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GEOLOGY OF THE UPPER TETLING RIVER DISTRICT ALASKA

BY

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GEOLOGY OF THE UPPER TETLING RIVER DISTRICT ALASKA

By Fred H. Moffit

ABSTRACT

The term upper Tetling River district is here applied to a small part of the Alaska range lying northeast of the Wrangell Mountains and extending from Suslota Pass to the Nabesna River. However, the geologic map and the description of the rocks include adjacent areas, which are needed to give a better understanding of the general setting. This part of the Alaska Range shows a maximum relief of about 6,000 feet between the bars of the Nabesna River and the high peaks of the divide which separates the drainage of the Copper and Tanana Rivers at the head of the Tetling River.

The rocks of the district are predominantly sedimentary—shale or slate, sandstone, conglomerate, and limestone—but include lava flows and tuffs, all of which make up a succession of bedded deposits ranging in age from Middle Devonian to Tertiary or younger. In addition to the bedded rocks there are areas of granitic intrusives.

The oldest rocks comprise slate, quartzite, limestone, and conglomerate of Middle Devonian age, which are intruded by large bodies of granitic rock and are locally schistose. The limestone outcrops are particularly conspicuous and are sparingly fossiliferous.

Following the Devonian rocks in the stratigraphic column are old lava flows and limestone, which are referred to the Permian on the evidence of fossils collected from the limestone and the association of the limestone with the lava flows.

The Permian lava flows and limestone are the latest of the Paleozoic formations. They are overlain by a great mass of sediments, including chiefly limestone, shale, sandstone, and conglomerate, which occupies a great synclinal basin that extends northwest and southeast and separates the areas of Devonian and Permian deposits. They include Upper Triassic, Upper Jurassic, and Lower Cretaceous beds, which are strongly folded and are intruded by dikes and sills of granitic rock. Their relation to both the underlying and the overlying rocks is that of structural unconformity. The youngest of the consolidated rocks are lava flows and tuffs, which began to accumulate in early Tertiary time and now cover most of the Wrangell Mountain area. Although the lava flows have been extensively eroded, they, unlike all the older rocks, are not folded and are only slightly tilted.

The district is strongly glaciated, and its unconsolidated deposits therefore include morainal material as well as the usual sand, silt, and gravel of the streams and lakes.

The upper Tetling River district has received some attention from prospectors, and evidences of gold and molybdenum have been found. However, aside from

the Nabesna mine at White Mountain, on the Nabesna River, which is now one of the leading gold mines of Alaska but which is not described in this report, the results of prospecting have not been encouraging.

INTRODUCTION

This paper describes the geology of a part of the Alaskan Range that lies in the headwater region of the Copper and Tanana Rivers. (See fig. 4.) Some of the area that is considered was mapped in

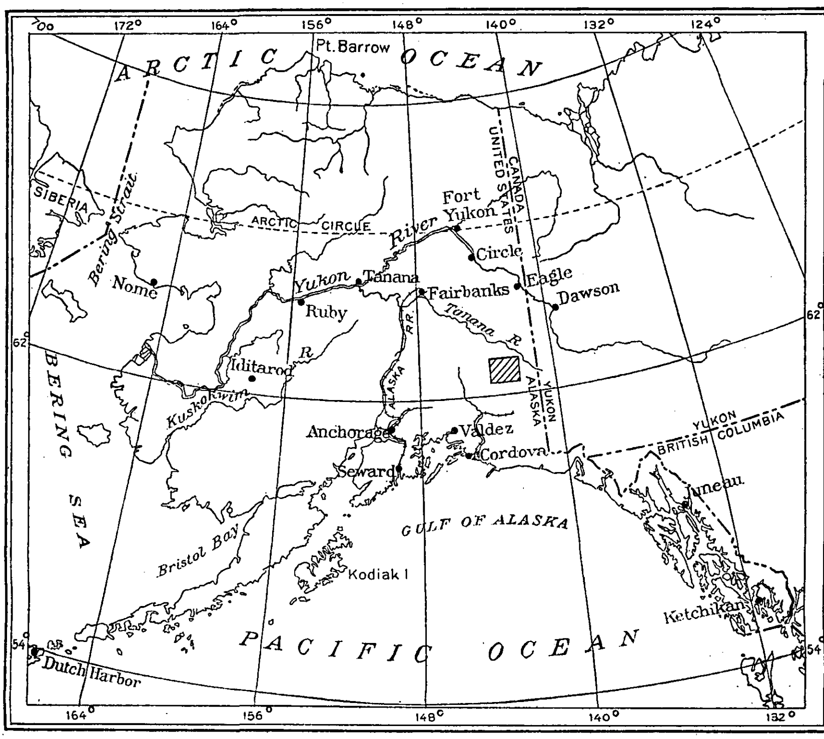

FIGURE 4.—Map of Alaska showing the location of the upper Tetling River district.

earlier years and was described in a previous report.[1] The part mapped in 1938, to which more special attention is directed here, is relatively small, comprising only a few hundred square miles. However, the topographic and geologic maps covering this area mark one further step toward the completion of a much larger project of mapping which has been under way for several years and has for its end a survey of all of the Alaska Range east of the Delta River.

Brooks,[2] who saw the high mountains northeast of the Wrangell

[1] Moffit, F. H., Geology of the Slana-Tok district, Alaska: U. S. Geol. Survey Bull. 904, 54 pp., 1938.

[2] Brooks, A. H., A reconnaissance in the White and Tanana River basins, Alaska, in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, p. 446, 1900.

group from the Tanana River in 1898, suggested for them the name "Nutzotin Mountains." He did not know the relation of the Nutzotin Mountains to the St. Elias Range on the south. He believed them to extend no farther northwest than the Nabesna River and to be separated from the Alaska Range by a broad depression through which "the Mentasta and Suslota trails from Copper River to the Tanana lead." We know now that the broad depression is occupied by mountains only slightly lower than the peaks on each side and that structurally the Alaska Range sweeps east and south around the volcanic peaks of the Wrangell Mountains and either dies out altogether or possibly merges with the St. Elias Range. The name Nutzotin has value only for designating a restricted part of the Alaska Range and has been so used on maps of the Geological Survey.[3] It was applied originally, and probably unknowingly, to mountains made up predominantly of Mesozoic slate, graywacke, and sandstone that occupy a great synclinal basin and extend from the international boundary on the southeast to Suslota Lake on the northwest. This report deals chiefly with the Mesozoic rocks that form the northwest part of this mountain chain and with the older rocks that lie adjacent to it on the northeast and the southwest. The district is of interest to the geologist because of the geologic problems to be solved and because of the mineral deposits already discovered and the possible presence of others still to be discovered.

The topographic map (pl. 2) that is used in this report to show the distribution of geologic formations in the district is compiled from surveys made by several topographic engineers, including D. C. Witherspoon, C. F. Fuechsel, Gerald FitzGerald, and T. W. Ranta. In 1902 Witherspoon, who at that time was associated with T. G. Gerdine in a mapping project that related principally to the Copper River Valley, made a reconnaissance survey of a large area, which includes parts of the upper Copper and Tanana River drainage basins and covers all the area dealt with in this report. Later surveys by Fuechsel in 1933, by FitzGerald in 1934, and by Ranta in 1937 and 1938 are extensions and revisions of Witherspoon's work made desirable by the need for maps covering unsurveyed areas and by a standard for topographic mapping of greater refinement than was practicable in the earlier days.

Topographic and geologic maps of the district adjacent on the north have been completed[4] and are available to those interested.

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[3] Mendenhall, W. C., Geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, pl. 20, 1905. Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska; U. S. Geol. Survey Bull. 417, pl. 1, 1910. Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, pl. 1, 1916.

[4] Moffit, F. H., op. cit. (Bull. 904), pl. 1.

The present geologic investigation extends the area covered to the Nabesna River and leaves an area, most of which lies between the Nabesna and Chisana Rivers, large branches of the Tanana River, to be completed at a future time. This future work will join that of Capps and Giffin[5] in the Chisana-White River districts and thus complete the reconnaissance mapping of the eastern part of the Alaska Range.

The present investigation, as has been stated, is a continuation of one that has been in progress for several years. In 1937, Ranta, taking up the work at the south boundary of the area covered by FitzGerald's earlier map, made a reconnaissance topographic survey that extends east from the head of Suslota Creek to the Tanana lowlands and lies for the most part north of the Nabesna River and the divide between the Copper and Tanana Rivers. This work was hindered to an exceptional extent by the frequent rains and persistent low-lying clouds of that season. The mapping was continued in 1938 on the south side of the Tanana-Copper River divide and was extended into the Wrangell Mountains so as to include the drainage area of the Copper and Nabesna Rivers. The usual field methods of topographic surveying were used in this project, but they were supplemented and the map work was facilitated by the use of airplane photographs part of which were taken by FitzGerald and part furnished by Mr. Bradford Washburn. During the later part of the working season a small area including the vicinity of the Nabesna mine was mapped on a larger scale and in a more detailed manner than is common in reconnaissance surveys. During the summer Ranta had the assistance of Harry Saxon as recorder and of H. Boyden and Harry Ravell as packer and cook, respectively. The geologic investigation of 1938 was restricted to the area north of Jack Creek and the Nabesna River. The writer examined a considerable part of this area in 1931 and 1934 but revisited much of it in 1938 in order to correct and extend the mapping of those earlier years and to adjust it better to the new topographic map. He was assisted in the camp activities by Ira Morgridge and Charles J. Smith, packers, and Barney Dawson, cook. He thus had an experienced and efficient party provided with the necessary horses, camp equipment, and food for the 3 months during which the field work was in progress. In 1938 the various operations of the party were retarded by unfavorable weather in June and July, but fortunately this did not continue throughout the season.

