East bank of Fohlin Creek 6,800 feet north of Bear Creek. Collector, G. C. Martin, 1914.

8876. East bank of Fohlin Creek 5,500 feet north of Bear Creek. Collector, G. C. Martin, 1914.

14484. Fohlin Creek 1 mile north of Bear Creek. Collector, Fred H. Moffit, 1928.

14485. Fohlin Creek 1 mile north of Bear Creek, 100 yards north of locality 14484. Collector, Fred H. Moffit, 1928.

14486. Fohlin Creek 1 mile north of Bear Creek, near locality 14485. Collector, Fred H. Moffit, 1928.

9965. First northern tributary of Bear Creek, a tributary of Fohlin Creek, half a mile from mouth of Bear Creek. Collector, Fred H. Moffit, 1916.

9966. Near but a little upstream from locality 9965. Collector, Fred H. Moffit, 1916.

9967. A little upstream from locality 9966. Collector, Fred H. Moffit, 1916.

9967a. Loose block at locality 9967. Collector, Fred H. Moffit, 1916.

9971. Same creek as locality 9965, at falls of creek, a little over 1 mile from Bear Creek. Collector, Fred H. Moffit, 1916.

14487. 1 mile from mouth of first northern tributary of Bear Creek east of Fohlin Creek. Collector, Fred H. Moffit, 1928.

8872. Bear Creek about 2½ miles above mouth. Float, the same piece of rock containing the plants of lot 6811 (p. 87). Collector, G. C. Martin, 1914.

2201. Old trail between Lakina and Kennicott Rivers. Collector, A. C. Spencer, 1900.

5. 3 miles east of Fohlin Creek, between camps 11 and 12, near head of Bear Creek. Collector, Oscar Rohn, 1899.

14471. About 1½ miles north of Bear Creek and the same distance east of Fohlin Creek. Collector, Fred H. Moffit, 1928.

8877. Bear Creek about 3 miles above its mouth. Collector, G. C. Martin, 1914.

8878. Bear Creek about 3 miles above its mouth, 100 yards above locality 8877. Collector, G. C. Martin, 1914.

8879. Bear Creek about 3 miles above its mouth, 100 yards above locality 8878. Collector, G. C. Martin, 1914.

9972. Bear Creek about halfway from Fohlin Creek to Fourth of July Pass. Collector, Fred H. Moffit, 1916.

9973. Bear Creek about halfway from Fohlin Creek to Fourth of July Pass, near locality 9972. Collector, Fred H. Moffit, 1916.

8880. Bear Creek about 400 yards below summit of Fourth of July Pass. Collector, G. C. Martin, 1914.

9975. Tributary that joins Bear Creek 575 feet below Fourth of July Pass. Base of sandstone. Collector, Fred H. Moffit, 1916.

9984. Bear Creek. Collector, Fred H. Moffit, 1916.

8871. Upper end of canyon of Fourth of July Creek. Talus nearly in place. Collector, G. C. Martin, 1914.

11389. Fourth of July Creek, 2 miles from Kennicott Glacier. Collector, Fred H. Moffit, 1922.

14465. Fourth of July Creek, south side, just above canyon and 1 mile below forks. Collector, Fred H. Moffit, 1928.

14466. Northern tributary of Fourth of July Creek 1½ miles from its mouth. Collector, Fred H. Moffit, 1928.

14467. Same as locality 14466. Collector, Fred H. Moffit, 1928.

14468. Northern tributary of Fourth of July Creek, 1½ miles from its mouth. Collector, Fred H. Moffit, 1928.

6. Canyon between camp 13 and Kennicott Glacier (Fourth of July Creek). Collector, Oscar Rohn, 1899.

2200. Along west edge of Kennicott Glacier, 7 miles from the Pot Hole. Float. Collectors, F. C. Schrader and A. C. Spencer, 1900.

9981. First creek north of Fourth of July Creek, tributary of Kennicott Glacier. Collector, Fred H. Moffit, 1916.

9982. Near locality 9981 and a little above it. Collector, Fred H. Moffit, 1916.

9983. First creek north of Fourth of July Creek, tributary of Kennicott Glacier. Collector, Fred H. Moffit, 1916.

11371. A quarter of a mile up first creek north of Fourth of July Creek, tributary of Kennicott Glacier. Collector, Fred H. Moffit, 1922.

14489. West side of Kennicott Glacier, 1 mile below Hidden Creek. Float. Collector, Fred H. Moffit, 1928.

14490. West side of Kennicott Glacier, 1 mile below Hidden Creek. Float. Collector, Fred H. Moffit, 1928.

14488. Fohlin Creek, 1 mile above Bear Creek. Float. Collector, Fred H. Moffit, 1928.

9. Top of high mountain east of camp 20 on McCarthy Creek. Collector, Oscar Rohn, 1899.

12. Near same place as locality 9. Collector, Oscar Rohn, 1899.

6301. McCarthy Creek. Collector, Fred H. Moffit, 1909.

6313. McCarthy Creek. Base of Mesozoic sandstone. Collector, Fred H. Moffit, 1909.

14029. McCarthy Creek Valley near head. Float. Collector, Fred H. Moffit, 1927.

14492. "Lubbe Creek", east side of McCarthy Creek, 1 mile north of Dimond Creek. Collector, Fred H. Moffit, 1922.

14495. Second eastern tributary of McCarthy Creek above Dimond Creek half a mile from McCarthy Creek. Collector, Fred H. Moffit, 1928.

14496. Same as locality 14495. Collector, Fred H. Moffit, 1928.

11378. McCarthy Creek, boulder 2 miles below glacier. Collector, Fred H. Moffit, 1922.

14031. McCarthy Creek Valley, 2½ miles south of glacier and 1 mile east of creek. Collector, Fred H. Moffit, 1927.

14034. McCarthy Creek, east side, 200 yards from creek and 1 mile from glacier. Collector, Fred H. Moffit, 1927.

11376. McCarthy Creek, north side of second tributary on east side below glacier. Collector, Fred H. Moffit, 1922.

11377. McCarthy Creek, ridge south of second tributary on east side below glacier, 2,200 feet higher than the creek. Collector, Fred H. Moffit, 1922.

14032. McCarthy Creek, east side, 2¼ miles south of glacier. Collector, Fred H. Moffit, 1927.

11372. McCarthy Creek half a mile below glacier. Float. Collector, Fred H. Moffit, 1922.

11374. McCarthy Creek, first tributary on east side below glacier, near mouth. Collector, Fred H. Moffit, 1922.

11375. McCarthy Creek, ledge on east side just north of second tributary below glacier. Collector, Fred H. Moffit, 1922.

11380. McCarthy Creek, east side of first tributary below glacier, 200 yards up the tributary. Collector, Fred H. Moffit, 1922.

11373. McCarthy Creek, east side of west glacier, about halfway up glacier. Collector, Fred H. Moffit, 1922.

14497. McCarthy Creek, east side at edge of west glacier. Collector, Fred H. Moffit, 1928.

14035. McCarthy Creek Valley, a short distance southeast of end of east glacier. Talus below cliff. Collector, Fred H. Moffit, 1927.

14500. East side of east McCarthy Creek glacier. Collector, Fred H. Moffit, 1928.

14051. East side of east McCarthy Creek glacier. Slide rock near outcrop. Collector, Fred H. Moffit, 1928.

14502. East side of east McCarthy Creek glacier. Collector, Fred H. Moffit, 1928.

2193. Nikolai Creek. Arkose gravel. Collectors, F. C. Schrader and A. C. Spencer, 1900.

2204. Nikolai Creek. Boulder in stream near Nikolai mine. Collectors, F. C. Schrader and A. C. Spencer, 1900.

2208. Head of Nikolai Creek. Collectors, F. C. Schrader and A. C. Spencer, 1900.

6304. Nikolai Creek. Base of Cretaceous sandstone. Collector, Fred H. Moffit, 1909.

6305. Nikolai Creek near locality 6304. Collector, Fred H. Moffit, 1909.

6302. Nikolai Creek. Base of Cretaceous sandstone. Collector, Fred H. Moffit, 1909.

6307. Head of Nikolai Creek. Collector, Fred H. Moffit, 1909.

6308. Nikolai Creek. Lower part of Cretaceous sandstone. Collector, Fred H. Moffit, 1909.

6309. Divide between Nikolai Creek and Nizina River. Collector, Fred H. Moffit, 1909.

6310. Nikolai Creek. Base of the Cretaceous sandstone. Collector, Fred H. Moffit, 1909.

6331. South fork of Nikolai Creek. Near base of Cretaceous sandstone. Collector, Fred H. Moffit, 1909.

8892. About 1¼ miles N. 48° E. of Nikolai mine. Float probably nearly in place and in yellow calcareous sandstone 250 or 300 feet above base of formation. Collector, G. C. Martin, 1914.

8893. About 1¼ miles N. 52° E. of Nikolai mine, on crest of ridge. In place and probably from same bed as yielded lot 8892. Collector, G. C. Martin, 1914.

8894. About 1 mile east of Nikolai mine, on top of mesa. Yellow sandstone float. Collector, G. C. Martin, 1914.

14503. Half a mile east-southeast of Nikolai mine, Collector, Fred H. Moffit, 1928.

14504. Three-fourths of a mile east-southeast of Nikolai mine, altitude 5,300 feet. Collector, Fred H. Moffit, 1928.

14505. 1½ miles east-southeast of Nikolai mine, on brow of cliff overlooking Nizina River. Collector, Fred H. Moffit, 1928.

14506. 1½ miles northeast of Nikolai mine, on Nikolai Creek. Collector, Fred H. Moffit, 1928.

14508. A quarter of a mile south of Nikolai mine. Collector, Fred H. Moffit, 1928.

14510. North end of Nizina River bridge. Collector, Fred H. Moffit, 1928.

1696. "Chitina drainage near cannel coal." Received from Dan Cane by F. C. Schrader, 1902.

6334. Texas Creek, a tributary of Copper Creek. Near base of Cretaceous beds. Collector, S. R. Capps, 1909.

14041. Nizina Valley, west side, between Nizina River and west fork, altitude 5,200 feet. Collector, Fred H. Moffit, 1927.

14511. Nizina River bar half a mile north of west fork. Collector, Fred H. Moffit, 1928.

14512. West side of Nizina Glacier, half a mile above "the barns", where trail starts east across glacier to Skolai Creek Valley. Collector, Fred H. Moffit, 1928.

14514. West side of Nizina Glacier 1 mile from lower end. Collector, Fred H. Moffit, 1928.

14515. Half a mile south of "the barns" and same distance west of Nizina Glacier. Collector, Fred H. Moffit, 1928.

14039. Nizina Glacier Valley, east side, 1 mile from end of glacier, on Moonshine Creek, about 1 mile from glacier. Collector, Fred H. Moffit, 1927.

14040. Nizina Glacier Valley, small southern tributary to Moonshine Creek; altitude 4,200 feet. Collector, Fred H. Moffit, 1927.

14038. Nizina Glacier Valley, east side, 3 miles south of Lower Skolai Lake. Collector, Fred H. Moffit, 1927.

6315. Sour Dough Hill. Collector, Fred H. Moffit, 1909.

6316. Mouth of Dan Creek. Collector, Fred H. Moffit, 1909.

6322. Copper Creek. Base of Cretaceous beds. Collector, Fred H. Moffit, 1909.

4811. Chititu Creek. Washed from shale bedrock near mouth of Rex Creek during mining operations. Collector, Fred H. Moffit, 1907.

6324. Rex Creek. Probably high in Cretaceous beds. Collector. Fred H. Moffit, 1909.

6325. Rex Creek. Cretaceous beds. Collector, Fred H. Moffit, 1909.

6326. Rex Creek. Probably high in Cretaceous beds. Collector, Fred H. Moffit, 1909.

6336. Rex Creek. Cretaceous shales. Collector, Fred H. Moffit, 1909.

8868. Mouth of Rex Creek. Collector, S. R. Capps, 1909.

8857. Blei Gulch, on fork east of trail; altitude 3,200 feet. Float from same locality as 8858 and probably from same beds. Collector, G. C. Martin, 1914.

8858. Blei Gulch, on fork east of trail; altitude 3,200 feet. Concretions in soft gray shale. Collector, G. C. Martin, 1914.

8859. Blei Gulch, on fork east of trail; altitude 3,100 feet. Collector, G. C. Martin, 1914.

8860. Float near mouth of Blei Gulch. Collector, G. C. Martin, 1914.

8861. Float near mouth of Blei Gulch. Another slab of rock from same place as 8860. Collector, G. C. Martin, 1914.

8862. Float near mouth of Blei Gulch. Another piece of rock from same place as 8860. Collector, G. C. Martin, 1914.

8863. Float near mouth of Blei Gulch. Another piece of rock from same place as 8860. Collector, G. C. Martin, 1914.

8864. Float from Blei Gulch. Collector, G. C. Martin, 1914.

8865. Float from mouth of Blei Gulch. Another piece of rock from same place as 8860. Collector, G C. Martin, 1914.

8867. Float from Blei Gulch. Collector, G. C. Martin, 1914.

6327. Mountain at head of Grubstake Gulch, two-thirds of a mile S. 85° W. of 8,135-foot peak; altitude 6,250 feet. Black concretionary shale. Collector, Fred H. Moffit, 1909.

6328. Mountain at head of Grubstake Gulch, a quarter of a mile S. 55° W. of 8,135-foot peak; altitude 7,500 feet. Impure limestone that forms upper 500 feet of mountain. Collector, Fred H. Moffit, 1909.

8870. Float from White Creek. Collector, G. C. Martin, 1914.

8869. Trail on ridge west of bend of Virginia Creek; altitude 4,160 feet. Concretionary shale. Collector, G. C. Martin, 1914.

6329. East fork of tributary that enters Young Creek from south half a mile above Calamity Gulch; altitude 3,450 feet. 15-foot limestone associated with shale. Collector, Fred H. Moffit, 1909.

9467. South side of Young Creek in gulch about 3 miles above mouth of Calamity Gulch. Nodular limestone in reddish shale. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9468. South side of Young Creek, first creek east of camp 4, about 3 miles above mouth of Calamity Gulch. Float in stream. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9469. North side of Young Creek, gulch just below Sheep station, at head of Sheep Creek; altitude about 5,200 feet. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9470. Ridge south of Young Creek, west side of Chitina River trail; altitude about 5,100 feet. Limestone nodules in gray and black shale. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9471. West branch of Young Creek, east bank, about 2 miles above forks; altitude 4,200 feet. Limestone concretions. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9472. West branch of Young Creek, east bank, about 3 miles above forks, opposite first glacier from west; altitude 4,300 feet. Nodular limestone. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9473. West branch of Young Creek above first glacier from west; altitude 4,300 feet. Float. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9474. West branch of Young Creek, above locality 9473; altitude 4,500 feet. Float. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9475. West branch of Young Creek just below first glacier from west; altitude 4,300 feet. Float. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9476. North side of east branch of Young Creek, stream entering from north just east of camp 8, 3 miles from forks; altitude 4,300 feet. Float. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9477. Young-Canyon Creek divide; altitude 5,600 feet. Black and gray shale. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9478. Young-Canyon Creek divide; altitude 5,600 feet. Black and gray shale. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9479. Upper part of east branch of Young Creek. Float. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9480. Upper part of east branch of Young Creek, same locality as 9479. Float. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9492. Bluffs on Young Creek west of big bend, half a mile above foot of trail to Chitina River; altitude 3,450 feet. Concretions in sandstone. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9493. Southern tributary of Young Creek half a mile above Calamity Gulch; altitude 3,225 feet. Concretions in black shale. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9494. Ridge south of Young Creek, 3½ miles southeast of mouth of Calamity Gulch; altitude 4,500 feet. Horizontal sandstone beds. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9491. Ridge south of Young Creek, S. 15° E. from northward bend of creek 1 mile above foot of Chitina River trail; altitude 4,000 feet. Gray sandy shale. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9487. Mouth of Canyon Creek, west side; altitude 1,460 feet. Nodules in gray sandy shale. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9488. Mouth of Canyon Creek, west side; altitude 1,470 feet. Conglomerate beds at base of sandy series. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9481. North side of Chitina River 1¼ miles N. 15° W. from Gibraltar Hill. Round calcareous concretions in gray slaty sandstone. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9483. Ridge between Barnard and Chitina Glaciers, 6 miles east of Short River; altitude, 6,475 feet. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9485. Creek north of Gibraltar Hill, halfway between Canyon Creek and Hawkins Glacier; altitude 2,125 feet. Nodules in pinkish sandstone. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9486. 3½ miles northwest of Gibraltar Hill; altitude 2,150 feet. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9489. Near south end of trail from Chitina Valley to Young Creek; altitude 1,900 feet. Sandstone nodules. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

9484. Stream entering Chitina River at camp 16, 3 miles below Chitina Glacier; altitude 2,500 feet. Float (gray sandstone). Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

Lower Cretaceous fossil plants

[Fossil determinations by F. H. Knowlton. The locality number in parentheses is the National Museum number of a collection of invertebrate fossils from the same place as that where the fossil plants were obtained].

	7279 (9950)	6812 (8863)	6811 (8872)	6814 (8879)	7280 (9971)	7281 (9972)	7574 (11389)	9	7035 (9483)	(9484)	7037 (9489)	7034 (9481)	7036 (9486)	7038 (9492)
Equisetites (fragment without teeth)		×												
Cladophlebis cf. C. moissenti Saporta												×		
Cladophlebis												×	×	
Dictophyllum														×
Hausmannia cf. H. forchhammeri or H. dichomata														×
Sagenopteris alaskensis? Fontaine		×		×										
Sagenopteris phillipsi (Lindley and Hutton)												×		×
Sagenopteris	×									×				
Sagenopteris?												×		
Taeniopteris lindgreni Nathorst												×		
Taeniopteris parvula? Heer											×	×		
Zamites megaphyllus (Phillips) Seward		×												
Cycadites							×							
Otozamites beani (Lindley and Hutton) Seward												×		
Otozamites bunburyanus Zigno												×		
Ginkgo schmidtiana Heer														×
Araucaria? (single scale)		×												
Pagiophyllum peregrinum Schimper		×												×
Pagiophyllum												×		
Taxites zamioides (Leckenby) Seward		×	×	×										
Pinus nordenskiöldi Heer														×
Elatides curvifolia (Dunker) Nathorst		×							×			×		
Podozamites or Zamites														×
Coniferous wood			×											
Wood						×								
Stems					×			×						

7279 (9950). Trail Creek, west side; altitude 3,500 feet. Soft gray sandy shale. Collector, Fred H. Moffit, 1916.

6812 (8863). Fohlin Creek, east bank, 4,900 feet above mouth of Bear Creek. Green sandstone with calcareous concretions. Collector, G. C. Martin, 1914.

6811 (8872). Bear Creek about 2½ miles above its mouth. Float; same piece of rock contains the invertebrate fossils of lot 8872. Collector, G. C. Martin, 1914.

6814 (8879). Bear Creek about 3 miles above its mouth, 100 yards above locality 8878. Collector, G. C. Martin, 1914.

7280 (9971). Boulder at falls of first northern tributary of Bear Creek, tributary of Fohlin Creek; altitude about 3,200 feet. Collector, Fred H. Moffit, 1916.

7281 (9972). Bear Creek, about halfway from Fohlin Creek to Fourth of July Pass; altitude 2,850 feet, Soft gray sandstone with nodular masses of fossils, base of Lower Cretaceous. Collector, Fred H. Moffit, 1916.

7574 (11389). Northern tributary of Fourth of July Creek, 2 miles from Kennicott Glacier. Collector, Fred H. Moffit, 1922.

9. Top of high mountain east of camp 20 on McCarthy Creek. Collector, Oscar Rohn, 1899.

7035 (9483). Top of ridge between Short River (Barnard) and Chitina Glaciers; altitude 6,475 feet. Platy sandstone. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

(9484). 4 miles northwest of lower end of Chitina Glacier, top of mountain on the north; altitude 2,500 feet. Gray sandstone. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

7037 (9489). South side of ridge between Young Creek and Chitina River, near trail; altitude 1,900 feet. Concretions in sandstone. Collectors, Fred H. Moffit, and R. M. Overbeck, 1915.

7034 (9486). North side of Chitina Glacier, 1.4 miles N. 15° W. from Gibraltar. Round calcareous concretions in gray slaty sandstone. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

7036 (9486). Creek 2 miles east of Canyon Creek, tributary to Chitina River; altitude 2,150 feet. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

7038 (9492). Bluffs of Young Creek, west of big bend. Concretions in sandstone. Collectors, Fred H. Moffit and R. M. Overbeck, 1915.

A word of explanation should be given in connection with the age assignment of the fossil plants from the upper Chitina Valley. Knowlton was of the opinion that the plants indicate Jurassic rather than Cretaceous age for the rocks containing them. This assignment is not in accord with that of the paleontologists who studied the invertebrate forms associated with the plants. In view of the much greater number of invertebrate forms, the fact that the vertical range of the ammonites is probably better established than that of the plants, and the correlations that appear to be necessary, the view of the invertebrate paleontologists is adopted in this report.

It is evident that the late Jurassic or early Cretaceous was a time of great change in Alaska, involving mountain building, profound erosion, and finally subsidence of the land. According to Martin,[49] "A widespread marine transgression in early Cretaceous time carried the sea over most if not all of the area which is now Alaska." This condition, however, applied to a greater area than Alaska. As stated by Anderson,[50] "It seems probable that conditions at the beginning of Cretaceous time were much the same throughout the entire Pacific border of North America, or farther, owing to widespread diastrophism at this epoch."

As intimated in the quotation from Martin, Cretaceous rocks are widespread in Alaska. They occur in all the major geographic provinces and form the surface rocks in large areas. Martin was led by his studies to the belief that although horizons well distributed throughout the Cretaceous are represented, the Lower Cretaceous beds occur more widely in Alaska than the Upper Cretaceous and that the Upper Cretaceous beds were not deposited in most of the areas of the present mountain axes or in the upper parts of the present major valleys, indicating that the major geographic features were already outlined in Upper Cretaceous time and that the highest deposits of that epoch were restricted to the coastal belts and the lower parts of the present major valleys. Much of the Cretaceous of the Chitina Valley he

[49] Martin, G. C., op. cit. (Bull. 776), p. 286.

[50] Anderson, F. M., Knoxville-Shasta succession in California: Geol. Soc. America Bull., vol. 44, p. 1239, 1933.

assigned to the Lower Cretaceous, but he listed "the marine shale, sandstone, arkose, and conglomerate of the Chitina Valley" among "the rocks that have been referred to the Upper Cretaceous." [51] In the first assignment he was correct, but, as pointed out on page 71, the evidence for the occurrence of Upper Cretaceous rocks on the north side of the Chitina Valley is open to question.

Cretaceous and older (?) rocks

CHARACTER AND DISTRIBUTION

The rocks included in the group that is here described as Cretaceous and older (?) are confined to the Chugach Mountains and occupy the entire southern border of the area under consideration, extending from the head of the Bremner River to the Klutina River. This, however, is not the limit of their extent, either as to the width across their strike or the length from east to west in the direction of strike, for they constitute one of the chief components of the range throughout a distance of several hundred miles. They consist almost exclusively of alternating beds of dark slate and graywacke, although a few minor beds of conglomerate or grit are found, and in many places throughout their known extent they are cut by light-colored dikes of granite and diorite. These rocks are strongly folded and faulted and locally are schistose or subschistose. They include part if not all the rocks adjacent to Prince William Sound that Schrader [52] called the "Valdez series" and correlated with Mendenhall's Sunrise series [53] of Kenai Peninsula and the part of the Chugach Mountains north of Turnagain Arm at the head of Cook Inlet. The writer [54] described the slate and graywacke of the Bremner River area under the name "Valdez group." It is known that rocks of Cretaceous age form part of this group in the Cook Inlet district, but that all or even a major part are definitely Cretaceous has not been shown. Older Mesozoic or even Paleozoic rocks may be included among them.

The great thickness of slate and graywacke that makes up the group is a monotonous succession of alternating coarse and fine deposits, which in general do not show marked contrast of bedding but rather grade from one to the other without sharp dividing lines or planes. Yet there appear to be slight differences between the slate and graywacke of the Bremner River area and those of the Tonsina district. These are largely differences in metamorphism and degree of infiltration by quartz. In the eastern area the slate is fine-grained and is greenish or bluish gray to nearly black. In places it shows well-

[51] Martin, G. C., op. cit., p. 289.

[52] Schrader, F. C., A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska, in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, p. 408, 1900.

[53] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: Idem, p. 305.

[54] Moffit, F. H., Geology of the Hanagita-Bremner region, Alaska: U. S. Geol. Survey Bull. 576, p. 22, 1914.

developed slaty cleavage, which, however, does not reach the degree of perfection found in roofing slates. The graywacke is a sandstone-like rock of gray or bluish-gray color, but it contains less quartz and more feldspar and dark-colored minerals than a typical sandstone. In many places it includes small fragments of slate and shale and might be regarded as a fine-grained conglomerate. The graywacke of the Bremner district and of the group generally differs from the slate in having coarser texture and less well-developed cleavage. Freshly broken surfaces of the rock are rough and show plainly its small constituent particles. On account of its jointing and its lack of good cleavage the graywacke, when exposed to the sun and frost, tends to break down in blocks rather than slabs.

In the Tonsina district the slate and graywacke have been changed from their original condition, particularly through the addition of vast quantities of quartz. The rocks themselves range from gray to black but are without strong contrast of color or other outstanding indication of bedding. Close examination shows the difference in coarseness of the material that composes the beds and makes it evident that the slate and graywacke must have been derived from a common source. The formation was built up of innumerable alternating beds of mud and dark sand from a few inches to many feet in thickness. Induration and further alteration changed these beds of mud and sand to slate and graywacke. Locally the alteration has gone further, and the slate and graywacke have become phyllite or even schist.

Throughout most of the Tonsina district the slate and graywacke are seamed with fine white quartz veins, which form their most outstanding feature. These fine veins fall into two groups. Those of one group follow the bedding or cleavage planes of the sedimentary rocks and appear to be folded and contorted like the bedding. The other veins cut across cleavage and bedding at various angles and are made up of thin sheets of white quartz which show on a joint face as parallel straight lines. In both groups the quartz veins are thin, many being only paper-thick and most of them measured in fractions of an inch. Most commonly the joint planes of the slate and graywacke show a grid or network of intersecting quartz veins of remarkable regularity in spacing and straightness.

Quartz veins of another variety, probably later in age, are not so common as the fine veins just described but are more conspicuous in large exposures of the country rock when viewed at a distance. These veins range in thickness from less than 1 foot to 10 feet or more and for the most part follow the north-south joint planes. They are lenticular in form. Few of them are known to extend more than 100 or 200 feet in the greater horizontal direction, and it is believed that a corresponding limitation of vertical dimension is to be expected.

These veins are of economic importance, as some of them are gold-bearing.

THICKNESS AND STRUCTURE

The thickness of the slate and graywacke beds is not known. Doubtless it is to be measured in thousands of feet, but as the stratigraphic limits and the structure of the formation are not fully understood, no definite figures for the thickness can be given. Throughout the area under consideration the beds are in contact along their north margin with rocks of the Strelna formation (Mississippian) and are believed to overlie them unconformably, although the contact in places is the result of faulting.

These rocks are one of the principal elements in a great mountain range and are exposed for many miles across the direction of their strike. The folding is pronounced, so that the beds show all attitudes from horizontal to vertical and may even be overturned in some degree. It is therefore evident that in crossing the range there must be repetition of beds, although the absence of distinctive beds that can be recognized from place to place makes this difficult to demonstrate. The absence of such beds also makes it difficult to recognize faults, even where they are of considerable displacement.

The slate and graywacke are broken by joint planes of several systems, the most common being a system in which the joints are approximately vertical and do not vary greatly from a north-south trend. Such joints are especially noticeable in the Tonsina district.

AGE AND CORRELATION

The assignment of the slate and graywacke to the Cretaceous is in part provisional and is made in the knowledge that future field work may require the differentiation and reassignment of some part of them. Evidence has accumulated slowly to indicate that part of the rocks of Prince William Sound, belonging in the group that Schrader designated the "Valdez series", were deposited late in the Mesozoic era. For a long time the most suggestive evidence consisted of a few fossils from the vicinity of the Valdez Glacier. However, during the field season of 1933 Park [55] made several collections of *Inoceramus* from the slate and graywacke north of Turnagain Arm which Reeside regards as Cretaceous and as probably Upper Cretaceous rather than Lower Cretaceous. On the evidence of this determination it appears that at least a part of the succession is correctly referred to the Cretaceous. The evidence, however, is too meager to determine positively the age of all the rocks occupying so great an extent of territory as that of the slate-graywacke group.

The assignment of the slate and graywacke to the Cretaceous period, particularly if the suggested assignment to the Upper Creta-

[55] Park, Charles, Jr., The Girdwood district, Alaska: U. S. Geol. Survey Bull. 849-G, p. 393, 1933.

ceous proves to be correct, raises a perplexing question when these rocks are compared with the Lower Cretaceous rocks on the north side of the Chitina Valley. Although both groups of sedimentary rocks were subjected to mountain-building forces, the slate-graywacke group was affected to a greater degree by these forces and shows more severe folding and more advanced metamorphism than the sandstone and shale. Possibly the sandstone was stronger and more competent to resist deforming pressure, or the forces that affected the Chugach Mountain area were greater than those which deformed the rocks of the Wrangell Mountains.