[5] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, 130 pp., 1916.

GEOGRAPHY

RELIEF AND DRAINAGE

The block of mountainous country to be described in this report extends northwestward from the Nabesna River nearly as far as Mentasta Pass and is bordered on the northeast and southwest by the lowlands of the Tanana and the Copper Rivers. This part of the Alaska Range has a width of approximately 35 miles. The drainage area, however, is unequally distributed between the two rivers, for the divide between them lies nearer the southwest than the northeast side of the range; moreover, the Nabesna River, rising from the ice fields in the heart of the Wrangell Mountains, has cut a straight, narrow, steep-walled valley directly across the Alaska Range and has caused the drainage divide to swing to the southwest in the southern part of the area, far from the axis of the range. The mountains reach their greatest height, 8,400 feet above the sea, in the group of snow-capped peaks between the Nabesna River and the head of the Tetling River. This altitude represents a relief of 6,200 feet as compared with the Nabesna River near the mouth of Platinum Creek, where the altitude above the sea is 2,200 feet. These high mountains, as far northwestward as Suslota Pass, show a characteristic topography resulting from the nature of the rocks that form them. The shale, sandstone, and conglomerate weather rapidly into sharp peaks and ragged ridges, which are separated by deep valleys nearly every one of which has a cirque basin at its head. Many small glaciers are present, and the evidence of vigorous glaciation in earlier times is at hand on every side. The larger valleys all owe their present form to erosion by ice, but many of the smaller gulches have been developed since the time of greatest ice activity and are V-shaped, the result of rapid weathering of relatively soft rocks (pl. 4, *A*). Toward the Tanana Valley the mountains north of the Nabesna River are lower and more rounded in outline. They gradually merge with the Tanana lowland and show little modification by ice, although a vast quantity of unconsolidated material derived from the higher parts of the range is spread around their lower slopes and out over the floor of the Tanana Valley.

This group of high mountains between Suslota Pass and the Nabesna River is the source of many streams that flow rapidly from the highland area. These streams include the headwater branches of the Little Tok and Tetling Rivers and of Cheslina, Totschunda, Platinum, and Jack Creeks, all of which belong to the Tanana River drainage, and in addition Suslositna, Suslota, and Rock Creeks, which are the larger streams originating on the Copper River side of the range. The tributaries of the Copper River are relatively small and drain an area the size of which is only a minor fraction of that drained by the streams of the Tanana side. The Copper River and Tanada Creek, shown on the west side of the map, belong to the drainage area of the Wrangell Mountains. The Nabesna River, much the largest stream of the district, has its source in the vast ice fields that lie between Mount Wrangell and Regal Mountain. It is a swift, turbulent stream of milky water loaded with sand and gravel, and it has built up a wide flood plain over which it spreads itself in a multitude of branching channels. After crossing the mountainous area and part of the lowland that borders it on the northeast, the Nabesna and Chisana Rivers unite to form the Tanana.

An interesting topographic feature, the origin of which is connected with faulting and the limestone of Platinum Creek, is a dam at the head of Soda Creek, which impounds a small lake between Soda and Totschunda Creeks. The dam is nearly 250 feet high and was estimated to be between 200 and 300 yards long crosswise of the creek. Its length parallel to the creek is nearly twice as great. It was formed by a landslide from the limestone mountain on the south (pl. 4, *B*) and evidently is not of very recent origin, for a few scattered spruce trees grow on the dam, and most of the fallen limestone blocks are weathered to coarse sand.

ROUTES AND TRAILS

In the earlier days the part of Alaska northeast of the Wrangell Mountains was far from the customary routes of travel and difficult to reach. Such trails as existed were poor, the distance from the coast was great, and the time required to reach the district was long. Now the branch of the Richardson Highway that serves the upper Copper River Valley and connects the main thoroughfare with the Nabesna mine has changed some of the adverse conditions and made it possible to reach the border of the district with only the usual harzards of travel by automobile.

Although the highway facilitates travel and transportation between the district and points in the Copper River Valley or places such as Valdez and Fairbanks, no roads or trails exist within the district itself. Nevertheless transportation by pack animals in the summer or by sleds in the winter meets with no unusual difficulties, for the valleys give ready access to most of the area, and no large and dangerous glacial streams have to be crossed. In most places good footing for animals will be found if reasonable thought is given to choosing a route of travel, although care must be taken to avoid trouble in crossing some small streams and soft places on hill slopes, especially those places where the willows indicate the presence of water. The timbered areas offer comparatively little difficulty, except where the ground is moss-covered and wet.

The general route of the Geological Survey party in 1938 was from mile 73 on the highway to Suslota Lake, up Suslota Creek and across a divide to the Little Tok River, thence to Buck Creek and the Tetling River, from the Tetling River to Cheslina Creek, and finally back to the south side of the mountains by a high pass between Cheslina Creek and the head of Totschunda Creek. This route leads through several passes well know to the natives but little used by the few white men who have visited the district. The route to the first of these passes begins on Suslota Creek, 6 miles east of the lake, and leads through a narrow, canyonlike valley, in which the low point of the divide lies, to a tributary of the Little Tok River. Almost directly east of this but a little north of it is a second pass, which is reached by a long, easy climb to the divide between the Little Tok and the upper valley of Buck Creek. It provides a short route to Buck Creek. Between the Tetling River and the head of Platinum Creek, at an altitude of 5,500 feet, is a pass that was used by the Survey party once during the summer for replenishing supplies from a cache at the Nabesna mine. The ascent to this pass on the Platinum Creek side is gradual and easy, but on the Tetling River side it is over glacial moraines and is both steep and trying for loaded pack animals. By careful selection of a trail and the construction of some switch-backs, the difficulties of this pass could be much reduced.

The high point of the pass between Totschunda and Cheslina Creeks has an altitude of 5,600 feet and is more difficult to reach than that of the pass between the Tetling River and Platinum Creek. On the Cheslina side the greatest obstacle to the crossing is at a point 2½ miles northeast of the summit, where it is necessary to climb several hundred feet through a steep, narrow gulch. On the south, or Totschunda side, is a smooth, steep hillside more than 1,300 feet high, which would be a hard climb for a loaded pack train unless a suitable switch-back trail were built. Furthermore, a trail over the great moraine about 1 mile below the summit of the Totschunda side should be picked out to avoid travel through the steep, rocky gulch that is the bed of the creek.

Travel along the north bank of the Nabesna River is prevented by the steepness of the mountain slope and by rock bluffs against which the river swings. The south side of the valley permits travel, but crossing the river below the established crossing on the trail to the Chisana district is so difficult and dangerous in summer that it is not used as a route to the Cheslina Valley.

Travel with horses in the lowland area of the Tanana Valley between the Nabesna River and the Tetling Lake is through a country of swamps, lakes, wandering streams, and scrubby timber and has not been attempted within the writer's knowledge since it was crossed by Brooks[6] and Peters in 1898, yet some prospector probably has taken horses there since that time.

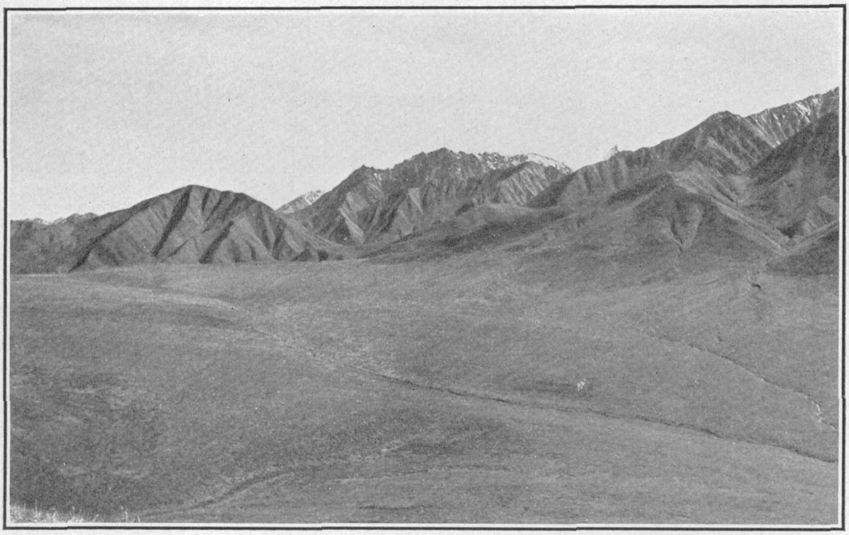
TIMBER AND FORAGE

The lower land on both sides of this part of the Alaska Range is covered with timber. Spruce and poplar and aspen in minor proportion are the common trees. They flourish where the soil is good and the ground well-drained but do not grow much above an altitude of 3,000 feet, although the timber line is somewhat variable, depending on the position of the land, its exposure to sunlight, and its protection from winds. The lowlands of the Copper and Tanana Rivers support a growth of trees that distinctly outlines the courses of the streams and the low ridges. The trees are nearly all spruce and extend in narrow bands along the valley bottoms into the mountain areas. The timbered areas are interspersed with small lakes and green, swampy, parklike areas.