CENOZOIC BEDDED ROCKS

TERTIARY AND LATER ROCKS

CHARACTER AND DISTRIBUTION

The higher parts of the Wrangell Mountains and much of the adjacent foothill area are occupied by lava flows and tuffaceous deposits that were poured out or ejected on a preexisting land surface of strong relief. The eruptions that produced these deposits began in Tertiary time and did not cease then but have continued intermittently practically to the present, for the youngest flows are later than some of the unconsolidated glacial deposits. Mount Wrangell, the only remaining active volcano of a group that contains at least three larger volcanoes, even now gives evidence of latent volcanic forces in the steam and light ash that issue from its crater at times. It thus seems certain that although the basal flows are Tertiary, an unknown but large proportion of the upper lava and tuff beds is later than Tertiary. Much of this volcanic material is hidden by perpetual snow and ice, yet in many places it is conspicuous because of precipitous cliffs, contrasting colors, and well-defined lines of bedding. Although the Tertiary rocks are dominantly volcanic, locally they overlie accumulations of sedimentary material such as conglomerate, fine variegated clays, and lenses of coal, which were laid down in fresh water or on the land in depressions of the uneven surface on which the lavas were poured out. These sedimentary rocks are variable in thickness and erratic in distribution.

The Tertiary and more recent lavas are shown on the geologic map as extending from Mount Wrangell eastward into the White River district. Throughout much of this distance they are difficult of access because of their position in the high mountains, but they offer more favorable opportunities for examination in the upper Nizina River and White River districts and have been studied there with more particular reference to their relation to the underlying rocks and the character of the land deposits at their base.

The lava and the fragmental material interbedded with it were derived from the same source and represent the same types of rock.

In general the flows are andesitic and basaltic lavas, but they show local variations. Mendenhall,[56] who made a careful petrographic study of the volcanic rocks on the west side of the Wrangell Mountains, described them under the name "Wrangell lavas." He found that the usual types are hypersthene or hornblende andesites but that more basic and more acidic derivatives, ranging from basalt to dacite, occur. Schrader and Spencer [57] described the Tertiary bedded volcanic rocks of the Chitina Valley as andesites, rhyolites, and strata of pyroclastic origin. Capps [58] classed the lavas of the White River district as mainly pyroxene andesites, usually containing hypersthene, and olivine basalts, and to a less degree dacites. "The fragmental materials include tuffs, composed of finely comminuted rock particles and pumice; volcanic breccias, of coarser, angular fragments; and layers of volcanic bombs." In the White River district, as elsewhere, the bedded structure is pronounced. Also a great variety of color is displayed. "Deep shades of brown, red, and green predominate, but they alternate with bright reds, yellows, pinks, and grays, the whole series being in striking contrast with the somber-colored associated formations." The horizontal lava flows under weathering produce a characteristic topography in which flat-topped hills and terraces stand out. Columnar structure is common.

It is evident from these descriptions that despite the wide separation of the localities the character of the lavas is much the same, with respect both to places and to the range in time from the outpouring of the early Tertiary flows to that of the more recent flows.

The Tertiary rocks of the upper Nizina River district are dominantly andesitic and basaltic lava, intercalated with tuff beds. Black glassy obsidian is abundant in the morainal debris on the west side of Frederika Glacier but was not seen elsewhere. It probably belongs among the latest outpourings of volcanic material and may be younger than Tertiary, as is the thick deposit of white volcanic "ash" that caps some of the mountains north of lower Skolai Creek. Included among the Tertiary rocks also is a comparatively small thickness of fresh-water leaf-bearing clay, sandstone, and conglomerate containing thin beds of coal, which lies at the base of the volcanic rocks on Frederika Creek.

The lavas and tuffs form the tops of all the high mountains north of a line drawn from McCarthy Creek Glacier to Chitistone Glacier (pls. 5, *B*, and 6, *A*). The beds have a northerly dip that is so small as to be almost unnoticeable, and they therefore appear to be practically horizontal. A striking feature of the volcanic rocks is the marked

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[56] Mendenhall, W. C., Geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, p. 58, 1905.

[57] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska: U. S. Geol. Survey Special Pub., p. 51, 1901.

[58] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, p. 59, 1916.

development of columnar structure in some of the lava flows. This structure is well exhibited in the upper part of Chimney Mountain, on the west side of Nizina Glacier, where the columns form a vertical wall around three sides of the mountain. Precipitous steplike slopes and impassable walls are characteristic of the volcanic deposits wherever they are seen.

Most of the lava flows are highly vesicular and in places are porphyritic. The most conspicuous phenocrysts are large tabular crystals of amber-colored feldspar. Vesicular lavas are, however, much more abundant than the porphyritic varieties and in many places are even more striking in appearance because of the irregular nodules of blue and white chalcedony and the crystalline quartz that were deposited in the vesicles.

Among the interesting features connected with the volcanic deposits are the leaf-bearing fresh-water beds and coal at their base in at least one locality and probably in others. These beds are found along the lowest slopes of the east side of Frederika Valley, extending from the glacier to Skolai Creek, and in a small area in their line of strike south of Skolai Creek.

The best exposures for studying the fresh-water beds are in the gulches near the lower end of Frederika Glacier, where the following section was measured:

Section in gulches near lower end of Frederika Glacier

	Feet
Basalt, great thickness.	
Light-yellowish tuffaceous bed	12–15
Gray sandy shale splitting into thin sheets	5
Black shale	15
Black sandy shale splitting into thin sheets	5
Coarse gritty tuff or sandstone, thin sandstone beds, variegated fine clay, black shale, and thin coal beds; abundant fossil leaves	150
Gray, yellowish-weathering conglomerate, finer above, containing local beds of shale	100
Brown-weathering conglomerate with well-rounded pebbles 2 inches or less in diameter	20
Basalt (Permian?).	
	310

In a nearby gulch on the south the upper part of the section is as follows:

	Feet
Basalt, great thickness.	
Tuff	20
Gray sandstone	20
Basalt flow	60
Tuff	18
Sandstone	4
White and gray fine-grained clay	10
Black and gray shale	4

All the sedimentary members of the first section above the conglomerate and of the second section contain fossil leaves, which are especially abundant and well preserved in the beds just above the coal beds.

The fresh-water beds strike from north to N. 25° E. and dip gently to the east under the lavas and tuffs that make up the mountains on the east side of the Frederika Valley. The section of fresh-water deposits is difficult to study, except in gulches where water exposes a fresh surface of the beds, for the soft clays wash over and hide everything on the hill slopes. These clays make up most of the middle part of the general section. They are gray or light gray or white, have a uniform fine grain, and when wet become a sticky mass, like hard grease. The coal is in thin beds that range from an inch or less to a foot in thickness and has no commercial value.

Between Frederika Glacier and Skolai Creek the exposures are poor. No exposures were seen in the canyon of Skolai Creek, but outcrops of gray and black shale and white to light-gray clay beds, including thin lenses of coal, are found south of Skolai Creek at the base of the Tertiary volcanic rocks east of the glacier opposite Frederika Creek. The beds contain well-preserved leaves and so far as could be determined do not exceed 75 feet in thickness.

Fresh-water deposits containing thin seams of coal crop out at the base of the Tertiary lavas on the "goat trail" at the head of the Chitistone River and on the mountain top northwest of the lower end of Chitistone Glacier. A poorly cemented conglomerate, about 75 feet thick, containing well-rounded pebbles and cobbles in an iron-stained claylike base and including thin beds of soft sandstone, separates the Tertiary volcanic rocks south of Regal Glacier from the underlying black Cretaceous shale. Neither of these localities was studied in detail, but they suggest that similar deposits, formed on the old Tertiary land surface, may be found in many places if the base of the lava flows is examined more thoroughly.

THICKNESS AND STRUCTURE

The earliest of the Tertiary lava flows and fragmental deposits filled the depressions in a land surface of unknown but considerable relief. Whatever deposits of sand, gravel, and clay had accumulated in lakes or streams or on the land as the result of erosion were buried beneath them. The lavas came in part from definite vents and eventually built up local symmetrical masses of volcanic material, as in Mount Wrangell and other peaks, such as Sanford and Drum, that may have once been equally symmetrical but are now scarred and deformed by weathering. In part, however, they came from earth fractures that were more widely distributed, breaking through the older rocks and then through the beds previously formed. Feeder dikes of this sort are to be seen near Russell Glacier, at the head of Skolai Creek.

The thickest sections of volcanic deposits not including the volcanic cones are probably in the central area of the mountain group, possibly toward the east side. The thickness is less at the margins of the area. The high peaks like Wrangell and Sanford are inverted saucer- or cone-shaped masses of lava and loose material blown from the vents and are to be distinguished from the nearly horizontal flows of the Nizina and White River districts.

The bedded volcanic rocks of the Nizina district rest with distinct structural unconformity on the older rocks and have a slight dip to the north, yet the dip is so small that practically they may be regarded as horizontal. The thickness of the volcanics in Castle Mountain, west of Russell Glacier, where the beds are horizontal and beautifully exposed, is more than 3,000 feet. The thickness in Mount Regal (13,400 feet), between Nizina Glacier and Mount Blackburn, may be over 5,000 feet, but this mountain is probably a vent like Mount Wrangell, with a cone of flows and tuffaceous deposits around it. Mount Blackburn (16,140 feet), like Mount Regal, is probably another local vent, but practically nothing is known of its composition or structure.

North of the White River Capps [59] found that the thickness of the volcanic deposits ranges from a maximum of at least 1,600 feet in Pingpong Mountain to only a few feet in their northern border, south of Beaver Creek.

It is thus evident that statements of the thickness of the volcanic deposits can apply only to particular localities. The maximum is found in the old volcanic cones and may include both Tertiary and post-Tertiary deposits. In the eastern part of the area, however, where the known vents of the volcano type are at a considerable distance, the lava flows and tuffaceous beds have a thickness of at least 3,000 feet.

Unlike all the older rocks and some of the younger glacial deposits, the lava flows and tuffaceous (?) beds are not folded, yet in places they have been tilted slightly from their original position. They are nearly in the same position as when first formed, but the older flows were subjected to a long period of erosion in preglacial and glacial time, and immense quantities of the material have been removed. The present valleys are cut through the volcanic rocks and deeply into the underlying rocks. In many places only cappings of the once continuous lava flows remain on the high mountains of the interstream areas.

AGE AND CORRELATION

Schrader and Spencer [60] were led by a consideration of the topographic development of the Copper River region to the conclusion that

[59] Capps, S. R., op. cit. (Bull. 630), p. 60.

[60] Schrader, F. C., and Spencer, A. C., op. cit. (Special pub.), p. 52.

the land surface on which the older volcanic rocks were spread out was developed in Tertiary time and that the volcanic rocks themselves are Tertiary and post-Eocene. Mendenhall [61] concluded that the oldest of the flows on the west side of the Wrangell Mountains must be nearly as old as Eocene, that the volcanic activity that began then has continued to the present time, and that the latest flows are very recent. Capps [62] regarded it as probable that volcanism began locally in Eocene time but that the general burial of the Wrangell region by lavas did not take place until the post-Eocene portion of the Tertiary period. From its relation to the underlying tillite, he found that a large part of the lava series north of the White River is of Pleistocene age.

Since these studies were made further evidence concerning the time when the basal lava flows took place has been found.

The fresh-water deposits underlying and interbedded with the basal lava flows and tuffs in the Skolai Creek Valley contain abundant fossil leaves. Five collections from this locality were made by the writer in 1927. The species were identified by E. W. Berry and are listed in the following table:

Fossil leaves from Skolai Creek Valley

	7902	7903	7904	7905	7906
Alder cone, probably Alnus kefersteinii (Goeppert) Unger					×
Betula sp.					×
Diospyros alaskana Schimper and several others			×		
Grasslike foliage, fragments		×			
Hicoria sp.			×		
Pinus sp. (needles)	×	×	×		×
Populus cf. P. balsamoides Goeppert					×
Taxodium tinajorum Heer				×	×
Vaccinium sp.					×

7902. Frederika Creek Valley, east side, three-fourths of a mile from Skolai Creek.

7903. Frederika Creek Valley, near mouth of gulch on east side, opposite end of glacier.

7904. Frederika Creek Valley, near mouth of gulch on east side, opposite end of glacier, a few hundred yards east of locality 7903.

7905. Skolai Creek Valley, south side, 1 mile from Skolai Creek on east side of small glacier opposite mouth of Frederika Creek.

7906. Skolai Creek Valley, south side, a quarter of a mile east of locality 7905.

Concerning the age of these forms Berry said: "All lots appear to be of approximately the same age and are doubtless to be correlated with the Kenai, inasmuch as all the lots contain representatives of it, notably those somewhat larger collections from 7904 and 7906."

The present tendency is to restrict the name "Kenai" to the rocks of the type locality on the Kenai Peninsula, although it was formerly used generally in Alaska geology to designate fresh-water sedimentary rocks of Eocene age. It thus seems well established that the age of

[61] Mendenhall, W. C., op. cit. (Prof. Paper 41), p. 57.

[62] Capps, S. R., op. cit. (Bull. 630), p. 61.

the bedded volcanic rocks making up so large a part of the Wrangell Mountains ranges from Tertiary (Eocene) to the present.

PLEISTOCENE AND RECENT UNCONSOLIDATED DEPOSITS

Much of the bedrock surface of most land areas is concealed by varying depths of unconsolidated waste material, resulting from the weathering of country rock nearby or at a distance. Fragmental material lies on the hill slopes near its source and there tends to be angular or unworn and of heterogeneous character, or is transported for short or long distances by water, ice, or the wind and tends to become worn, rounded, and sorted with respect to size and specific gravity of the fragments. Most of it is destined finally to reach the sea, but it may accumulate for a time as beds of sand, gravel, or related material.

For convenience of description, the unconsolidated deposits of the Chitina Valley and the adjacent area may be regarded as including residual waste on hillsides, glacial deposits, stream and lake deposits, and wind-blown sand. Local deposits of volcanic ash might also be mentioned. Typical deposits of each of these classes are present, yet in general the classes grade into one another to some extent and in some places may be difficult to distinguish. The deposits of any one class, moreover, may differ among themselves in form. The glacial deposits, for example, may be ground moraine, partly reworked till, terminal and lateral moraines, or other forms; the stream gravel may be gravel in the flood plains of the present streams or older terrace gravel. In reconnaissance mapping these unconsolidated deposits are usually not examined with as much care as the rock formations. They are not differentiated on plate 2, even in places where distinctions could be made, but are all represented by the same color. Furthermore, no attempt is made to include the unsorted residual waste on hillsides with the unconsolidated deposits shown on the map, but areas occupied by it are mapped as being composed of the underlying rock.

Rock waste, not including the detritus from glacial erosion, is produced as a result of freezing, thawing, temperature changes, chemical changes, abrasion, and other agencies wherever the bedrock is exposed to their action. It is almost universally present, except on slopes that are too steep for it to accumulate or where it has been removed by ice, water, or wind. Under the action of frost or water it gradually creeps down the slopes and eventually reaches the streams, by which in time it will be carried to the sea. This material hardly calls for further description, although it is widespread and is the first stage in the formation of much of the unconsolidated deposits to be described.

The debris that accumulates at the foot of cliffs, the mouths of gulches, and the bottoms of all steep slopes where a rapid breaking down of the rocks above is in progress may form deposits of unworn and unsorted waste that are much thicker than the loose material on the hill slopes. Many of these deposits spread out to form fan-shaped accumulations on the sides of valleys and may crowd the streams far out of their natural courses in mid-valley.

A kind of deposit that is not uncommon in the Chitina Valley and is of much interest to the student of topographic forms is the so-called rock glacier.[63] In form rock glaciers resemble true glaciers, but they are made up of blocks and fragments of angular rock such as are seen in the ordinary talus slope. The space between the fragments is filled with ice wherever the rock glaciers have been examined. No ice is seen on the surface, although it is present at the heads of some of the rock glaciers in the cirque basins where they originate. The rock glaciers usually show characteristic surface markings, which tend to be longitudinal, parallel, or radial ridges in the headward parts but are concentric lobes in the lower parts. These markings are evidence of a slow motion. Excellent examples of rock glaciers are found on McCarthy Creek (pl. 13) and on the Kotsina River, but they occur in many other places.

The greatest accumulation of unconsolidated material within the region is that of the Copper River lowland or "basin." It includes a great variety of fragmental waste derived from the surrounding mountains and brought to its present position chiefly through the agency of glacial ice and water. It consists in part of unmodified glacial till, in part of well-sorted and stratified sand, gravel, and silt, and in part of deposits that represent almost every degree of gradation between these extremes, having undergone more or less sorting by water. In addition a large amount of fine wind-blown sand is included. These deposits represent the load that was transported by ice and glacial streams from many distant sources and was deposited under varying conditions as the positions of the ice fronts and the stream courses were changed. The unexpectedly distant source of some of the material is well shown by fossiliferous boulders in the till deposits near Tonsina that so far as is known could have come only from the Chitina Valley or the mountains on the north or west borders of the Copper River lowland.

If numerous cross sections of the lowland deposits could be made, it would doubtless be found that in different places all the various kinds of deposit—till, gravel, sand, and silt—were being laid down contemporaneously and that no one deposit forms a continuous, unbroken sheet throughout the area. At present all the deposits are frozen a short distance below the surface, and little if any underground drainage exists, as has been shown by attempts to obtain a supply of well water at different places.

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[63] Capps, S. R., Rock glaciers in Alaska: Jour. Geology, vol. 18, pp. 359–375, 1910. Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S Geol. Survey Bull. 448, pp. 52–59, 1911.

Although deposits of fine material that was transported and laid down by the wind are not restricted to the Copper River lowland, they are more noticeable along the streams that cross the lowland than in other parts of the region and therefore will be mentioned here. Such deposits are well shown in the banks of the Copper and Chitina Rivers in the vicinity of Chitina, and still better on the high bluffs north of the Tonsina River. Along the Tonsina River the deposits form a ridge like a railway embankment at the top of the gravel bluffs that bound the river valley in the lowland area. These embankments were evidently formed from dust that was carried there by the wind. The swirling currents of air swept upward along the steep faces of the exposed gravel and dropped their load of dust and fine sand as they spread out over the edge of the bluff. Most of the load was lost immediately, but a considerable part was carried farther away from the river. Clouds of dust carried by the strong wind are common sights along the Copper and Chitina Rivers in summer, and the trees and vegetation along the banks are covered with fine sand and dust. Undoubtedly a very considerable amount is added to the soil in this way.

The depth of the unconsolidated deposits of the Copper River lowland is not known. The only evidence on this point is that furnished by the larger streams, such as the Copper, Tonsina, and Klutina Rivers, which have cut their channels into them to depths that reach 400 feet. Mendenhall [64] measured a section in the northern part of the lowland, in the divide between the Gulkana and Delta Rivers, that showed about 600 feet of coarse and fine bedded gravel and sand. This is the maximum thickness known at present, but it is evident that greater thicknesses probably exist, for none of the streams within the basin have cut their channels to bedrock. The lowland area shows little relief. Its poorly drained surface is dotted with lakes and ponds and elsewhere is covered with vegetation that has locally formed beds of peat. No deposits of preglacial age have been recognized here, and only the glacial deposits and present gravel are known. It is therefore assumed that these deposits are of Pleistocene and Recent age.

A somewhat different type of glacial deposit is the ground moraine that is widely distributed in parts of the Chitina Valley. This consists of debris that was carried in or on the ice and was left when the ice melted. The material is a heterogeneous mass of angular fragments from many sources that underwent little sorting by water, and it forms deposits with irregular surfaces on the wide valley floor above the present stream courses. Deposits of this kind are shallow compared with those of the Copper River lowland and in most places are

[64] Mendenhall, W. C., Geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, p. 67, 1905.

ROCK GLACIER ON McCARTHY CREEK THREE-QUARTERS OF A MILE ABOVE THE MOUTH OF THE EAST FORK.

Showing the source of supply in the talus cones above, also the surface markings—longitudinal in the upper portion, concentric below.

little more than a veneer on the country rock. The uneven surface is poorly drained, so that small ponds and lakes are numerous.

Terminal and lateral moraines, not associated with the existing glaciers, are not prominent in most of the area considered, although they are well developed in a few places. Terminal moraines are being formed at present and undoubtedly were formed in the past, yet few of them escape destruction by the streams of water that arise from the melting ice. Nearly all are attacked, and the material in them is gradually carried into the stream wash. Lateral moraines are common features of nearly all the glaciers of the region, but like the terminal moraines they are rarely preserved after the ice disappears.

Sand and gravel deposited in lakes and ponds differ from the unconsolidated deposits already described, particularly in having undergone sorting by water and in being more worn, so that the fragments tend to become rounded rather than angular. Also beds of water-laid sand and gravel are more homogeneous than beds of till.

The water-laid sand, gravel, and silt may be described in general terms as present stream and lake deposits and terrace or bench deposits. The latter include the low gravel benches, usually covered with vegetation, that lie a few feet above the stream flood plain or the lake surface, and bench deposits at still higher levels, conspicuous among which are the thick gravel deposits that were formed at the mouths of valleys now or formerly dammed by glacial ice.

In a region like the Chitina Valley and the surrounding area it is probable that much the greater part of the deposits that are described as stream and lake deposits originated as glacial deposits—that is, they were delivered to the streams by the ice or they are reworked glacial deposits. Probably only a minor part of them are wholly the product of present stream erosion. Most of the larger streams of the region head in glaciers that deliver directly to them the burden of fragmental material carried by the ice. This material is carried by the streams as long as the currents and volume of water are great enough to sustain it. When it is dropped it is added to the flood-plain gravel deposits, where it is mingled with other gravel contributed by nonglacial tributary streams. As the load is deposited the channels become clogged and the carrying streams are diverted to other courses, where deposition is continued. The process is not wholly one of building up, however, for in places the water attacks deposits previously formed, either flood-plain or bench gravel, and adds them to its load. The result of all this is a slow downstream migration of whatever loose material comes under the influence of the water. Although a similar process goes on in nearly all the streams, it is most noticeable in the valleys of the heavily loaded glacial streams. Temporary interruptions of the migration are shown by the low benches or terraces bordering many flood plains, for such benches are merely the remains of former flood plains into which the streams have cut their channels.

Conspicuous high benches of gravel are present along the lower courses and near the mouths of many streams where their valleys unite with the larger trunk valleys. Most of these deposits also owe their existence in part to the former presence of glaciers. They consist of material that accumulated behind the barrier of ice which occupied the main valley and closed the mouths of those tributaries that were free of ice. Later, when the barrier disappeared, the side streams cut their channels through the gravel and left the high benches standing above them. The reconcentration of gold that took place when the streams were cutting their channels through the deep deposits of auriferous gravel formed in this way yielded the rich gold placers of Dan and Chititu Creeks.

Bench gravel of somewhat similar origin was deposited on mountain sides, above the bottoms of the valleys, by streams that flowed along the margin of the glaciers. Such gravel deposits now appear to be much out of place. They could have been formed only where the water was unable to find a lower course beneath the ice.

Deposits of well-washed sand and gravel, of a kind that is most desired for building material, do not appear to be present or, at least, to be of any considerable extent in this region. Such deposits are commonly the product of long-continued erosion of rocks capable of yielding the appropriate minerals, particularly quartz, and of repeated sorting or sorting by large bodies of water. If deposits of this kind, comparable with the Nenana gravel [65] on the north side of the Alaska Range, were formed here in preglacial time, they were removed by the ice, and no similar deposits have been formed since the ice disappeared. The clays and fine sands at the base of the Tertiary lavas are of more uniform grain and composition and of more homogeneous character than any of the known younger deposits.

Deposits of volcanic ash are locally conspicuous but make up only a small part of the unconsolidated fragmental material. They are present chiefly in the White River area, where they form a thin layer in the general soil cover, are interbedded with peat overlying the gravel terraces along the river, and have accumulated in bodies like snowdrifts on the mountain slopes south of the river near the international boundary. Near the mouth of the North Fork of the White River the ash bed is from 2 to 2½ feet thick and is overlain by about 7 feet of peat (pl. 11, *A*), a circumstance from which Capps [66] estimated the time of the eruption as probably about 1,400 years ago.

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[65] Capps, S. R., The eastern portion of Mount McKinley National Park, Alaska: U. S. Geol. Survey Bull. 836, pp. 279–294, 1933.

[66] Capps, S. R., An ancient eruption in the upper Yukon Basin; U. S. Geol. Survey Prof. Paper 95, p. 63, 1915; The Chisana-White River district, Alaska; U. S. Geol. Survey Bull. 630, p. 83, 1916.

Most of the unconsolidated deposits are covered with vegetation. Where they are subject to the action of water, as on the flood plains of streams or at the margins of lakes, or where they are exposed by stream cutting in the banks of rivers and creeks, they may offer favorable opportunities for examination. In general, however, they are concealed over a large part of the area which they occupy, so that it is difficult either to determine their boundaries or to discover what beds and kinds of material are present. As a consequence, the representation of their boundaries on the geologic map is probably less accurate than that of any other formation.

INTRUSIVE ROCKS

Igneous rocks are rocks that have solidified from a molten state, either within the crust of the earth or on its surface. Molten rock that welled out over the surface as lava flows and the fragmental volcanic material that accompanied it in places formed bedded deposits that are structurally much like sediments laid down in water. In the Chitina area such rocks include principally the lava flows of the Strelna formation, the Nikolai greenstone, and the Tertiary and younger lavas and have been described in preceding pages. Melted rock that was forced under great pressure between or through the beds of sedimentary formations or into already existing igneous rocks and then cooled produced the dikes, sills, and other intrusive bodies that are to be considered in this section.

Much remains to be learned about the record of igneous activity in Alaska, yet some outstanding facts that may have application to the Chitina Valley are already recognized. The Mississippian epoch of the Carboniferous period is marked by the greatest outpouring of basic lavas on the land surface known to have taken place at any time in the geologic history of Alaska. Furthermore, this outpouring of surface lavas accompanied and was a consequence of intrusion of basic igneous rocks into the then existing crust. A second great outpouring of lavas took place in Permian time and also was doubtless accompanied by intrusion. These two events of the Carboniferous period are well established but should not be thought of as taking place suddenly, for they must have continued throughout intervals of time that were vast even when measured by a geologic time scale.

In Jurassic or Cretaceous time, possibly in both, occurred a period of mountain building that affected the whole Pacific coast line of North America. Vast bodies of granitic rock, including diorite, granodiorite, monzonite, and other types, were intruded into the older rocks and now, through erosion, are revealed in the great batholiths of the coast ranges. Intrusives belonging to this period occur in many places in Alaska, and some of them, such as those of the Talkeetna Mountains, bordering the Copper River Basin on the west, have been looked on as offering exceptionally good criteria for determining the time of their intrusion. The Talkeetna Mountains include a great central core of igneous rock, made up largely of quartz diorite and granite that apparently were intruded in late Middle Jurassic [67] or early Upper Jurassic time. This age assignment, however, is not established beyond question. Evidence has been found to indicate that some of the intrusive rocks of the Chitina Valley are approximately of this age. On the other hand, it is certain that a large part of the granitic intrusive rocks are younger. Many of them were not formed till after the Lower Cretaceous sediments were laid down, and some are of post-Eocene age.

Intrusive igneous rocks are distributed throughout the area under consideration, yet they make up only a small proportion of the rocks exposed. They do not belong to any one period of intrusion but are the product of repeated intrusion and of igneous activity that was recurrent and long continued. For the purpose of this account they may be divided into those that were intruded only into host rocks that are older than the Chitistone limestone and those that occur in the Chitistone limestone and younger rocks as well as in the older rocks. Each of the divisions includes intrusives of different kinds and of different ages. The occurrence of the intrusive rocks is of economic importance because some of them without doubt have a genetic relation to the occurrence of ore deposits. The distribution of the intrusives and their relation to the host rocks will be given with only a brief account of their petrographic character and mineral composition.

OLDER INTRUSIVES

The distinction between intrusives that cut only the Permian and older rocks and those that cut the Mesozoic and later rocks also is not everywhere easily made. In general the older intrusives include more basic rocks and are likely to show greater alteration, expressed by chemical change and gneissic or schistose structure. The widely distributed, more conspicuous light-colored dikes and sills of the region belong largely to the younger group of intrusives.

In the western part of the Chitina Valley the older intrusives are associated chiefly with the Strelna formation but are not restricted to it, for in a few places they cut the Nikolai greenstone. The common varieties are basic diorite and gabbro. They are altered dark-gray or green rocks and in places show a reddish-brown surface due to weathering. They occur at various places in the Strelna formation but were not distinguished on the map from the other rocks making up the formation. The largest exposure of the gabbro is in Iron Mountain, west of Strelna Creek. These rocks invade the lower part of the

[67] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance of the Matanuska and Talkeetna Mountains, Alaska: U. S. Geol. Survey Bull. 327, p. 20, 1927.

Nikolai greenstone on Clear and Nugget Creeks but do not cut the upper part of the greenstone nor the Triassic sediments.

The intrusives in the rocks south of the Chitina River that are correlated with the Strelna formation include dikes, sills, and irregular bodies of granodiorite and quartz diorite. Diabase occurs at a few localities, and one dike of peridotite is known. Several times of intrusion can be made out, and different degrees of alteration are shown. Between Canyon Creek and the Chitina River is a complex of intrusive bodies. Diabase is the prevailing type and in part is altered to greenstone. Diorite is also present and like the diabase is much altered. The dioritic rocks on the Tebay River show well the occurrence of successive intrusions. The earliest intrusives penetrated the sedimentary rocks intimately and altered their character almost beyond recognition. The latest intrusives are fresh and probably belong to the younger group. A peridotite dike consisting of pyroxene and much-altered olivine with metallic sulphides cuts the schist and limestone near the head of Canyon Creek. This peridotite is of interest because it carries nickel.