Both white and black spruce are present, and of the two, the white is superior for most purposes. The best spruce timber grows on the well-drained gravel benches that border the lower courses of the streams or at the foot of the mountain slopes. The inferior timber occupies the poorly drained and therefore wet and cold ground of the lowland areas or the nearly level land between stream courses. It occurs as a sparse growth of scrubby trees, which are prevailingly of the black spruce variety and have little value except for firewood. The finest spruce timber seen by the writer in this district is near the forks of Cheslina Creek, where a heavy growth of tall, straight trees occupies the low gravel benches (pl. 5, *A*).

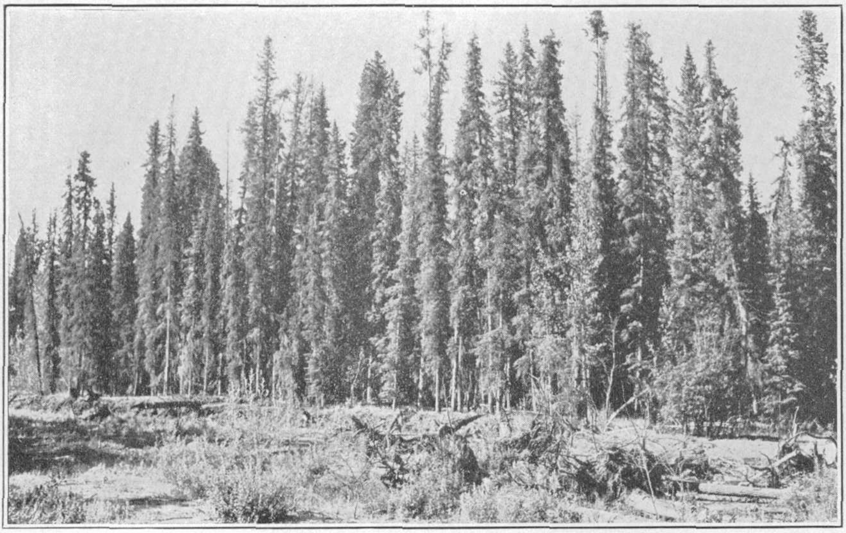
Poplar and aspen grow on the well-drained ridges and mountain slopes and nearly always indicate good ground for travel. They have little commercial value but lend a pleasing aspect to the landscape, especially in the autumn season when their leaves have turned to the golden yellow that is their most notable characteristic. The willows also turn yellow in the fall. They grow in great variety and range in size from tiny shrubs a few inches high to small trees large enough to furnish tent poles and firewood. Alder, which is so abundant and large on the coast, is less common and is smaller in this part of Alaska.

[6] Brooks, A. H., A reconnaissance from Pyramid Harbor to Eagle City, Alaska: U. S. Geol. Survey 21st Ann. Rept., pt. 2, p. 339, 1900.

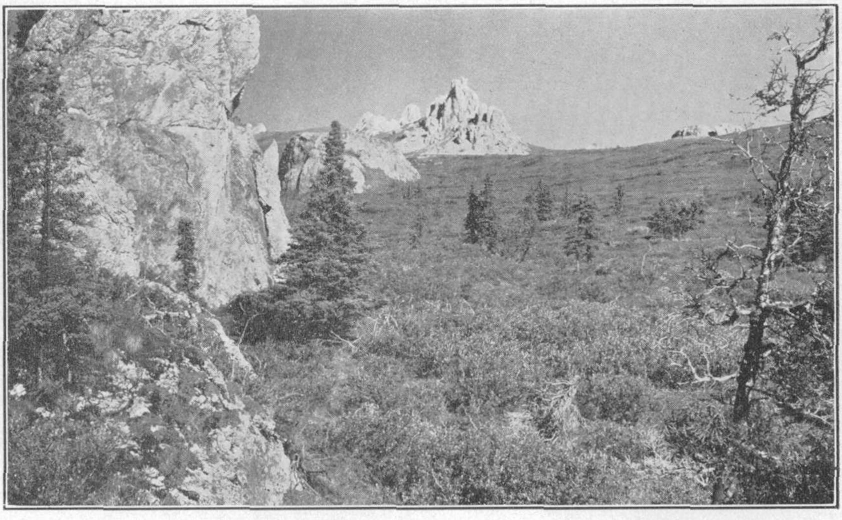


A. MOUNTAIN BETWEEN THE TETLING AND NABESNA RIVERS.
Shows the characteristic weathering of the sandstone and shale of the Nutzotin Mountains.

B. SMALL LAKE FORMED BY A LANDSLIDE AT THE HEAD OF SODA CREEK.



A. SPRUCE TIMBER ON CHESLINA CREEK.



B. OUTCROPS OF MIDDLE DEVONIAN LIMESTONE IN THE LOW DIVIDE BETWEEN THE TETLING RIVER AND CHESLINA CREEK.

Forage for horses is an important consideration to the traveler who is dependent on his pack train for the transportation of his camp equipment and food supplies. Fortunately grass was abundant in nearly all parts of the district traversed by the writer in 1938, but a quantity sufficient for working horses cannot be counted on much before the middle of June nor after the middle of September. The best pasturage is found near the timber line in the upper parts of the valleys and on the hill slopes. Forage is likely to be poor or altogether wanting in the damp lowland areas, although the tender young shoots of bunchgrass in the "nigger head" swamps are relished by horses and the coarse grass that grows around the edges of lakes will supply feed till it gets too old and tough. Horses that are accustomed to the country are fond of certain willows and will sometimes leave good grass to feed on them. They also like some of the vetches, equisetum, and other plants. Such animals will thrive on feed that would scarcely sustain those just brought in from the outside and unaccustomed to the fare. Native or acclimated horses are also more likely to handle themselves well in wet ground, and they are less annoyed by flies and mosquitoes.

GEOLOGY

INTRODUCTION

Sedimentary rocks predominate in the part of the Alaska Range under consideration, but they are associated with lava flows and in places are invaded by igneous rocks. The water-laid deposits include shale, sandstone, grit, conglomerate, limestone, and related sediments, which range in age from Middle Devonian to Tertiary. This list does not take into account the unconsolidated gravel, sand, and morainal deposits. If these rocks are considered in relation to the time of their formation, the Paleozoic era is represented by Middle and Upper Devonian and Permian sedimentary beds and volcanics, the Mesozoic era by Upper Triassic, Upper Jurassic, and Lower Cretaceous sedimentary beds, and the Tertiary period by lava flows. All these rocks are cut by intrusives, and all show tilting or folding that ranges in degree from moderate inclination in the Tertiary lava flows to close folding and overturning of folds in the Devonian beds. The older rocks, moreover, are recrystallized and have yielded the coarsely granular limestone of the Cheslina Valley or have developed a well-marked schistosity, which is pronounced in the vicinity of the great body of granitic rock that was intruded into the Devonian sedimentary deposits. The Permian rocks are altered nearly as much as the Devonian. The rocks of the Mesozoic age, shale, sandstone, and conglomerate of the higher part of the range, show folding and faulting to an intermediate degree and in general are not schistose. This association of rocks is represented diagrammatically in figure 5 by a columnar section, which shows the relations of the different formations but not their thicknesses.

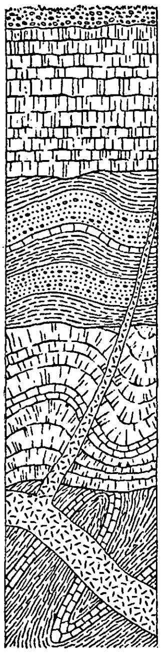


FIGURE 5.—Diagrammatic columnar section showing the stratigraphic relations of the sedimentary beds exposed in the Alaska Range between the Nabesna River and Suslota Pass.

A more detailed description of these rocks is given in the remaining pages of this report. Their distribution is shown on the geologic map (pl. 3). This map is in part a revision of the geologic map that accompanied a report[7] on the Suslota Pass district. At the time the earlier report was written the occurrence of Devonian rocks in the district was not yet known and the areal extent of the Mesozoic rocks was thought to be greater than it is. The present map therefore differs from the older one in these respects, as well as in the area covered and in the more accurate representation of formations, which has been made possible by greater knowledge and by a revised topographic base map on which to show them.

DEVONIAN ROCKS

CHARACTER AND DISTRIBUTION

So far as is known at present, the oldest rocks that crop out in the district comprise a group of beds occupying a small area extending

[7] Moffit, F. H., The Suslota Pass district, upper Copper River region, Alaska; U. S. Geol. Survey Bull. 844–C, pl. 2, 1933.

from the head of Buck Creek southeastward to the Nabesna River. The most conspicuous members of this group are limestone beds, which appear in interrupted but well-alined outcrops throughout the whole area of Devonian rocks. Most of the group, however, is made up of gray or black slate, hard, gray, siliceous beds, quartzite, yellowish, sandy, and gritty beds, cherty conglomerate, and brown mica schist. These rocks are considered together because of their association in the field, and although some of the beds contain fossils that have been identified by the paleontologists as Middle and Upper Devonian most of them are without fossils and may possibly be in part of a different age.

All of the rocks are folded and most of them are more or less schistose, but those that display the most pronounced schistosity are the beds adjacent to the great body of granitic rocks that bounds the Devonian rocks on the northeast. It is evident that the intrusion of the granitic rocks brought about important changes in the invaded sedimentary rocks, such as the development of schistosity just mentioned, recrystallization of the original constituents, and the addition of material not originally contained in the sediments, particularly quartz.

The clastic rocks occupy much the larger part of the area described as Devonian. No volcanics, such as lava flows and tuff beds, were recognized, but dark granular intrusives were noted, interbedded with or cutting across the sedimentary members, and from the degree of their alteration they appeared to be older than the diorite intrusive mass to the northeast.

The most conspicuous members of the Devonian group of sedimentary deposits are limestone beds. They owe their prominence to the peculiarity of their weathered outcrops, which because of their form and color are a notable feature of the landscape (pl. 5, *B*). The limestone is massive in structure, coarsely crystalline, and light bluish gray. Its resistance to weathering and its granular texture, together with the accidents of folding and faulting, have combined to produce an alinement of light gray pinnacles and crags that contrasts strongly with the darker background, which stands high above the associated rocks and makes it easy for the eye to follow the course of the beds for many miles across the country.

The limestone occurs in several distinct beds separated by phyllite or schist members derived from original mud and sand deposits. Because of folding and faulting these beds are difficult to distinguish from one another, and their exact number is not known. They do not crop out continuously. Doubtless some of the outcrops are parts of continuous beds, but others were either distinct lenses of limestone originally or are parts of beds that have been separated by faulting or folding and have no connection with one another.

In the divide between the north branch of Cheslina Creek and the Tetling River three distinct lines of outcrops seem to indicate three distinct beds of limestone. Possibly there are more. The outcrops extend north-northwest to the Buck Creek Valley, and in the opposite direction they continue down the Cheslina Valley and into the ridge between Cheslina Creek and the Nabesna River. Southwest of these are outcrops that indicate another distinct bed, which must be separated from the other limestone beds by a considerable thickness of the clastic sediments; but whether this limestone is stratigraphically above or below the other beds was not learned.

Not enough work has been done to determine how far the Devonian rocks may extend into adjacent areas. Moreover, it does not appear probable that their distribution in the lowland area of the lower Nabesna Valley will ever be known with certainty, for that area is occupied by unconsolidated glaciofluvial deposits that hide the underlying rocks.

STRUCTURE AND THICKNESS

So little is known about the structure and thickness of the Devonian sedimentary deposits of the area under consideration that these two features can be described only in general terms. The beds in the belt extending from the Tetling River to the forks of Cheslina Creek occupy an area that averages at least 4 miles in width. The boundary between the Devonian rocks and the Mesozoic slate and sandstone beds on the southwest probably involves both faulting and a great structural unconformity, for no Carboniferous rocks were recognized in the vicinity. The boundary on the northeast is between Devonian rocks and a complicated mass of diorite and related rocks that form the backbone of a high ridge extending from Cheslina Creek to Mentasta Pass. The diorite was intruded into the older rocks and produced marked changes in them, the most noticeable of which are schistosity and the development of new minerals. These changes are greatest near the intrusive mass and diminish away from it. Between the two boundaries the rocks are closely folded and much faulted. The only beds that are readily distinguishable are the limestones, which, however, cannot be successfully distinguished from or correlated with one another and give little aid in determining stratigraphic relations and structure. The principal limestone zone includes a number of limestone beds interstratified with sandy or shaly beds, which altogether make a thickness of several hundred feet, the largest limestone bed being 100 feet or more thick. This is the condition in the divide between Cheslina Creek and the Tetling River, where the limestone is best displayed. The limestone diminishes and finally disappears altogether in the Buck Creek Valley, but it continues down the Chesalina Valley in lines of outcrops that suggest a diverging of the beds there. The limestone is much faulted, and probably the thickness of the beds has been affected by the pressure that folded them. The field relations suggest that the beds were not of uniform thickness originally and that they may even have been interrupted, for in places they are evidently cut off along the strike. The possibility arises that the limestone beds near the Devonian-Mesozoic boundary may correspond to some of the beds of the main limestone belt and that they reappear in that location because of folding, but no evidence to support that interpretation was obtained. Since neither the top nor the bottom of the Devonian beds have been recognized and the structure involves intense folding and faulting, all that can be inferred as to the total thickness of the beds is that it is probably many hundreds if not thousands of feet.

AGE

It has been pointed out that the rocks designated as Devonian include a variety of sedimentary deposits, most of which have not yielded fossils. The limestone beds, however, are not so greatly metamorphosed as to destroy all the organic remains that were present in them originally and are sparingly fossiliferous, so that collections of fossils were made. All the fossils found are marine invertebrates and appear chiefly on weathered surface, where they stand out in slight relief but are difficult to free from the enclosing rock. They are distinguished with difficulty if at all on a freshly broken surface and are collected successfully only when weathering has been sufficient to loosen them without destroying them. The number of species collected is small,[8] but the forms are sufficiently diagnostic to indicate their geologic age, which ranges from Middle to Upper Devonian.

Devonian rocks are known in various parts of Alaska, but those of the Yukon-Tanana region [9] and of the upper Susitna Valley [10] suggest themselves first as possible correlatives of the Devonian rocks of the Nabesna area. Limestone is a prominent member in the succession of beds in both these regions, although clastic deposits in wide variety are likewise included.

INTRUSIVES

Intrusive rocks invaded the Devonian sedimentary beds and may be seen at various localities throughout the district, but their outstanding occurrence is in the high ridge north of Buck Creek

[8] Moffit, F. H., The Slana-Tok district, Alaska: U. S. Geol. Survey Bull. 904, p. 18, 1938.
[9] Mertie, J. B., Jr., The Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 872, pp. 92–93, 1937.
[10] Capps, S. R., The eastern portion of Mount McKinley National Park: Geol. Survey Bull. 836–D, 251–255, 1933.

and the north fork of Cheslina Creek. This ridge owes its existence to differential weathering and the resistance offered by the intrusive rocks to the forces that sought to destroy them and is only a little less prominent than the ridge formed by the Mesozoic beds to the south. Dikes or sills of dark granular intrusive rock were found also at several places in the hills between the Nabesna River and Cheslina Creek. They are considerably altered and do not possess features that produce any special contrast with the enclosing sedimentary beds, so that they are inconspicuous and the number of their outcrops might easily be misjudged in reconnaissance mapping. The degree of their metamorphism suggests that they are older than some, if not all, of the intrusives of the high ridge on the north, although this difference may also be due to lower power of resistance to alteration.

The main body of intrusive rocks in the high mountains north of the prominent topographic depression formed by the valleys of Buck and Cheslina Creeks extends in practically unbroken continuity from the Nabesna to the Little Tok River, a distance of 19 miles, and appears in disconnected areas still farther west. Its maximum width, in the mountains between Buck and Tuck Creeks, is 5 miles. The form of this body of igneous rocks is difficult to visualize. The exposures in some of the high mountains look like a capping of the older rocks or possibly a mass of diorite overlying but folded into the older rocks. On the other hand, the border of the diorite in places gives the impression of a contact surface dipping steeply.

This body of intrusives is complex and is made up of different rocks, most of which belong to the diorite family, but with variants having a more basic composition. In places the diorite is fresh-looking and coarsely crystalline, so that hornblende, biotite, and striated feldspars are readily distinguished with a hand lens, but more commonly it is finer in grain, is of a dull gray or slightly greenish-gray color, and has an arrangement of the minerals that suggests the gneissic structure. The microscope shows pyroxene, epidote, and chloritic materials, in addition to much plagioclase feldspar, and brings out clearly the extensive alteration that the original rock has undergone. A porphyritic variety of the intrusive is present in many places and attracts immediate attention because of the large size and abundance of the phenocrysts. The phenocrysts are chunky crystals of feldspar, which reach diameters of more than 2 inches and are twinned, as is often recognizable in the outcrop because of the way sunlight is reflected from the cleavage planes of the separate twins.

Differences in original mineral composition and in degree of alteration of the minerals and the presence or absence of secondary structures, such as schistosity, suggest that intrusion of the rocks showing these differences took place at different times, probably separated in the geologic time scale, but the only certain conclusion concerning their age that can be stated now is that they are younger than the rocks they intrude, that is, they cannot be older than Middle Devonian. Their present appearance seems to indicate that some of them are older than the Mesozoic sediments bordering the Devonian rocks on the south, but, on the other hand, some of them may be as recent as the light-colored dikes and sills that intrude the Mesozoic rocks.