The rocks extending westward from the Copper River to the Klutina River that are correlated with the Mississippian rocks of the Chitina Valley are cut by both the older and younger intrusives. The older intrusives are more abundant and include more basic rocks, but the distinction between older and younger is locally in doubt. Numerous large exposures of light-colored granitic rocks are seen in the mountains between the Copper River and Kimball Pass and probably are largely of the older group. Between Bernard Creek and the Little Tonsina River is a complex mass of granular igneous rock that consists in large part of gabbro and dunite, a rock consisting originally of olivine but now altered partly to serpentine. Quartz diorite is also present but belongs, in part at least, to the post-Cretaceous intrusives. An area of granular igneous rock that includes the head of Squirrel Creek, a western tributary of the Tonsina River, is made up of quartz diorite, the relation of which to the surrounding rock is not certainly known. The diorite is considerably more altered than the numerous dikes and sills of the slate and graywacke area to the south and in consequence is regarded as belonging to the older group of intrusives.

The intrusives of the White River district belong to two distinct groups [68] that appear to correspond in some degree to the groups of the Chitina Valley. The older group includes intrusives that range from granodiorite through diorite and diorite porphyry to gabbro and gabbro porphyry. They occur in small exposures in the mountains south of the White River and in other localities but form no

[68] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, p. 83, 1916.

large areas within the part of the district under consideration. They cut Permian rocks but are not known to cut the Mesozoic rocks.

YOUNGER INTRUSIVES

The younger group of intrusives includes all those intrusives that are younger than the Nikolai greenstone and range in age from earlier than late Upper Jurassic to post-Eocene. They are dominantly light-colored and porphyritic and occur as dikes and sills throughout the region, although they occupy extensive areas in some parts of it. The intrusives of this younger group, like those of the older, are not restricted to one period of igneous activity. So far as is known, the earliest of these intrusions took place before the Upper Jurassic and Lower Cretaceous sediments of the Kotsina-Kuskulana district were deposited. In the area southeast of the Kuskulana River, including the valleys of Slatka, Trail, and MacDougall Creeks, are granular intrusives that belong to this period. South of Trail Creek the rocks are light-gray granular intrusives of medium grain that were identified as granodiorite and are of post-Triassic age. North of Trail Creek the rocks are fine-grained light-colored intrusives, related to the granodiorite, that are designated quartz latite. Upper Jurassic and Lower Cretaceous sediments were deposited on the granodiorite and quartz latite, thus furnishing a means of determining the upper age limit of the intrusives. Granodiorite occurs in isolated areas on Porcupine Creek and in Granite Peak, north of the Kotsina River, and probably is of the same age as the granodiorite near Trail Creek. No other intrusives that can be certainly correlated with those of Trail Creek have been identified.

The Lower Cretaceous rocks of the Nizina district were invaded by masses of light-colored quartz diorite porphyry, occurring as dikes, sills, and laccoliths, as is well shown in Porphyry Mountain and Sourdough Peak. The intrusives are white to creamy white and various shades of gray and brown, and the contrast of color between them and the dark host rocks makes them conspicuous. This contrast is further emphasized by the superior resistance of the dikes to weathering. They show considerable difference in texture, ranging from fine-grained, almost aphanitic phases to distinctly granular phases that contain phenocrysts of feldspar and quartz. In most places their intrusion had little effect on the country rock, yet locally extensive silicification of limestone and shale and recrystallization of limestone were produced. It seems probable that the intrusives of this period are the most widely distributed and numerous of all the intrusives of the area, although their age limits are imperfectly known.

The intrusive rocks of the upper Chitina River that are correlated with those just described include granite, quartz diorite, syenite, and diorite and form the largest area of granitic rocks within the Chitina Valley. The occurrence of syenite is of interest, as this rock is not common in Alaska. These rocks have their greatest development in the area south of the upper Chitina River, where they are known to occupy many hundreds of square miles, although their full extent has not been determined. Conclusive evidence for the age of the large batholiths was not found in the upper Chitina Valley, but smaller bodies of intrusive rock that are regarded as apophyses of the large bodies cut the Cretaceous sediments.

Light-colored dikes and sills of granitic rock cut the slate and graywacke of the Chugach Mountains, south of the Chitina River and westward from the Copper River to the Klutina River, wherever they have been examined. Most of them are rocks intermediate between the diorites and granites, although at a few places diabase, a more basic rock that may belong in the group of younger intrusives, has been found within the area of the Paleozoic rocks. Many of the dikes are mineralized, and it is believed that they have a genetic relation to the auriferous veins of the region.

In the White River district the younger intrusives appear to be somewhat more basic than the light-colored dikes that cut the Cretaceous shales of the Nizina district. They range from oligoclase andesites and oligoclase dacites to gabbro porphyry and basalt.[69] They occur abundantly on Rocker Creek near the international boundary and in many other places, where they form small stocks, dikes, and sills. Intrusives of this group cut Upper Jurassic and Lower Cretaceous rocks, also the Tertiary sedimentary rocks on Rocker Creek and the post-Eocene lava flows. Probably some of the vents represented by the dikes and sills supplied the material for the younger lava flows north of the White River. This is plainly true of the dikes that cut the lava flows on Skolai Creek. It should not be assumed, however, that the dikes are all of such recent origin, for they are not restricted to a single period. Some of the intrusive rocks are so young geologically that they cut the unconsolidated Pleistocene gravel of the lower Chitina Valley.

GEOLOGIC HISTORY

The events that make up the geologic history of the Chitina Valley are recorded only imperfectly by the rocks that are seen there now. Moreover, the record of the rocks has not been thoroughly examined and is difficult to interpret. It will therefore be necessary to piece out the story in some important parts with material that has been gathered from other places, if a consistent account is to be given. Any disproportionate emphasis on the more recent events must be understood as indicating more knowledge of the facts rather than their greater relative importance.

[69] Capps, S. R., The Chisana-White district, Alaska: U. S. Geol. Survey Bull. 630, p. 83, 1916.

The earliest known events in this history were connected with the deposition of marine sediments in early Carboniferous (Mississippian) time, and their record is to be found in the rocks of the Strelna formation. Inasmuch as deposits of Mississippian age are widely distributed in Alaska it is a fair presumption that a large part of the Territory must have been below the sea at that time. In the Chitina Valley, as well as in some other parts of Alaska, the tuffaceous beds and basaltic flows associated with the Mississippian marine sedimentary rocks afford evidence of contemporaneous volcanic activity. The absence throughout Alaska, except in a relatively small area in southeastern Alaska, of sedimentary beds that can be definitely assigned to the Pennsylvanian epoch of the Carboniferous, suggests that during that time Alaska was a land mass. The later part of the Carboniferous, or Permian epoch, however, was a time of pronounced volcanic activity and of resubmergence. In the Chitina and White River Valleys it began with outpourings of lava and ejection of fragmental material. These events were followed by the deposition of highly fossiliferous marine sediments, intermingled with volcanic material, and then by another time of dominating volcanic activity during which lava flows without included sediments were piled up to a thickness of many thousands of feet, forming the Nikolai greenstone. In a few places the lavas show pillow structure, which may indicate extrusion under water, but with the exception of the tuffaceous beds and thin flows of basalt interbedded with the sedimentary middle members of the series there is little known evidence to indicate under what conditions the outpourings took place.

The absence in the Chitina Valley of sedimentary deposits belonging to the Lower and Middle Triassic and the lower part of the Upper Triassic probably indicates elevation of the land during that time, although possibly the accumulation of the thick mass of lava, forming the Nikolai greenstone, that began in Permian time may have continued into the Triassic. Elevation of the land above the sea implies that the processes of erosion were at work, and it therefore seems most probable that plain evidence of so long an interval of erosion as would be represented by the time interval of the Lower and Middle Triassic epochs should be found. Yet structural unconformity between the Nikolai greenstone and Chitistone limestone that would furnish such evidence has not been recognized, although the thin bed of shale between the two formations possibly represents this time of exposure to weathering. The absence of the Nikolai greenstone between the Permian limestone and Triassic shale north of Skolai Creek may also indicate such a period of erosion, although, on the other hand, the lava flows may never have been formed there.

The end of the Paleozoic era was probably a time of widespread emergence, which was continued throughout Alaska until the beginning of the Upper Triassic epoch.[70] Lower Triassic rocks have not been recognized in Alaska, and Middle Triassic rocks are reported at only one locality, in northern Seward Peninsula. From these facts it seems probable that the outpouring of the Nikolai lavas was followed by a period of erosion, brought about by elevation of the land above the sea, which continued into Upper Triassic time, as suggested above.

The Upper Triassic was a time of submergence, when seas invaded the sinking land and laid down thick deposits of limestone and associated argillaceous beds. It seems probable that the Chitistone limestone, among the earliest of the Upper Triassic deposits of Alaska and of relatively small extent, was formed in a small arm of the sea. As subsidence continued and more land was submerged the area of Upper Triassic sediments was extended, with the result that the younger beds overlap the older and are more widely distributed. Martin [71] says of the distribution and extent of these sediments:

Triassic rocks are widely distributed in Alaska, being now known at many localities in nearly all parts of the three major mountain regions, though absolutely restricted to those regions. The most striking fact regarding the distribution of Triassic rocks in Alaska is this remarkable agreement between the areas of present Triassic outcrops and the areas of the major mountain regions.

The deposition of limestone in the area that now includes the Chitina Valley was succeeded by the deposition of mud that eventually became shale, and the warm-water animals of the limestone-forming sea were replaced by colder-water forms, the remains of which are found at the top of the limestone and in the shale, indicating a change in both the source of sediments and the temperature of the sea.

Martin [72] believes that this change was brought about through an elevation of the land, a period of erosion, and resubmergence, after which the currents of warm water were replaced by colder waters and the conditions of marine life were altered. He finds evidence for this belief in the absence throughout Alaska of a fauna that should be found between the faunas of the limestone and the shale and, in the western part of the Chitina Valley, in structural relations involving the Triassic sedimentary rocks that may be explained in this manner. If this period of erosion within the Upper Triassic epoch affected the Chitina area, it seems to have left no structural evidence of itself in the fine sections of the Triassic in the Nizina district, and the proof of its occurrence must be sought in the evidence supplied by the faunas of the area and by the conditions in other parts of Alaska.

Deposition of the McCarthy shale in Upper Triassic time was followed by a general emergence of the land and a period of erosion that continued till the later part of Lower Jurassic time. Late in the

[70] Martin, G. C., op. cit. (Bull. 776), p. 129.
[71] Idem, p. 3.
[72] Idem, p. 124.

Lower Jurassic there was a moderate submergence, accompanied by intense volcanic activity that affected the southern coast of Alaska but is not known to have reached the Chitina area. Later the submergence became more widespread, and the Middle Jurassic tuffaceous shale (Tuxedni fauna) was laid down near the mouth of the Chitina River. At a still later time Upper Jurassic black shale (Naknek fauna) and possibly other sediments were deposited. In the Cook Inlet region the Middle and Upper Jurassic rocks, including the Tuxedni, Chinitna, and Naknek formations, appear to be the product of uninterrupted sedimentation, but in the Chitina region no rocks corresponding to the Chinitna shale are known. Between the times when the McCarthy shale (Upper Triassic) and the first of the Lower Cretaceous conglomerate and sandstone beds were formed in the Chitina region, mountain-building forces had strongly folded all the existing rocks, including the McCarthy shale, and long-continued erosion had planed off the upturned beds and removed an enormous quantity of material to the sea. Whether these events occurred prior to the deposition of the Middle Jurassic tuffaceous shale is not known from evidence in the Chitina Valley, but in the Cook Inlet region the Tuxedni (Middle Jurassic) sandstone rests unconformably on the older rocks. It thus appears likely that mountain building may have taken place in the Chitina region also. The absence in the Chitina Valley of rocks corresponding in age to the Chinitna shale suggests that either the sea had receded from this area in Chinitna time or that the Chinitna rocks have since been removed by erosion. So little is known about the Upper Jurassic shale of McCarthy Creek that the events immediately before and after its formation that have to do with its relation to the McCarthy shale and the Cretaceous beds cannot be stated. Possibly that shale and the Middle Jurassic shale at the mouth of the Chitina River are both remnants of beds that once extended over a large part of the region but have been almost completely removed by erosion. In the Cook Inlet region the time when the Naknek beds were formed was a time of vigorous mountain building.

Whatever may have been the time of folding of the Upper Triassic and older rocks, the erosion that beveled the tops of their upturned beds was followed eventually by subsidence and the deposition of Lower Cretaceous marine sediments. The first beds laid down were conglomerate and sandstone, but the overlying beds include much shale in some places and sandstone and sandy shale in others. These deposits accumulated to the thickness of many thousands of feet in the Nizina district and in the Nutzotin Mountains, northeast of the Wrangell Mountains, beyond the limits of the areas shown on the geologic map, indicating long-continued, relatively stable conditions and shallow waters. They were probably derived from a nearby land mass where rapid erosion was in progress.

Upper Cretaceous time does not seem to be represented by any rocks on the north side of the Chitina Valley. The Chugach Mountains, to the south, are believed to be made up in part of marine Cretaceous (Upper? Cretaceous) shale and graywacke, although it is by no means improbable that they also include older Mesozoic rocks in addition to known Paleozoic rocks. The stratigraphic relation of these Upper (?) Cretaceous deposits to the Lower Cretaceous rocks north of the Chitina River is unknown. The two are nowhere in contact but are everywhere separated by much older rocks. According to Martin [73] the sea had receded from all of Alaska at the beginning of Upper Cretaceous time. Later, during the submergence that took place in Upper Cretaceous time, extensive marine deposits were laid down in the Yukon and Kuskokwim Basins, the Arctic coastal plain, and other places. Possibly the slates and graywackes of the Chugach Mountains were formed then, although evidence for this is still too meager for a positive statement. The end of the Cretaceous period was coincident with a cessation of sedimentation and the withdrawal of the sea from Alaska. Since then no extensive submergence has occurred, for throughout interior Alaska no younger marine sedimentary rocks are known.

The end of the Mesozoic era and the beginning of the Tertiary period was marked by widespread diastrophism. Emergence of the land was accompanied by mountain building and the intrusion of vast quantities of igneous rock in the present mountain areas. It seems probable that the light-colored granitic dikes and sills that invaded all the Mesozoic rocks of the Chitina Valley and the Chugach Mountains are part of this intrusion. In places whose location is vaguely known or surmised highland areas were developed. Especially the uplift of the Alaska and Chugach Ranges began. Erosion became vigorous and locally fresh-water deposits were formed. Doubtless the formation of the Alaska and Chugach Ranges was a long process, involving folding, faulting, intrusion, and the removal of an immense quantity of material. It is believed that before the Tertiary coal-bearing beds were deposited erosion of the highland areas proceeded to such a stage that the relief of Alaska was much less than at present and the streams draining the upland areas carried mainly fine material. The products of this erosion are in part represented by the sand, gravel, and clay, with their thick interstratified coal beds, that accumulated on the land surface in lakes, streams, and elsewhere.