PERMIAN ROCKS

CHARACTER AND DISTRIBUTION

The later part of the Paleozoic era is represented in the upper Tetling River district by Permian rocks. They are exposed within the area shown on the geologic map (pl. 3) in a belt of lava flows, intrusives, and sedimentary beds that lies on the southwest side of the Mesozoic sedimentary formations and extends from the Nabesna River to the Slana River. Actually they extend beyond these rivers in both directions but are there outside the limits set for this report. Within the area considered, the rocks are almost exclusively of igneous origin and comprise basaltic lava flows and a variety of granitoid intrusives that are prevailingly dark gray. Both the lava flows and the intrusives are metamorphosed, but only locally has the alteration been sufficient to give them a schistose structure. In general the alteration appears to be more advanced in the granitoid rocks than in the lava flows.

The lava flows are more widely distributed than the granitoid rocks and exceed them in quantity. They are dense, heavy basalts of dark gray or brownish-gray color. Commonly the surfaces of outcrops are speckled with small crystals of feldspar. Some of the lava flows are amygdaloidal, or even vesicular where the amygdules have been dissolved out. Tuffaceous beds were not recognized, although they are abundant in some areas outside the limits of the geologic map.

Only one area of Permian sedimentary beds of unquestioned age was recognized in the field work of 1938. This is the area of massive, bluish-gray limestone that is exposed in the northwest end of the ridge between Platinum and Totschunda Creeks. The limestone of White Mountain, between Jack and Jacksina Creeks, was formerly correlated on lithologic grounds with the limestone of Platinum Creek. This correlation now seems improbable. The limestone of White Mountain includes a massive basal portion, possibly 1,000 feet thick, overlain by thin-bedded limestone, which is extensively garnetized as a result of intrusion by a large mass of diorite. This limestone strongly resembles the Upper Triassic limestone of the Chitina Valley.

STRUCTURE AND THICKNESS

The structure of a complex assemblage of rocks that have been subjected repeatedly to deformation by mountain-building forces and wasted by subaerial erosion is almost necessarily complex also. Although the Permian granitoid rocks give only obscure evidence of structure, the lava flows and the limestone beds bear evidence of severe folding and much faulting. They have been subjected to at least as much deforming force as the Mesozoic beds adjoining them and in view of their greater age may well have been subjected to more. Yet it should be noted that both the lava flows and the Permian limestone are more resistant to deforming force than the shale and sandstone and the thin-bedded limestone of the younger rocks and do not exhibit as close and complicated folding in any of the exposures that were examined.

Estimates of the thickness of the bedded parts of the Permian rocks as they occur in the area studied are only rough approximations and must be considered in connection with the results of measurements in other neighboring areas, if a just estimate is to be had. An estimate of the minimum thickness of the lava flows would not be less than 1,000 feet. The limestone of White Mountain is nearly that thick, although the limestone of Platinum Creek is considerably less. These figures are given as suggesting the order of magnitude of the thickness rather than as actual measurements. It seems probable that the lava flows are much thicker, for the Permian beds of the Mankomen formation in its type locality are dominantly lava flows and tuffaceous beds and have a thickness of at least 6,700 feet.[11]

The Permian rocks of this district are not known to overlie or adjoin older rocks from which they can be differentiated and furnish no recognized evidence for suspecting that any of the lava flows or limestone beds are the base of the series, which consequently has not been identified. On the other hand, they are in contact with Mesozoic beds along their north boundary from the Nabesna River to Suslota Pass. This boundary probably represents a depositional and structural unconformity and possibly a fault of great magnitude in addition.

The oldest of the Mesozoic rocks are beds of Upper Triassic limestone, which occur interruptedly at various localities along the boundary, as will be seen on the geologic map. Where the limestone is absent other younger Mesozoic beds come in, and, as will be pointed

[11] Mendenhall, W. C., Geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, p. 40, 1905.

out later (p. 135), probably involve unconformity within the assemblage of Mesozoic sedimentary beds as well as at their base.

A great fault marks the boundary of Permian and Mesozoic rocks on Totschunda Creek and brings the older lava flows and the limestone into contact with the younger shales. Although this fault has not been traced in detail, it is thought to extend southeast across the Nabesna River and probably to be identical with the great fault that Capps [12] describes as bringing the Devonian and Carboniferous (Permian) beds on the south into contact with the Cretaceous beds on the north in the Chisana district.

This fault is the site of the "soda springs" (pl. 6, *A*), at the head of Soda Creek, and probably was a contributing cause of the landslide that produced the lake near the springs.

AGE AND CORRELATION

The Permian rocks of the Nabesna district, as they have been described in previous pages, are not truly representative of the thick series of bedded deposits of which they are a part. This series extends along the south side of the Alaska Range and the northeast border of the Wrangell Mountains from the head of the Slana River to the White River within the Territory of Alaska. Mendenhall [13] described the occurrence of Permian rocks in the upper Slana River district and gave them the name "Mankomen formation." Capps [14] later gave an account of their occurrence in the southern area, where they have a wide distribution, and in accordance with the interpretation of that time (1916) regarded them as of Carboniferous (Pennsylvanian) age. On the basis of later work and additional collections of fossils, George H. Girty, who made most of the original determinations, came to the conclusion that all the collections previously regarded as Pennsylvanian should be classed as Permian. This is the interpretation followed in this report.

A small collection of typical Permian fossils was obtained from the limestone area of Platinum Creek,[15] or its tributary, Soda Creek, where the lime beds rest on the lavas. No other collections of Permian fossils were made between that locality and Suslota Pass. Fossils were not found in the limestone of White Mountain, but the beds that formerly were doubtfully correlated with the Permian limestone of Platinum Creek are now regarded as probably of Upper Triassic age.

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[12] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, p. 32, 1916.

[13] Mendenhall, W. C., op. cit., pp. 40–51.

[14] Capps, S. R., op. cit., pp. 33–47.

[15] Moffit, F. H., The Suslota Pass district, upper Copper River region, Alaska: U. S. Geol. Survey Bull. 844–C, p. 147, 1933.

It appears from what has been said that the evidence for the age of some of the rocks that are classed with the Permian deposits is not sufficient to eliminate the possibility of their being older than Permian. In other areas, such as that of the White River district, the fossiliferous Permian limestones and limy tuffs are interstratified with lava flows and tuff beds and occupy the median position, being underlain and overlain by the volcanic deposits, which exceed them in thickness. This relation makes it difficult to determine the age of the underlying lavas or other igneous rocks and leaves open a question as to their being correctly assigned to the Permian epoch, since it is possible, so far as the evidence of the fossils is concerned, that they may be older.

The intrusives that cut the Permian beds are in part younger than the Mesozoic rocks, that is, they are not older than Lower Cretaceous; in part they are older than the Mesozoic rocks, or older than Upper Triassic. This age relation is suggested by the degree of their metamorphism, for some of the intrusives are less altered than the others and are comparable in this respect to the dikes and sills that intrude the Mesozoic beds. The older intrusives may belong to one or more periods of intrusion but have not been differentiated from one another on the basis of age.

UNDIFFERENTIATED PALEOZOIC ROCKS

The rocks that are shown on the geologic map as undifferentiated Paleozoic rocks occur in the northern section of the district, and in only a small part of it. They lie outside the area visited in 1938 and will be described only briefly, since they are considered in more detail in a previous report.[16]

The prevailing rocks of the group are slate and argillite, but conglomerate, quartzite, grit, graywacke, and limestone are also present. Locally some members of the group show metamorphism and are schistose. The principal areas of these rocks represented on the geologic map are two mountain masses, one northwest of Suslota Pass and the Little Tok River and the other north of Tuck Creek. Fossils have been found in the limestone beds of the first area but not in the second. These fossils are of Permian age, with the exception of those from one locality, which are Devonian. Those of Devonian age are so intimately associated with Permian rocks that a differentiation between Devonian and Permian beds was not made. However, it seems probable that most of the undifferentiated Paleozoic rocks northwest of Suslota Pass and the head of the Little Tok River will prove to be Permian beds into which a small proportion of Devonian beds have been folded.

[16] Moffit, F. H., Geology of the Slana-Tok district, Alaska: U. S. Geol. Survey Bull. 904, pp. 27–30, 1938.

Less reason is known for regarding any of the undifferentiated beds north of Tuck River as Permian. These beds differ from those west of the Little Tok River in having a greater proportion of sandstone or quartzite and in being intruded by numerous sills of dark, medium-grained rock, which in different localities may be described as basalt, diabase, or basic diorite. Such sills are most common on the Tuck Creek, or south side, of the mountain ridge.

The undifferentiated Paleozoic beds are intruded by granitic rocks in the form of dikes, sills, and irregular-shaped bodies, which appear from their differences in metamorphism to belong to more than one period of intrusion. Most of these intrusives, including the great body forming the ridge between Buck and Tuck Creeks, are diorite, but more basic varieties are common.

So far as is known, no reason exists for supposing that the undifferentiated beds include rocks of any other age than Devonian and Permian, unless lower Carboniferous beds are also present. Some suggestion of this has been found in the fossils, but not enough to warrant a definite statement in the matter. Further, more detailed work should clear up this point as well as make it possible to separate the Devonian and Permian rocks from each other and to gain a better knowledge of the thickness of the beds that they comprise. In either group the thickness must amount to several thousand feet.