Probably the formation of the fresh-water, leaf- and coal-bearing deposits of the Wrangell Mountain area and the beginning of vol-

[73] Martin, G. C., op. cit. (Bull. 776), p. 477.

canism are to be correlated with similar events in the formation of the Alaska Range and with the laying down of the coal beds there and the injection of igneous rocks that cut the coal-bearing formations.

In the Wrangell Mountain area the accumulating fresh-water deposits were overwhelmed by lava flows and tuffaceous deposits that buried them beneath thousands of feet of volcanic material and are still in process of formation. The piling up of the lavas of the Wrangell Mountains, however, was only a local incident in the growth of the great ranges, although it gave rise to a major feature of the topography. These Tertiary lavas of the Wrangell area have been only slightly affected by deforming forces, although the Tertiary fresh-water deposits in other parts of Alaska are moderately folded, as in the Alaska Range, where further evidence of the long continuance of the mountain-building processes is furnished by the tilted and folded coal measures.

During the long period of Tertiary time the great geographic features of Alaska, the outline of its coast, its major valleys, and its mountain ranges were blocked out and brought to the form they had when the invasion by ice began. The Tertiary sedimentary and volcanic deposits were subjected to extended erosion. On the margins of the Wrangell Mountains the streams cut through the lava flows and entrenched themselves deeply into the older rocks. In the Chugach Mountains the principal valleys were carved out. Great quantities of rock waste were carried to the sea. The agencies of weathering were effective for a long time, and oxidation and other chemical changes penetrated far deeper into the rocks than is possible under present climatic conditions.

This regime was finally ended by climatic or other changes that brought about a burial of much but not all of Alaska under glacial ice. The history of glaciation in Alaska has been deciphered only in part. The effects of the most recent glaciation are so widespread and pronounced that they obscure or conceal altogether the effects of the earlier ice invasions. How many stages of glaciation there may have been is not known, although the White River district furnishes evidence of a period which was earlier than the last great (Wisconsin) stage and which may correspond to one of the earlier stages of Pleistocene glaciation in the Northern States and Canada. Capps [74] finds this evidence in folded tillite deposits that include sheets of lava. Doubtless the ice advanced gradually and from many centers of accumulation. Probably it formed first in the high mountains, as it does now, and slowly took possession of greater and greater areas, not by a steady, uninterrupted advance but with alternating stages of progression and recession. When the ice reached its state of greatest accumulation during the last period of glaciation it extended far be-

[74] Capps, S. R., op. cit. (Bull. 630), pp. 63-67.

yond the limits of the mountain valleys. It had advanced into the main valleys and, after filling them, moved out from the mountain areas into the intermountain basins. The broad lowland of the Copper River Basin, bounded by the Alaska and Chugach Ranges and the Wrangell and Talkeetna Mountains, was buried under thousands of feet of ice and formed part of a great field from which ice overflowed its barriers wherever the opportunity was presented. Just how many places of escape existed and where they were is not known, but it is certain that ice made its way from this intermountain basin northward into the Tanana River Valley and southward to the Pacific Ocean. Some measure of its thickness in the basin is seen from the fact that the mountains south of the Chitina River and east of Taral were overridden by ice moving southward. Consequently the depth must have been more than 5,000 feet nearby in the Chitina Valley. Stuck Mountain, north of Tonsina, was completely buried, and its top was strongly glaciated, indicating a minimum thickness of 2,000 feet, which is much less than the maximum.

The effects of this glaciation are many but are perhaps most noticeable in the modification of the valleys. At the time when the ice reached its maximum probably only the tops of the highest mountains were above its surface. During its advance and retreat it acted as an efficient tool in cutting away the sides and bottoms of the valleys through which it moved. Possibly this action was at its maximum when the ice was deepest, for the weight on the cutting tools was then more. On the other hand, the movement of ice in many valleys may have been retarded or even stopped by the great mass of ice that accumulated in the Copper River Basin as the result of inflow from the surrounding valleys and of direct precipitation.

Erosion of the valley sides and bottoms changed their original V-shaped cross-section profile to the U-shape that is the characteristic feature of most of them now. In doing this it cut away the points of the projecting spurs and straightened the sides of the valleys. The effects on the valley floors are usually less evident, for the deposits of stream gravel and till conceal them. In places, however, the overdeepening of the floors near the heads of valleys retarded the drainage and produced lakes, most of which in this region have since been drained by the cutting of rock-walled channels or canyons through the barriers. In many places, especially along the Copper River below Wood Canyon, well-marked benches, cut one above another in the rock of the valley walls, show that the ice stream was not constant, yet stood at different levels for periods that were long enough for a considerable amount of erosion to take place. More conspicuous than these, topographically, are the steep-walled cirques that terminate nearly all the valleys of the high mountains and were formed by rapid headward erosion of the valleys, under the influence of glacial ice. This process is going on at present where ice accumulates in the high mountains, although many cirques are now free of ice.

A second effect of glacial erosion, combined in places with the effects of filling by glacial debris, was the modification of the older drainage lines. Some of these changes were only temporary, but others were permanent. Examples of this modification are numerous and include abandoned channels that were cut across spurs or along the edge of the ice, the damming of one stream by morainal material and the capture of its upper part by a neighboring stream, and the deepening of a low saddle so that a shortened course was provided for a stream when the ice disappeared.

Although many drainage changes caused by glaciation are known, only a few of the more outstanding changes can be noticed here. The present course of the Copper River through Wood Canyon appears to be one of the notable results of the occupancy of the Copper River Basin by ice. It is believed that in preglacial time the Chitina and other rivers draining into the Copper River Basin found an outlet to the sea by some other route than the present one, either through Cook Inlet or less probably by way of the Yukon Valley. The diversion of the interior drainage across the broad divide separating the Copper River Basin from a stream that flowed southward to the Pacific Ocean and occupied a valley that later became the lower valley of the Copper River was brought about by the raising of the drainage level or the impounding of water by the ice and was maintained long enough for the present channel through Wood Canyon to be cut in the rock barrier. Glacial filling at some points and warping of the land surface probably assisted in producing this result, and with the withdrawal of the ice the present course of the Copper River to the Pacific Ocean was established.

The depression that is followed by the Copper River & Northwestern Railway for about a mile southward from the town of Chitina and by the highway for several miles north of it is part of the channel of a stream that flowed along the margin of the ice when the great glacier that occupied the Chitina Valley still existed. The erosion of such a channel in hard rock must mean that the stream was held on the valley side, high above the present level of the Copper River, for a long time. Similar channels cut in the rock on mountain slopes but on a much smaller scale are not uncommon, and terraces of similar origin are numerous.

A conspicuous example of stream diversion, due chiefly to glacial agencies, is furnished by the upper part of the Manker Creek Valley, in the Tonsina district. The natural course of Manker Creek is northward through the valley to the Klutina River, but its upper waters have been diverted so that now the upper valley is drained eastward through a deep, strongly glaciated cross valley to Greyling Creek and

Tonsina Lake. This diversion was brought about by a combination of factors, the chief of which are that glacial erosion lowered the floor of the cross valley practically to the level of the Manker Creek Valley and that the filling of gravel in Manker Creek raised the bed of that stream. The adjustment of levels is now so close that in time of high water some of the water of the upper Manker Creek Valley seeks its natural outlet through the lower valley to the Klutina River, although most of it flows into Greyling Creek.

Less spectacular than the changes resulting directly from glacial erosion are the changes brought about through glacial filling. The enormous quantity of debris that was produced by the action of the ice and the streams associated with it and transported by them for varying distances from its source was in part deposited on the land and in part carried to the sea. Most but not all of the land deposits underwent some sorting by water. They appear to make up the larger part of the great but unknown thickness of the unconsolidated deposits of the Copper River Basin and of the stream and terrace deposits. The unsorted or less well-sorted deposits are the terminal and lateral moraines and the ground moraine that is so widely distributed in the Chitina Valley. These deposits were dropped in place by the ice as it melted and account for many of the ponds and lakes and interesting topographic features, for recent weathering has not yet destroyed their irregular surfaces, and drainage lines have not been established.

Weathering, erosion, the transportation of the resulting waste by ice and water, the re-sorting and re-deposition of older unconsolidated deposits, chemical alteration, and many other changes are the latest events of a stage of glaciation that is still in progress and forms part of the present chapter of the geologic history of this region.

ECONOMIC GEOLOGY

MINERAL DEPOSITS

The purpose of this section is to present an account of the way in which valuable minerals occur in the Chitina Valley and neighboring areas, rather than to give detailed descriptions of individual mines and prospects except where such descriptions may serve to illustrate principles of ore occurrence. Accounts dealing with the productive mines and with most of the known prospects have been published from time to time in reports that are listed on pages 6–7. A repetition of those accounts here would extend this section more than is desirable, and anyone interested in getting information about particular properties is therefore requested to refer to the earlier reports. Unfortunately there has been no opportunity to visit some of the promising prospects that have been developed in recent years, and they have not been described in the publications of the United States Geological Survey.

It is believed that a description of the types of deposits and their occurrence may be of assistance both to those searching for new prospects and to those who are developing prospects already discovered. A paper of this nature, prepared by the writer,[75] has already been published. This section of the present report is a revision of the earlier paper and includes such changes and additions as are made necessary by more recent information.

Copper, gold, and silver are the only minerals that have been mined commercially within the area under consideration. They are named in the order of the money value of the metal already mined—an order that is not likely to be changed for many years, because the value of the copper already produced is far in excess of the value of the gold and silver combined. Both copper and gold are mined for themselves alone, but silver is produced almost wholly as a byproduct of the mining of copper, although a small quantity is obtained from the gold placers, and a still smaller quantity was recovered from the ores of a single silver-gold vein that is no longer being exploited. Gold has so far been recovered chiefly from placer gravel, where it is commonly associated with considerable native copper and a little native silver. A relatively small amount has been obtained from the silver-gold vein mentioned above and from a second gold lode on which active mining development is now (1935) in progress, although capacity production has not been reached.

Other minerals, such as lead and molybdenum, are known to be present in the region, but they have had no commercial importance up to this time. They are associated with gold in auriferous veins and locally with intrusive rocks. Tin has been reported, but its occurrence has not been substantiated, to the writer's knowledge.

As the general geology of the region has been described in preceding pages, no further account of the structure and stratigraphy will be required for an understanding of the relations of the ore deposits to the rocks in which they are found.

AGE OF MINERALIZATION

A study of the ore deposits in connection with the general geology of the area leads to the conclusion that they are to be referred to more than one period of formation. The age of different ore bodies cannot be stated definitely, but certain limitations of age can be determined. Gold, silver, or copper is found in the Strelna formation, in the Nikolai greenstone, and in the shale overlying the McCarthy shale—that is, in rocks that range in age from Mississippian (lower Carboniferous) to Lower Cretaceous. The age of the enclosing country rocks, how-

[75] Moffit, F. H., The metalliferous deposits of Chitina Valley: U. S. Geol. Survey Bull. 755, pp. 57-72, 1922.

ever, tells little about the age of the mineral deposits except that the country rocks are the older. The mineral deposits may have been formed at some one particular period after the rocks were formed, or they may have been formed at different times. Moreover, the formation of the ore bodies was not a sudden process, completed at a stroke, but took place slowly as the mineral-bearing waters made their way through the devious openings in the rocks and gradually deposited their metal content.

In the Kuskulana Valley there are bodies of igneous rock that were intruded into Triassic and older rocks but not into the sedimentary rocks overlying the Triassic. These intrusive bodies consist of granodiorite or closely related rocks. In places they are themselves mineralized with copper sulphides, and elsewhere they have produced contact-metamorphic deposits of copper and other metallic minerals at the borders of the rocks which they invaded. Several large veins of magnetite were formed in this manner on MacDougall Creek. Water-worn pebbles of this magnetite have been found at the base of the Upper Jurassic (?) conglomerate that lies unconformably above the older sedimentary rocks and the igneous intrusive at this place and furnish evidence that the mineralization here and probably nearby on Berg Creek was later than Upper Triassic and earlier than Upper Jurassic.

Evidence for a definite determination of the age of the copper mineralization in the Nikolai greenstone and the Chitistone limestone is lacking. Obviously it was later than the deposition of the Chitistone limestone (Upper Triassic) and may belong to the period of mineralization that occurred before the Upper Jurassic sediments were deposited, as mentioned in the preceding paragraph, or to a still later period of mineralization, such as that which brought about the formation of auriferous deposits in the Lower Cretaceous shales and possibly in older rocks.

The gold deposits may also have originated in more than one period of mineralization, for gold-bearing quartz veins are known in the Strelna formation (Mississippian). These deposits, however, may be much younger than the enclosing rock and belong to the period of mineralization described in the next paragraph.

In the Nizina district the Lower Cretaceous shales are cut by many conspicuous dikes and sills of quartz diorite porphyry, and these dikes and sills are associated with veins of quartz carrying pyrite and free gold. Molybdenite is present, and probably stibnite. The creek gravel yields also galena, cinnabar, barite, and marcasite (?), but these minerals were not seen in the veins. It is evident from the age of the enclosing rocks that the vein minerals, or at least the veins carrying gold, represent a period of metal deposition distinct from that of MacDougall Creek and Berg Creek, are Lower Cretaceous or later in age, and indicate the occurrence of at least two periods of mineralization.

Silver is associated with both the copper and the gold and is present in veins carrying galena and in one vein consisting principally of tetrahedrite, but no evidence has been obtained to indicate a distinct period of mineralization for this metal.

CHARACTER OF THE DEPOSITS

For convenience in description the ore deposits are considered under the divisions copper, gold, and silver, although two or more of the metals occur together at different localities and therefore the divisions overlap one another in some degree.

COPPER

Copper is found in the Chitina Valley and the upper White River Valley as lodes of native copper and compounds of copper and as native copper in placer gravel. The copper minerals that have been recognized in the lode deposits include antlerite, arsenates of copper, bornite, brochantite (?), chalcanthite, chalcopyrite, chalcocite, covellite, cuprite, enargite, freibergite (?), luzonite, malachite, native copper, tennantite, and tetrahedrite, most of which were identified in ores from Kennecott. These minerals are by no means equally abundant or everywhere present. As measured by past production, chalcocite, covellite, enargite, and the carbonates azurite and malachite should be placed first, and the others, except possibly bornite, should be regarded as of little interest to the miner.

It is unnecessary for the purpose of this paper to enter into a discussion of the source of the copper in the copper deposits further than to state that they were probably deposited from hot ascending solutions. A most excellent statement concerning the source of the copper and the manner of its deposition has been made by Bateman and McLaughlin [76] as a result of a painstaking study of the ore deposits at Kennecott.

The copper lode deposits may be best considered by classifying them in accordance with the kind of rock in which they are found, especially as this is the common practice among those familiar with them. Two classes are thus distinguished—copper deposits in limestone and copper deposits in lava flows, particularly in the Nikolai greenstone. These two classes differ in mineral associations and to a certain degree in form, but they are believed to belong to the same period of mineralization and to be different expressions of a single process of mineral deposition, owing their distinguishing features to the chemical and physical character of the enclosing rock rather than

[76] Bateman, A. M., and McLaughlin, D. H., Geology of the ore deposits of Kennecott: Econ. Geology, vol. 15, no. 1, pp. 1-80, 1920

to differences in chemical composition of the original mineral solutions.

The largest and best-known examples of copper deposits in limestone are those of Kennecott, which will therefore be described briefly as typical of this class of deposits. As given by Bateman,[77] the ore minerals at Kennecott, except those obviously due to oxidation, are chalcocite, covellite, enargite, bornite, chalcopyrite, luzonite, tennantite, pyrite, sphalerite, and galena. No gangue minerals are present. To this list should be added other minerals that are plainly due to oxidation processes. They are malachite, limonite, covellite, antlerite, azurite, arsenates of copper, chalcanthite, cuprite, and possibly brochantite. The minerals in both lists are given in the order of their abundance. It was estimated by Bateman that the sulphide ores make up about 75 percent of the ores mined and that of the sulphides chalcocite constitutes from 92 to 97 percent, covellite from 2 to 5 percent, and other sulphides less than 1 percent. Besides copper the ores of Kennecott carry a considerable quantity of silver, which is recovered in smelting. Very little gold is present.

The ore bodies are in the lower beds of the Chitistone limestone, which here dips 23°–30° NE. and is separated from the underlying greenstone by a bed of red and green shale ranging in thickness from 4 to 7 feet. This shale is inconspicuous but is generally present throughout the area. The ore deposits, viewed in the large, have the form of elongated tabular bodies standing on edge with their long axes approximately parallel to the dip of the limestone-greenstone contact. A cross section on a plane parallel to the strike and perpendicular to the bedding planes of the limestone shows that the ore bodies tend to take the form of narrow wedges with the base down and the thin edge up. The position and form of the principal ore bodies are due to two systems of faults, of which one is vertical and almost parallel to the direction of dip of the limestone, and the other is inclined and parallel to the limestone beds. Other faults are present but need not be considered, as they were not involved in the formation of the ore bodies. The bedding or "flat" faults are at the base of the wedge-shaped ore bodies that occupy the vertical fissures. Bateman [78] says of the ore bodies:

> The average height of the main Bonanza vein from the base to the apex, measured normal to the incline, is about 210 feet in the upper levels and 150 on the lower levels. It has been followed for a distance of about 1,900 feet, measured along its base, and the width varies from 2 to 50 feet. The main Jumbo vein, exclusive of its enlargement at the flat fault, averages about 360 feet in height, from 2 to 60 feet in width, and has been followed down on its base for 1,500 feet.

Since these descriptions were written mining on the Jumbo, Bonanza, and Mother Lode veins has been carried to greater depths, and

[77] Idem, pp. 35, 45.
[78] Idem, p. 30.

a large quantity of ore has been removed, but the more recent work has not indicated any important changes in the character of the ore bodies. The Mother Lode shaft or incline has reached a depth of 2,800 feet below the main level, and the lowest ore bodies show the same degree of oxidation as was found above.

The form of these ore bodies deserves attention, because of its possible significance to the prospector. Bateman has shown by careful surveys in the Bonanza mine that the ore bodies trend parallel to the axis of a gentle transverse downfold in the Chitistone limestone, a fold whose axis pitches to the northeast, in approximately the same direction as the dip of the major folds. He suggests that the wedge-shaped form of the ore bodies results from this transverse folding, by which the beds of greater radius on the outside of the fold were under tension and tended to separate along planes of fracture, whereas the beds of shorter radius nearer the center of the fold were under compression and tended to remain closed. Folding might well result in fracturing and the formation of wedge-shaped openings whose long dimensions were parallel to the axis of the folds and whose widest parts turned downward where the folds are synclinal or upward where they are anticlinal. At the Bonanza mine the transverse folding is synclinal, and the wide parts of the ore bodies that occupy the fractured limestone turn downward, as would be required by such a method of formation. The walls of the fractures may never have been separated more than enough to allow solutions to circulate, for the folding took place slowly, and the separation may have gone on no faster than the ores were deposited. The openings may also have been enlarged by solution as the water circulated through them.

The ore bodies are not so simple in form as the preceding description may suggest. As pointed out by Bateman,[79] the ore deposits at Kennecott form vein deposits, irregular-shaped massive replacement deposits, and stockworks in the limestone. Bateman further divides the replacement deposits into irregular massive deposits, veins, and disseminated deposits, with all gradations between.

These distinctions may be better understood if the folded beds of the Chitistone limestone and the greenstone are pictured as having been subjected to forces that produced faulting with an unknown amount of movement along planes of the limestone practically parallel to the bedding and vertical fractures approximately parallel to the strike of the beds. The joint planes and openings were not everywhere simple, clean-cut, and regular. The rock in places was broken by many irregular fractures. The ore-bearing solutions made their way in the main along vertical fractures just above the bedding-plane faults but entered all other openings to which they had access. The mineral content was deposited partly in open cavities but more often

[79] Bateman, A. M., and McLaughlin, D. H., op. cit., p. 20.

by a replacement of the limestone itself—that is, the limestone with which the solutions came into contact was taken into solution, and copper ores were deposited in place of the dissolved limestone. In some localities the replacement of the limestone was complete, so that great masses of pure copper minerals occupy the space once filled by limestone. In other localities, as in the stockworks and disseminated deposits, the replacement has not proceeded so far, and limestone forms here a small or there a large part of the ore. Irregularities of thickness of the wedge-shaped vein deposits show that the replacement went on more rapidly at some points than at others. The forms of the ore bodies are therefore dependent on the accidents of fracturing in the limestone, the facility with which the circulating waters made their way through the openings, and the degree of completeness of replacement by copper minerals.

A common experience in mining these ores is to find that an ore body terminates abruptly or that a tiny stringer of copper minerals, apparently of no value whatever, if followed a sufficient distance, opens out into a large mass of ore. It is therefore necessary to explore every indication of mineralization, for otherwise valuable ore may be missed.

The original copper deposits have undergone oxidation resulting from the chemical action of surface waters, which circulated through the ore bodies at a time preceding the beginning of glaciation but practically ceased to circulate when glaciation began. No difference in the amount of oxidation has been noticed as the mine workings were carried deeper into the mountains—that is, to the 2,800-foot level. It is estimated that 25 percent of the ore mined is oxidized.

No other ore bodies even remotely comparable in size and richness with those at Kennecott have been found in Alaska, and few have been found elsewhere, if both size and richness are considered, although other mines have produced and will produce more copper. Small ore bodies similar to those at Kennecott, however, have been found in several places in the Chitina Valley, including nearby McCarthy Creek; Glacier Creek, near the Chitistone River; and Boulder Creek, which is a tributary of Dan Creek. A small body of high-grade copper ore was also found in the base of the Chitistone limestone on Copper Creek, which flows into the Kotsina River. Of these occurrences those of McCarthy Creek, known formerly as the Green Butte mine, and Glacier Creek most nearly resemble the deposits at Kennecott. None of them have proved to have economic value, although considerable money has been spent in prospecting them, and the Green Butte mine shipped copper ore at one time. They indicate, nevertheless, the possibilities of finding copper deposits in the Chitistone limestone.

The features suggested by the Kennecott copper deposits that may be of assistance to prospectors and should be kept in mind are (1) that the only productive ore bodies so far found in the district are in the Chitistone limestone; (2) that gentle transverse downfolds or synclines in the Chitistone limestone should receive attention, because the folding may have been accompanied by the production of fractures in the limestone favorable to the circulation of ore-bearing solutions; and (3) that the most insignificant veinlets of copper minerals in the limestone should not be neglected, for experience has shown that they may open out into large bodies of ore. In connection with the second feature just mentioned it should be said that structural features of this kind may be difficult to detect and that the possibility of recognizing them may depend on careful work of a kind that most prospectors are not equipped to do.

It is not intended to imply that commercially valuable copper ores are unlikely to be found in the greenstone or that downfolds in the limestone are the only places favorable for ores. It can readily be seen that openings of the same nature as those described may be formed on the tops of anticlines, and that strong faults of almost any kind may furnish the opportunity for ore-bearing solutions to circulate. It is true, however, that copper deposits have not been found in the overlying Nizina limestone, which underlies the McCarthy shale.

Copper deposits in greenstone are found chiefly in the Nikolai greenstone but occur also at several localities in basaltic flows of the White River Valley and in the Strelna formation, underlying the Nikolai greenstone. The latter deposits have not given much promise and for the most part resemble those in the younger flows. The copper deposits of the Nikolai greenstone are in part contact-metamorphic deposits and in part deposits produced by the action of heated circulating ground waters.

Contact-metamorphic deposits are known at two places in this region, both in the Kuskulana Valley. The greenstone in the ridge between Clear and Porcupine Creeks is intruded by a mass of granodiorite not readily distinguishable from the greenstone itself. Small quantities of sulphide minerals, chiefly pyrite and chalcopyrite, are nearly everywhere present in the intrusive rock, but near the contact with the greenstone the sulphides are much more abundant. The pyrite and chalcopyrite are associated with magnetite, hornblende, and pyroxene. They occur as veins and as disseminated deposits which in places form small high-grade deposits but in general are of low grade and could be mined only by handling a great quantity of country rock.

Contact-metamorphic deposits occur also on MacDougall Creek, where the geologic relations are complicated and somewhat obscure, but a large mass of light-colored quartz latite with associated porphyritic dikes was intruded into rocks that include Triassic limestone and shale and possibly some of the older rocks. Large bodies of magnetite were formed, and in places the country rock, especially the limestone, was silicified and garnetized. Veins containing pyrite and chalcopyrite cut the country rock in this vicinity and apparently represent part of the mineralization brought about by the intrusion. Some of these veins, such as that of the North Midas mine, contain gold and a considerable quantity of silver.

It is characteristic of contact-metamorphic deposits that they are irregular in form and variable in mineral content, so that the mining of such deposits often presents more uncertainties than that of vein deposits. Development work on MacDougall Creek did not meet with encouraging results, and work on Clear Creek has only disclosed a large body of low-grade material that cannot be mined profitably under present conditions.

The more common copper deposits in the greenstone have the form of veins, stockworks, disseminated deposits, and amygdules or fillings of the gas cavities of basaltic flows. The term "stringer lodes" has been applied to them. A brief review of the character and structure of the greenstone will assist in understanding the form of these copper deposits.

The Nikolai greenstone, which contains most of these deposits, includes a great thickness of basaltic lava flows covering a large area in the Chitina Valley and possibly having a much greater extent than is yet known. Individual flows range in thickness from a few feet to several hundred feet, but the regularity of these flows is such as to give the greenstone the appearance of bedded sedimentary rock. Mineralogically and texturally the basalt shows great similarity throughout the succession of flows and also in the individual flows. As a rule the tops and bottoms of flows are not distinguishable by textural features. Scoriaceous surfaces are not recognized, and gas cavities are not especially characteristic of the tops of the flows, although this feature was noted in a few localities.

The lava flows form hard, resistant rocks, and although everywhere chemically altered from their original condition, they are much less soluble than the overlying limestone. They have been folded in the same way and at the same time as the limestone but have reacted differently to the deforming forces. They have accommodated themselves to deformation in part by bending and faulting but still more by breaking into innumerable blocks of various sizes, bounded by fracture planes whose slickensided surfaces show movement of one block on another, even where well-defined fault planes are not present. Such fractures provided most intricate channels for the circulation of mineral-bearing waters.

In the greenstone deposits are found bornite, chalcopyrite, pyrite, chalcocite, malachite, azurite, native copper, silver-bearing tetrahedrite (possibly in part freibergite), cuprite, covellite, and chalcanthite, of which bornite, chalcopyrite, chalcocite, and pyrite are most abundant. The copper minerals are accompanied in many places by quartz, epidote, and calcite.

A study of a large number of prospects in the Kotsina-Kuskulana district led to a separation of the copper sulphides in greenstone into the following classes:[80]

Argentiferous tetrahedrite ores.
Chalcocite ores.
Bornite and bornite-chalcocite ores.
Bornite-chalcopyrite ores.
Pyrite-chalcopyrite ores.

These associations of minerals apparently represent the original character of the deposits, and in the few places where other copper minerals were found with the minerals in one of the above-named classes it was fairly certain that the extra minerals were of later origin.

A few of the copper deposits take the form of well-defined veins of considerable extent. Such veins are found in the Strelna formation as well as in the Nikolai greenstone. By far the greater number of copper deposits are of the stockwork and disseminated types. Mineral-bearing solutions in circulating through the greenstone along available openings have deposited copper minerals and to a certain extent have replaced the greenstone. These solutions also penetrated into the greenstone walls adjacent to the channels and deposited copper minerals that have no evident connection with the main veins. In this way copper deposits were formed that are notably irregular in form and uncertain in extent.

The copper filling in the vesicles of lavas is chiefly native copper. These amygdaloidal copper deposits are found at several localities, of which the best known is that on Shower Gulch, at the head of the Kotsina River. Native copper is also found as thin sheets or as slugs and irregularly shaped masses mingled with quartz in veins in the greenstone. In such places it appears to have resulted from the alteration of earlier copper minerals. A third mode of occurrence of native copper is with gold and silver in some of the stream gravel. Placer copper has been found wherever streams cutting rocks of the Nikolai greenstone have been worked for gold and is present in pieces that range in size from small shot to masses of several hundred pounds or at one locality even more than a ton.

The largest mass of native copper so far discovered in the Chitina Valley is that from Nugget Creek,[81] in the Kuskulana district, which was found in the stream bed and was on display in Chitina for several years but is now at Gulkana. Another large mass of native copper

[80] Moffit, F. H., and Mertie, J. B., Jr., The Kotsina-Kuskulana district: U. S. Geol. Survey Bull. 745, p. 86, 1923.
[81] Idem, p. 133.

weighing two or three times as much as that from Nugget Creek was found in slide rock on the White River in Canadian territory a few miles east of the international boundary.[82] This mass is a slab averaging 8 feet by 4 feet by 4 inches and weighing 6,000 pounds. In the Nizina district native copper has been recovered from the gold placers and shipped to the smelters but has not been found in paying quantities in bedrock.

Silver-bearing tetrahedrite is known at only one locality on the Kotsina River, where it occurs in a vein with chalcopyrite, galena, and a small amount of a bismuth-bearing mineral, probably bismuthinite.