MESOZOIC ROCKS

CHARACTER AND DISTRIBUTION

The Mesozoic rocks of the upper Tetling River district are marine sediments, without known interstratified lava or tuff members, and comprise fewer types of rock than either the Devonian or Permian formations. They are predominantly shale or argillite and sandstone but include important grit and conglomerate members and a relatively insignificant proportion of limestone. The most outstanding feature of the Mesozoic rocks is their ribbonlike banding, which is due to the alternation of thin beds of shale with thin beds of sandy shale or sandstone that is characteristic of a large proportion of them.

The Mesozoic beds occupy an area that has an average width of about 10 miles, and extends from Suslota Pass to the Nabesna River and thence, outside the limits of the geologic map, nearly if not quite to the international boundary. They make up much the larger part of the mountains to which the name Nutzotin more properly applies and give rise to a characteristic landscape, which, when viewed from some high point, especially from the Tanana Valley side, presents a maze of narrow valleys and sharp peaks, many of which rise above the level of perpetual snow.

Between the Nabesna and Chisana Rivers the mountains stop abruptly at the margin of the lowland area and present a nearly straight front. North of the Nabesna, although the straight front is maintained, they are separated from the lowlands by groups of lower mountains and rounded hills, so that they are less marked as an individual mountain chain.

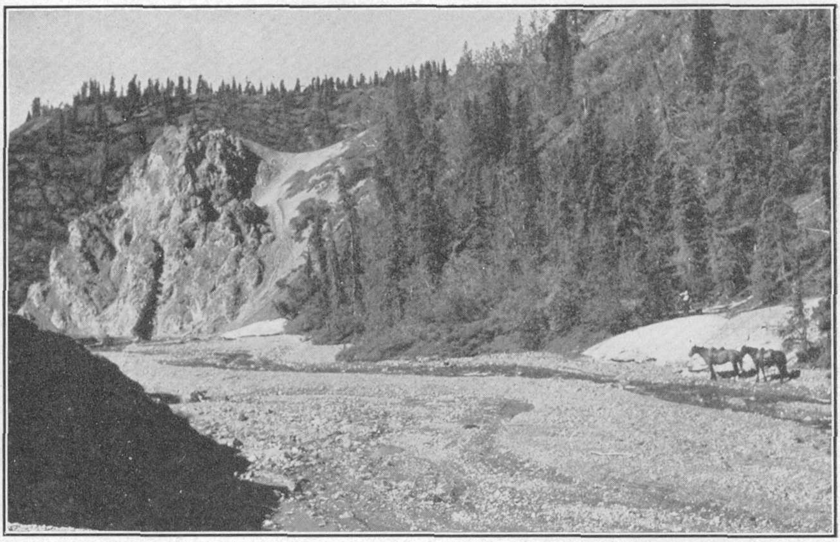
In the vicinity of Suslota Pass the Mesozoic rocks consist of alternating thin beds of dark-gray shale and lighter-gray sandy shale or fine sandstone. These beds occur in pairs. The lower member of the pair is the sandy bed, which grades into the overlying dark shale member without any sharp line of demarcation. On the other hand, the boundary between the shale and overlying sandy bed is distinct. In many places an individual bed 2 inches thick is difficult to find, and beds less than 1 inch thick predominate. As a result of the alternation of light and dark beds the rocks have the banded appearance previously mentioned. The banding is most pronounced on weathered surfaces and may not be visible on a freshly broken surface, although with increase in the proportion of quartz sand in the lower member of the pair the contrast of color is also increased. The lighter or sandy beds are fine-grained, so that even the hand lens does not distinguish individual sand grains. The shale beds are also fine-grained and commonly without cleavage. Possibly argillite would be a better descriptive term for the dark beds than shale. In a few places the banded rocks are cut by intrusives, which have silicified and whitened the sandy beds and thus greatly increased the contrast of color.

As the banded rocks are followed southeastward across the Tetling River and the head of Cheslina Creek toward the Nabesna River, the average thickness of the bands increases gradually, the grain of the material in the sand beds becomes coarser, and the proportion of sandstone to shale also increases. Occasionally a bed of sandstone several feet thick may be seen, as well as beds of grit and conglomerate. Also a very coarse conglomerate with a large proportion of limestone and diorite pebbles and diorite boulders and blocks of limestone several feet in diameter makes its appearance in the higher mountains and in the stream and morainal deposits derived from them.

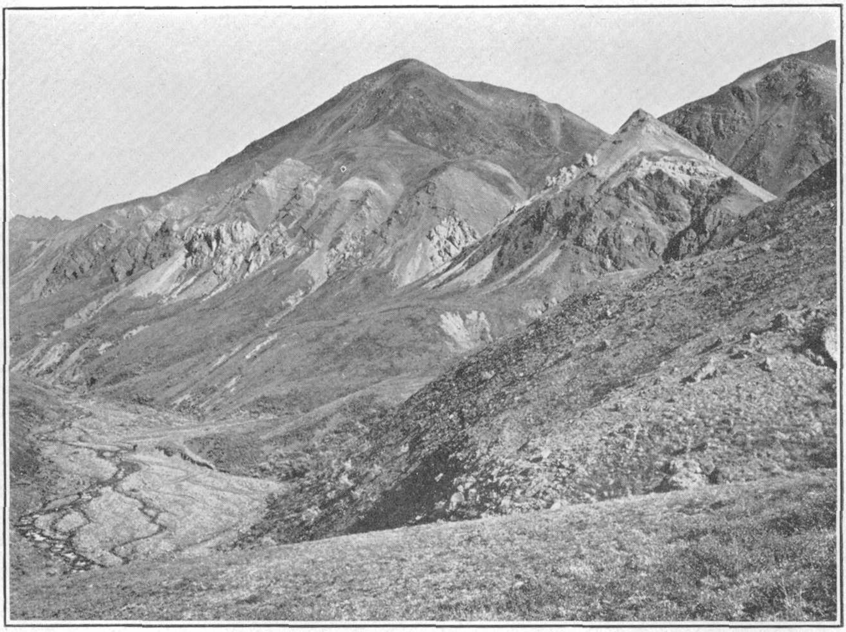
On the southwest side of the area of Mesozoic rocks, black or dark-gray shale without the characteristic banding, gray shale with scattered pebbles, and a massive limestone overlain by thin-bedded limy argillite appear in addition to the banded beds. The dark-gray shale is the lowest member of the succession, except the limestone, and is generally present on this side of the area.

THICKNESS AND STRUCTURE

The Mesozoic beds are structurally unconformable to the Devonian rocks on the northeast and the Permian rocks on the south-

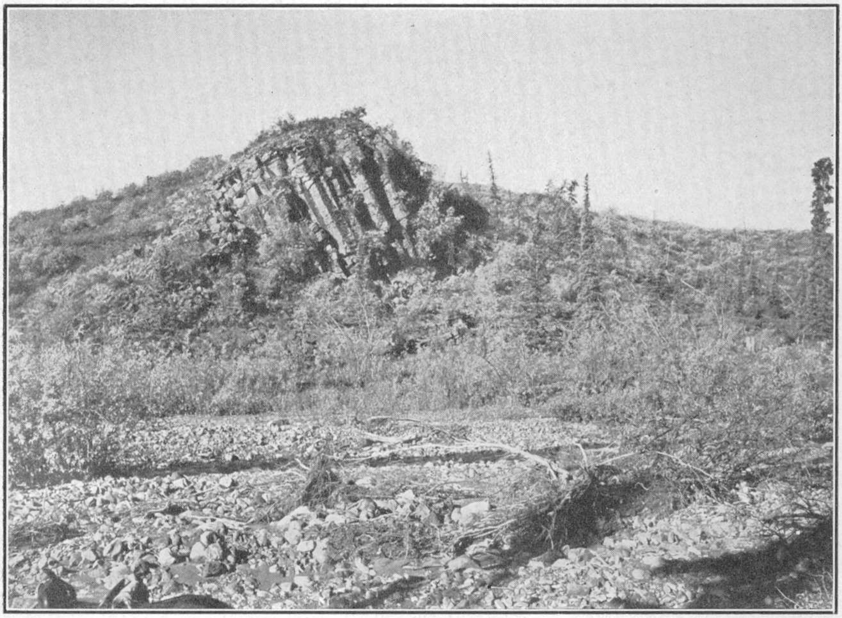


A. DEPOSITS OF TUFA AT MINERAL SPRINGS NEAR THE HEAD OF SODA CREEK.

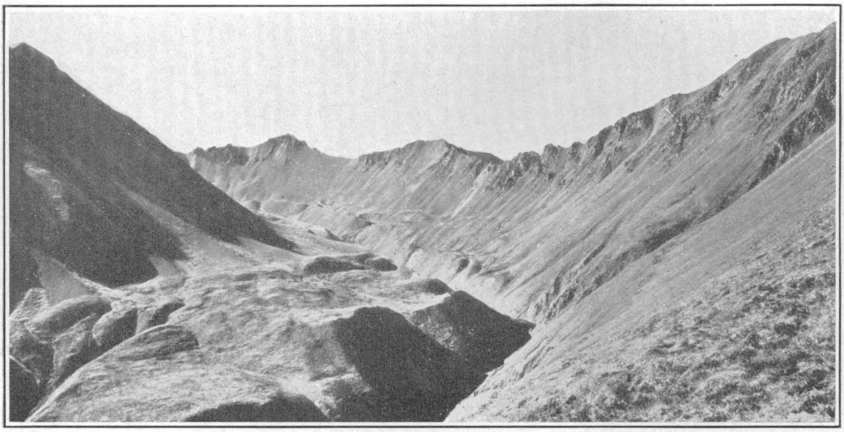


B. VIEW ON LOST CREEK SHOWING DARK PERMIAN LAVA FLOWS IN THE FOREGROUND.

The Permian lava flows are overlain by a thick bed of Upper Triassic limestone, on which rests thin-bedded limestone, also of Upper Triassic age. The dark rocks forming the mountain tops are shale and sandstone, partly of Upper Jurassic age and partly Lower Cretaceous.



A. COLUMNAR BASALT OF TERTIARY AGE ON THE WEST SIDE OF TRAIL CREEK ABOUT 3 MILES FROM THE HIGHWAY.



B. MORAINAL DEPOSITS AT THE HEAD OF TRAIL CREEK.

west. This relation results in part from original deposition of the sediments on beds that were already folded and eroded and in part from faulting, which took place long after the Mesozoic beds were laid down. Which condition holds at a definite locality may be difficult to determine; in fact, the depositional unconformity is as much a matter of inference as of observation. Yet the greater metamorphism of the older rocks and the absence of beds that should be present somewhere between the Mesozoic and older rocks leave little doubt concerning the depositional unconformity. Fault contacts of the Permian and Mesozoic beds were seen at a number of places, especially on Soda Creek, which is probably one of the best examples.

The Mesozoic rocks form a great synclinorium in which the beds of the southwest side lie in broad, open fields, whereas those of the northeast side lie in closely compressed and even overturned folds. However, the structure is more complicated than the foregoing statement implies, for it is probable that two minor unconformities occur within the Mesozoic beds themselves. A massive bed of Upper Triassic limestone, probably more than 100 feet in maximum thickness and overlain by thin-bedded limestone or limy argillite of somewhat greater thickness, overlies the lava flows that make up the lower slopes of the mountains between Lost Creek and Little Jack Creek. (See pl. 6, *B*.) No other Upper Triassic rocks are known nearer than Cooper Pass, southeast of the Nabesna River. These beds are overlain by shale beds, which may be Jurassic or Upper Triassic but more probably are Lower Cretaceous, as Lower Cretaceous fossils were collected from shales in the vicinity. Finally, the higher part of the backbone of the ridge between Suslota Pass and the Nabesna River is a massive conglomerate or succession of interstratified conglomerate and sandstone beds, in which the basal part contains much coarse material, including boulders of different igneous rocks and numerous large blocks and smaller fragments of limestone. Fossils were collected from some of the limestone blocks, but they are not sufficiently diagnostic to determine the period in which the animals that they represent lived more closely than Mesozoic.

These relations are interpreted as indicating a structural unconformity between the Upper Triassic limestone and the overlying shale and probably a second unconformity at the base of the coarse conglomerate within the shale-sandstone-conglomerate group. The evidence at hand seems to indicate that the first unconformity is the greater—that the limestone and thin-bedded argillite were folded and partly removed by erosion before they were buried under younger deposits. The second unconformity, if it exists, is thought to involve only a minor discordance of structure.

In a general way the sequence of Mesozoic beds in this district is as follows. At the base are the massive limestone and overlying thin-bedded limestone or argillite. They are overlain unconformably by dark-gray shale containing rare isolated limestone bodies and grading upward into banded shale and fine sandstone, which toward the southeast become progressively more sandy and include beds of yellowish-gray sandstone, grit, and fine conglomerate. Limestone is rare in these beds. Finally, at the top of the section are the previously mentioned alternating beds of coarse conglomerate and sandstone with a minor proportion of shale, which appear to lie unconformably upon the older deposits.

Only a rough estimate of the thickness of these beds can be made with the data at hand, but such an estimate, even if inaccurate, gives a better concept of the great volume of the deposits than can be had without it. The three principal divisions of the Mesozoic beds have been outlined and will be considered, beginning with the oldest.

The limestone that is exposed in the mountains from Lost Creek to Little Jack Creek is only part of the bed, or beds, originally laid down there. The rest has been removed by erosion or concealed through the accidents of folding and faulting. For this reason the limestone appears to vary in thickness at different localities, and it becomes necessary to choose for measurement the place where the greatest known thickness is shown. One of the small eastern headwater tributaries of Lost Creek has cut a canyon across the boundary of the Mesozoic rocks and the underlying lava flows. This canyon exposes slightly more than 100 feet of massive gray limestone, which is overlain by several hundred feet of highly contorted, thin-bedded limestone, or limy argillite. The relations of these rocks are complicated by faulting and intrusion, but the locality gives an exposure where the beds are as thick as in any locality so far examined. For the present, therefore, the limestone and limy beds of this vicinity may be regarded as probably not more than 500 feet thick.

The limestone is overlain by dark-gray shale, which is exposed from Suslota Creek to the Nabesna River and forms the lower part of a great accumulation of deposits made up mostly of shale and sandstone. A section beginning at the forks of Soda Creek and continuing northward up the stream was measured by pacing and was found to include approximately 1,500 feet of shale, intruded by numerous dikes and sills but without conspicuous banding, which dips northward under banded shale and sandstone. The dark-gray shale is adjacent to a great east-west fault and shows folding and shearing, which may have obscured an original banded structure, although little evidence of such banding is now recognizable.

From the measured section the banded rocks continue northward across the direction of strike into the high mountains, where they are overlain by the coarse conglomerate and sandstone beds of the high peaks. The banded rocks of this vicinity dip north into the mountains and are estimated to be at least 2,000 feet thick.

Although conglomerate beds are interstratified with the shale and sandstone in many places, they are made up of well-rounded gravel of fine or medium size and can be distinguished from the overlying coarse conglomerate and sandstone that rest unconformably on them. These later beds are subordinate in amount to the shale and shale-sandstone beds but are estimated to be not less than 1,000 feet thick. They include not only the basal part, made up of alternating deposits of coarse conglomerate and sandstone in beds ranging up to 50 feet or more in thickness but also an upper part, which includes conglomerate, sandstone, and banded sandstone and shale.

From the figures that have been given, it appears that the total thickness of the Mesozoic beds approaches 4,000 feet, but it should be kept in mind that these figures represent minimum thickness and that the true thickness may prove to be much greater. The estimates are not the results of careful measurements but are based on the field observations and a study of the topographic map. They are tentative and will doubtless require correction when more information from the remainder of the district is obtained.

INTRUSIVES

Dikes and sills of igneous rock were intruded into the Mesozoic beds in many places but are not uniformly distributed throughout the area occupied by such beds nor through the whole of the stratigraphic section. They are especially common in the more shaly lower beds on the southwest side of the area of Mesozoic rocks, where, because they contain a small proportion of iron sulphides themselves or possibly were accompanied by sulphides at the time of intrusion, they give to the host rocks a rusty color, which is conspicuous on the weathered surface of the mountain slopes. The name "Totschunda Creek" is derived from Indian words meaning "red stone" and is appropriate, as the rocks of this appearance are readily traced from the north side of the Totschunda Creek valley to Suslota Creek.

Most of the dikes are of the diorite family and range from medium-gray, fine-grained rocks, in which individual crystals are scarcely distinguishable, to light-gray, porphyritic rocks with abundant small phenocrysts of hornblende and larger phenocrysts of feldspar as much as half an inch in diameter. A few dikes of dense black basaltic rock were seen.

The time of intrusion of the igneous rocks is not closely determined. Probably the dikes and sills belong to more than one period of intrusion. The most abundant dikes appear to be in the lower part, possibly the lower third, of the shale-sandstone beds, but it will not be possible to say whether the intrusion took place before or after

Lower Cretaceous time or whether it may have taken place both before and after until the differentiation between Upper Jurassic and Lower Cretaceous beds has been made.

AGE

Fossils are few in the Mesozoic rocks, and not more than 20 different species have been collected, yet they are of such kinds as to leave no doubt concerning their Mesozoic age. The largest number of species from a single locality comes from the limestone of Lost Creek. This collection contains a fauna [17] that was unknown in North America previous to this discovery and offers a problem of determining the position of the fossils within the Triassic period. However, when studied in connection with other collections it leaves little if any doubt that the limestone is Upper Triassic. Upper Triassic fossils were not found in the shale overlying the limestone, so that no fauna like that of the McCarthy shale [18] of the Chitina Valley is known in the vicinity, and the McCarthy shale is not recognized here.

A few fossils have been found in the beds that overlie the Upper Triassic limestone. They come from widely scattered localities in the shale-sandstone area and constitute a scanty fauna. Fortunately two of the species of pelecypods that were collected are characteristic of definite geologic epochs, one of the Upper Jurassic, the other of the Lower Cretaceous, so that the occurrence of rocks belonging to these two epochs is established on paleontologic grounds. A differentiation of the Upper Jurassic from the Lower Cretaceous beds has not been made, but it is doubtful that the coarse conglomerate with abundant limestone blocks, which has been described, indicates the beginning of the Lower Cretaceous deposition.