The copper deposits in greenstone are believed to have undergone weathering and possibly alteration during the same period as the deposits in limestone. In Tertiary time the land was subjected to a long period of denudation, during which weathering agencies were active. With the coming of the glacial ice much of this activity ceased or was retarded, but in the mountainous areas, at least, mechanical erosion was speeded up. Vast quantities of rock were removed, and much of the weathered surface material was carried away. If oxidation and enrichment or impoverishment of the ore bodies had taken place previously, most of the resulting material was removed. Yet at Kennecott the processes of oxidation acted on sulphide ores in limestone at great depth below the present surface. No reason is known for supposing that copper deposits exposed at the surface in this district will be found to be either richer or poorer below the surface. The surface exposures are dependent on the accidents of erosion, which may have progressed only so far as to expose the beginning of an ore body or which may have exposed a maximum cross section or removed all but the last traces of the body. The first two possibilities are well illustrated by the conditions at Kennecott. When the Bonanza mine was discovered a large section of the ore body was exposed at the surface, and hundreds of tons of high-grade ore that had been eroded from the exposed vein lay in the talus on each side of Bonanza Ridge. The deposit at the Jumbo mine, on the other hand, was little more than indicated by surface exposures, and not until mining had proceeded for some time was the immense size of that ore body disclosed.

GOLD

Gold is present in the gravel deposits and in mineralized veins of widely separated localities within the area considered. Much of the greater part of the gold already recovered from such deposits was placer gold and was taken from the stream gravel of Dan and Chititu

[82] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, p. 53, 1910.

Creeks and their tributaries, in the Nizina district. Other streams that have yielded placer gold are Young and Golconda Creeks. Insignificant amounts of placer gold have been produced from Slatka Creek, in the Kuskulana Basin, and from Fall Creek, near Tiekel. The gold placers of the Chisana district are outside the limits of the area considered in this paper.

One characteristic of the gold placers that have been most productive should be emphasized particularly. The richest gravel owes its richness largely to a concentration of gold that was disseminated through the deep bench gravel and was brought to its state of concentration by the erosive action of streams that sorted out and removed the lighter constituents from the bench gravel, leaving behind the heavier material, just as is done in a sluice box. Further reference is made to this fact on pages 128–129.

Auriferous veins in the bedrock furnished the gold that, through the processes of weathering and transportation by water and other means, was finally distributed in the gravel. It is proper therefore to consider the vein deposits first.

Gold-bearing veins are known in rocks of the Strelna formation and in rocks of the Chugach Mountains that have been correlated with the Strelna. The greater number of known veins, however, are in rocks of Lower Cretaceous or later age on the north side of the Chitina Valley and in that great assemblage of slate and graywacke beds in the Chugach Mountains that is believed to be largely if not wholly of Mesozoic age and to have been deposited at least in part during Cretaceous time.

It is probable that the gold was deposited during at least two periods, of which one was earlier than that of the Upper Jurassic (?) rocks east of the Kuskulana River and the other necessarily later than that of the Lower Cretaceous shales that enclose the veins of the Nizina district. Possibly other periods are also represented, but no gold-bearing veins are known in the Tertiary rocks. Evidence for a period of gold deposition earlier than Upper Jurassic is not complete. Possibly the gold-silver veins of Berg Creek are not connected with the contact-metamorphic copper deposits nearby on MacDougall Creek but are of later age. If this is true the gold deposits may eventually prove to belong to only one period.

All the gold veins so far discovered occur in rocks that are cut by granodioritic intrusives, and although the dependence of one on the other has not been demonstrated, the association is close in places and is thought to be significant. Mertie [83] has shown the existence of such a relation in the Yukon and Kuskokwim regions, and its existence in this area also is probable.

[83] Mertie, J. B., Jr., The occurrence of metalliferous deposits in the Yukon and Kuskokwim regions: U. S. Geol. Survey Bull. 739, pp. 149–165, 1922.

The gold-bearing veins have not been explored sufficiently to warrant a separation into distinct types, yet differences in manner of occurrence are apparent. The silver-gold deposits of Berg Creek occur as veins of iron and copper sulphides with a little quartz and are found in a body of porphyritic granodiorite. Pyrite is the prevailing sulphide, but chalcopyrite is present and shows an iridescent stain where weathered. Mill tests showed that the richest ore comes from oxidized parts of the veins and that silver predominates largely in quantity over the gold.

A frequently mentioned gold vein on Benito Creek near the trail from Strelna to Elliott Creek consists of quartz and a subordinate quantity of coarsely crystalline calcite, with which are associated chalcopyrite, bornite, pyrite, and free gold. Stains of azurite and malachite have resulted from the oxidation of the copper sulphides. This vein is in rocks of the Strelna formation. Although it has been known for many years and considerable work was done on it at one time, no serious attempt has been made to exploit it recently and little more is known of its possibilities.

The gold-bearing veins of the Chugach Mountain area, such as those found along the lower Copper River, near the Richardson Highway, and in other localities, consist of quartz carrying metallic sulphides and free gold. Galena is present in places, also arsenopyrite, sphalerite, pyrite, and a little chalcopyrite. These veins cut slate and graywacke and are associated with light-colored dikes of diorite and granite. Many of the veins have yielded rich samples of gold ore, and several have produced gold commercially. The largest and best known of the productive veins is at the Cliff mine of the Chugach Mines Co., on Valdez Arm, which lies outside the area under consideration. Another vein that yielded between $10,000 and $20,000 before the rich ore was exhausted is the Ellis mine, on Boulder Creek near Tiekel. This vein, like the gold-bearing veins nearby on Mill Creek and on Hurtle Creek, consists of gold-bearing quartz that was deposited in one of the systems of north-south joint planes that cut the slate and graywacke beds and are characteristic of the Tonsina district. The quartz of the north-south joint system appears to be later than the quartz veins that follow the foliation of the subschistose country rock and the equally prominent vein system that includes the multitude of thin parallel veins which are seen everywhere in that district. At least it may be said that the mineralization was associated with north-south veins. The weathering of veins of this trend probably accounts for the gold in the gravel of Fall Creek and of Quartz Creek, a stream that flows into the Tonsina River and produced a little placer gold during the gold excitement of 1898 and 1899.

At present (1935) much local interest is centered on the prospecting of gold-bearing veins at the head of Golconda Creek, a tributary of the Bremner River, where the slates and graywackes are cut by many light-colored porphyritic dikes and an area of mineralization that has long been known was produced. Without much doubt the placer gold of Golconda Creek was derived from veins of this system. The principal mining development is that of the Bremner Mining Co., on the ridge northwest of the divide between Golconda and Monahan Creeks. Several veins have been prospected. The type is illustrated by the one first exploited, which lies along the east side of a dike trending a little west of north and consists of quartz in which the most conspicuous metallic minerals are pyrite and galena. The property has been equipped with a mill, tram, and other mining machinery but had not come into full production when this was written.

The gold-quartz veins in the Cretaceous shales of the Nizina district contain pyrite and free gold, with locally some molybdenite and probably some stibnite. Galena, cinnabar, barite, and marcasite may also be present, for they are found in the creek gravel. A small vein on Rex Creek was found to consist of quartz with molybdenite and pyrite and assayed 0.18 ounce of gold and 12.80 ounces of silver to the ton. A dike rock near this vein seemed to be little altered and contained pyrite with traces of both gold and silver. These occurrences are cited to show the evidence for a local source of the gold in the creek gravel and to indicate that prospecting for gold lodes is justified.

Gold placers in this district have been mined profitably only in the drainage basins of Dan and Chititu Creeks and on a tributary to the north branch of the Bremner River south of the Chitina Valley. In the Dan-Chititu area the placer gold has been derived from gold-bearing veins in the Cretaceous shales, and in the Bremner area from veins in rocks of the slate-graywacke succession.

The gold of Dan and Chititu Creeks and their tributaries is associated with native copper and native silver. Native copper, however, does not accompany the gold on tributaries such as the upper part of Rex Creek, where the Nikolai greenstone is not exposed and where foreign gravel derived from the greenstone farther east in Chitina Valley was not brought in by the glaciers. This fact is suggestive and points to the Nikolai greenstone as the bedrock source of the native copper in the gravel deposits.

One feature of the gold placers that was referred to above and deserves consideration again is that the most productive gravel is that in which a concentration of gold from the bench gravel has taken place. The deep bench-gravel deposits of both Dan and Chititu Creeks contain gold distributed throughout their thickness, although they show a partial concentration of gold in places. As explained on page 102, the deep gravel deposits in these streams are in part the product of glaciation and accumulated in the side valleys behind ice barriers that occupied the Nizina Valley. When the ice disappeared the streams attacked the gravel deposits, removing part of the gravel and bringing about a concentration of the heavy material contained in them, thus forming the richer stream placers.

Prospecting tunnels have been driven in numerous places to test the bench gravel, and gold has been mined from it both by underground mining operations and by open-cut hydraulic methods. These operations have shown that much of the gold in the bench gravel is concentrated near bedrock or in places on "false bedrock" at varying distances above bedrock. Further, the bench gravel itself contains old stream-channel deposits of gravel with concentrations of placer gold. Parts of well-defined old channels, above the present stream courses, have been mined on both sides of lower Dan Creek and on Rex Creek and have yielded considerable gold. It is only such old channel deposits in the bench gravel and the richer concentrations on bedrock that have been mined profitably so far. Possibly the upper part of the bench gravel is too poor to be mined for its own gold content, so that the cost of its removal must be borne by the lower and richer gravel when the time comes for exploiting the benches.

Reconcentration of gold from the deep bench gravel into present stream gravel is common in many parts of Alaska. The older gravel deposits were trenched, and much of the material was removed or is being removed by present-day streams. During this process the gold in the reworked gravel receives a further concentration, with the result that the creek gravel is much enriched. A knowledge of this process should lead the prospector to give special attention to those localities where streams are seen to be reworking bench gravel.

SILVER

The occurrence of silver has been mentioned in considering copper and gold. Silver occurs in this district in association with the copper ores of Kennecott, where it is present to the amount of 14 to 16 ounces to the ton of high-grade ore or 1.73 ounces to the ton of ore as mined in 1932; in the pyrite-chalcopyrite veins on Berg Creek; in the tetrahedrite veins on the Kotsina River; and as native silver associated with native copper and gold in the gold placers of the Nizina district. Samples taken from gold-bearing veins in different parts of the district commonly contain some silver.

For the purpose of this paper it is not necessary to discuss the silver recovered in smelting the copper ores of Kennecott, as that is plainly a byproduct of copper mining.

The claims on Berg Creek were staked and prospected for copper, but the veins now being mined were found on exploration to be worth more in gold and silver than in copper. Later, when the mill was started, it was learned that silver predominated largely in quantity over the gold.

Silver is the only metal in the silver-bearing tetrahedrite veins of the Kotsina River that may have a commercial value, but exploration of the veins has not progressed to the stage where their value has been demonstrated. The veins are apparently in rocks of the Strelna formation but are close to the Nikolai greenstone and not more than a third of a mile from a mass of granodiorite which intrudes the Strelna rocks. The country rock enclosing the deposits is much shattered and faulted. The veins consist of a quartz gangue containing tetrahedrite, galena, azurite, and malachite. Bismuth is present in tiny veinlets of bismuthinite (?) cutting the tetrahedrite. No similar veins have been found elsewhere in the Chitina Valley.

Veins carrying a large proportion of galena among other sulphides are found on the south side of the Chitina River in the mountain between that stream and the Tebay River. These veins are reported to carry silver, but there has been no production of silver or other metals from them to this time. They are in rocks that are correlated with the Strelna formation.

Nuggets of silver and also of copper and silver ("half breeds") are frequently found in the sluice boxes on Dan and Chititu Creeks. One of the largest silver nuggets from the Nizina district known to the writer was found on Chititu Creek and consisted of a mass of native silver and quartz weighing 7 pounds. Other large nuggets have been found, and some of them may have been even larger than the one mentioned. Silver is not likely to be produced from placers in this district except as a byproduct in the mining of placer gold. No evidence is known to indicate that silver is anywhere present in commercial placers. Doubtless the copper will be sought in the placer gravel before silver, if it ever becomes profitable to mine either metal where gold is not present.

SUMMARY

Evidence of the occurrence of metallic mineralization is found in all parts of the area considered in this report. The search for nonmetalliferous deposits, such as sand, clay, and stone, has not been pushed, for even if they are present they have little value in the present stage of the development of Alaska, and the outside market is too distant for profitable exploitation. Seams of coal have been found associated with the late Mesozoic and Tertiary rocks but are too small to have value. In the present knowledge of the geology of the area it seems safe to say that a search for either coal or oil is most likely to prove unsuccessful.

Copper, gold, and silver are being mined in the Chitina Valley. Copper far outranks the other two metals in value of production. Much the larger part of the copper so far produced has come from deposits in the Chitistone limestone at Kennecott. Practically all the gold has been taken from the gold placers of Dan and Chititu

Creeks, although a small proportion came from other placers and from lodes. Silver is an important constituent of the ores from Kennecott, is present in the gold placers, and has been recovered from one vein deposit.

The only producing copper mine is in the basal beds of the Chitistone limestone, but copper deposits also occur in the basaltic lava flows of the Nikolai greenstone and in similar basaltic lavas of the Strelna formation, which underlies the Nikolai. Experience gained from mining and from a consideration of the known occurrences of copper minerals indicates that the most favorable horizon in the Chitistone limestone for copper deposits is in the beds near the Nikolai greenstone. This conclusion, however, is not universally applicable, for the original outcrop of the Mother Lode mine, now being exploited by the Kennecott Corporation, was many hundreds of feet stratigraphically above the base of the limestone, possibly near the middle of the formation. A few copper deposits in greenstone occur as well-defined fissure veins, but by far the greater number were formed by the deposition of copper minerals in preexisting openings or by the replacement of the wall rock along irregular and intricate systems of fractures.

Gold and silver are found in formations ranging from the tuff, limestone, shale, and basalt flows of the Strelna formation to the Cretaceous shales. Gold is produced chiefly from placer gravel, and silver from the silver-bearing copper ores of Kennecott, but both metals are being produced from vein deposits, so that the expectation of finding other gold-silver veins is reasonable. The probable dependence of gold-silver mineralization on the intrusion of granodioritic rocks should be kept in mind in prospecting for placer deposits as well as for veins.

Prospectors searching for copper or gold lodes in this district should not expect a necessary or probable increase in the value of ore deposits at depth, for in general the original zone of oxidation and enrichment was largely removed during the period of intense glaciation. Yet in this connection it is well to remember that the earlier ideas on the subject had to be modified when it was found that oxidation had been effective at the lowest depth reached in the Mother Lode mine at Kennecott—that is, a level far below the present surface but still about 1,500 feet higher than McCarthy Creek, on the east. The depth of an ore body below the present surface and the vertical distribution of high-grade ore are likely to depend largely on the accidents of erosion. The richest part of the lode is as likely to be exposed at the surface as the poorest.

Furthermore, the prospector for placer gold should pay particular attention to deep gravel which is being reworked by present streams, for this process at many Alaskan localities has resulted in a reconcentration of low-grade deposits and the formation of valuable placers.

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