Mesozoic sedimentary beds are widely distributed in Alaska. Beds that correspond in age to the Mesozoic beds of the Nabesna district and resemble them in many respect occupy large areas on the north side of the Chitina Valley and have recently been described.[19] Although the two areas are separated by high mountains made up chiefly of Tertiary lavas and other volcanic deposits, they must have been deposited under similar conditions and at one time may have been continuous deposits.

TERTIARY VOLCANICS

CHARACTER AND DISTRIBUTION

Although the Tertiary volcanics of the Wrangell Mountains are outside the area with which this report is chiefly concerned and re-

[17] Moffit, F. H., Geology of the Slana-Tok district, Alaska: U. S. Geol. Survey Bull. 904, p. 32, 1938.

[18] Moffit, F. H., Geology of the Chitina Valley and adjacent area, Alaska: U. S. Geol. Survey Bull. 894, p. 62, 1938.

[19] Moffit, F. H., op. cit. (Bull. 894), p. 42 et seq.

ceived little attention during the field studies, they should have some consideration here as being the top of the stratigraphic section and the youngest of the consolidated rocks shown on the geologic map.

The Tertiary volcanics make up most of the Wrangell Mountains and cover an area roughly 100 miles long by 50 miles wide. Only a small part of this area is shown on the geologic map. It includes the mountains south and east of Tanada Lake, which are made up of nearly horizontal lava flows. The Wrangell lavas welled out from a large central area where thousands of feet of volcanic material was piled up in the course of eruptions many times repeated. Toward the margins of the area the lavas thinned out and then stopped altogether. At times the outflow of liquid rock was accompanied by the expulsion of fragmental material, which was thrown out with explosive violence, yet fragmental deposits of this kind appear to make up only a small proportion of the whole mass in this vicinity.

From observations in different localities it is evident that the thickness of the accumulated flows varies widely from place to place. Probably the greatest thickness will be found around the vents, such as that of Mount Wrangell, where it reaches many thousand feet. Such localities are not representative. The thickness of the lavas of Castle Mountain, west of Russell Glacier, is somewhat more than 3,000 feet.[20] This locality is not near any known volcanic vent of the Wrangell type, and the thickness here probably is representative of much of the area.

In general the flows are andesitic and basaltic lavas of various colors, particularly deep shades of brown, red, and green. The tuff beds and other fragmental deposits commonly show brighter, more contrasting colors. Some of the lavas are porphyitic, some are vesicular, and in some the vesicles have been filled with secondary minerals, such as quartz, which in places is blue and produces amygdules of especially attractive appearance.

Bedding is a notable characteristic of the lava flows and in many parts makes it possible to identify them at a distance, especially in the high peaks where the rock walls are nearly perpendicular. This structure is emphasized by a light fall of snow, which brings out the terraces and flat tops of the hills. Columnar structure is common but is not conspicuous in most of the exposures, although several small areas of lava between Platinum and Lost Creeks are particularly fine examples of columnar jointing. (See pl. 7, *A*.)

The Nabesna River, Jacksina Creek, and Jack Creek have cut into or through the lavas, so that parts of these streams are flowing

[20] Moffit, F. H., op. cit. (Bull. 894), p. 96.

on rocks that underlie the lava. In this way outliers of the lavas, cut off from the main body, were formed on the north side of Jack Creek and in other places. Difficulty in distinguishing these more recent lavas from the Permian lavas sometimes arises, because part of the Permian lavas are vesicular and almost as fresh-appearing as the later flows. This difficulty is more likely to arise where the amygdules have been dissolved out from the Permian flows. In general, however, the Permian lavas are somewhat altered and less fresh in appearance.

AGE

Outpouring of the lavas of the Wrangell Mountains began in early Tertiary time and has continued intermittently to the present, as is shown by the fact that the most recent lavas cut unconsolidated morainal and stream deposits and that Mount Wrangell still emits steam and occasional light falls of volcanic ash. The earliest lavas were poured out on a land surface that had long been above sea level and had undergone extensive erosion yet still showed considerable relief. The surface doubtless included low-lying areas with lakes and swamps and meandering watercourses and higher areas with rounded hills from which the streams brought down the sand and gravel and other waste products that weathering produced. Although the base of the lava flows in the Nabesna district was not examined and the relation of the flows to the underlying rocks is not known from nearby observation, it doubtless is true that future investigation will reveal the presence of an old weathered land surface with the same characteristics as that which was recognized in the Chitina Valley.

Evidence for determining the age of the earliest of the flows was not obtained in the Nabesna district but has been found elsewhere. At several places in the Chitina Valley [21] the earliest lava flows rest on freshwater beds, which include fine clays, limy beds, conglomerate, and coal, and have yielded good collections of plants that are of Tertiary (Eocene) age. The lavas therefore appear to have been erupted during that comparatively recent geologic time when most of Alaska is thought to have been a land on which vast bodies of freshwater deposits were accumulating and thick and widespread beds of peat and other vegetation, now mined as coal, were being laid down. Although these land deposits are not old in the geologic sense, they are old in the sense of having been exposed to weathering and erosion sufficiently long for the carving of deep valleys and the removal by the streams of many cubic miles of the material even in such resistant rocks as the lavas of the Wrangell Mountains.

[21] Moffit, F. H., op. cit. (Bull. 894), pp. 94–98.

UNCONSOLIDATED DEPOSITS

The unconsolidated deposits of the Nabesna district are of Pleistocene and Recent age and include the loose material that accumulates on hill slopes and mountain sides as the result of weathering, the heterogeneous fragmental material transported and deposited by ice, and the assorted silt, sand, and gravel laid down by streams or the water of ponds and lakes. These unconsolidated deposits cover so much of the area that if they were shown accurately on the map little else would be represented.

Generally the loose rock waste on hill slopes has not traveled far and is made up of fragments of bedrock of the nearby vicinity, which show wide variation in size. For the most part these fragments are angular and have received no more sorting by water than results from the action of rain and melting snow. Mixed with the remains of dead plants and other organic material this deposit forms the soil of the hillside. It is the source from which the other unconsolidated deposits are derived, but it needs no further consideration here.

The unconsolidated deposits that are more commonly considered are glacial deposits and the deposits laid down by water. As many of the water-laid deposits of the district were derived from glacial deposits, the glacial deposits will be described first.

All of the mountainous area of the district was once buried under ice, which in places reached a depth of many hundreds or thousands of feet. This ice gradually melted till now only a few small glaciers at the heads of streams in the higher mountains remain. It is thus much less effective as a carrier of rock debris than formerly, but during the many long years while it occupied the valleys it was loaded with rock waste that rolled down from the mountains or was picked up from the valley floors and carried away. Much of this material was transported many miles from its source, and eventually all of it was either delivered to the streams to undergo sorting, wear, and deposition, or was left just where the ice dropped it as melting took place.

In the open valleys, such as that through which the highway passes, or on the high, flat land between the upper Tetling and the Nabesna Rivers the deposits are largely unsorted debris but in places include washed gravel. For the most part the deposits are shallow, but are crossed by ridges that may be terminal moraines or possibly deposits of the esker type, in which the thickness is greater. Small mounds or hillocks of similar deposits are also present.

Well-defined terminal moraines are uncommon in the district, except at the margins of the present glaciers. Terminal moraines are generally destroyed almost as fast as they are formed by the streams coming from the ice. Nearly all those that remain are in the more open valleys, where the water was probably less confined and had an opportunity to spread out or was diverted, so that the moraines escaped destruction.

The district nevertheless furnishes many excellent examples of morainal deposits built up by the valley glaciers, for most of the streams heading in the high mountains of the shale-sandstone area have deposits of this kind in their headwater valleys (pl. 7, *B*). Doubtless the large number and unusual development of the moraines is due to the rapid weathering of the country rock. In many places it is clear that the moraines cover stagnant ice at the lower ends of small glaciers, which still show white ice in their upper parts. In other places no glacial ice is in view, but stream cutting or some uncommon condition favorable to melting discloses clear ice beneath a thick cover of glacial debris. Such facts suggest that probably most of these morainal deposits in the upper valleys have a core of ice so well insulated from air, flowing water, and melting temperatures that it has been preserved for an indefinitely long time. The lower ends of most of the large glaciers of the Wrangell Mountains are covered with debris that remains on the surface when the surface ice melts. The thickness of these accumulations is commonly not so great as to obscure the relation of the debris to the ice beneath. In this respect the deposits described are somewhat different, for as a rule they are so thick as to give little suggestion of the underlying ice and in places are even covered with vegetation.

An excellent example of the moraines is found at the head of the south fork of Cheslina Creek, where the heaps of loose rock waste cover the narrow valley floor for a distance of nearly 4 miles; yet other examples are found on almost every major stream heading in the area of Mesozoic rocks. They are absent, however, in the mountains northeast of the valley of Buck Creek and the depression between the Tetling and Nabesna Rivers.

The unconsolidated deposits laid down by water originated in part through the ordinary processes of weathering and erosion and came to their present location without the intervention of glacial ice. Probably a much larger part was contributed directly to the streams by glaciers or was derived from morainal heaps that were formed by the glaciers but were removed and redeposited by the streams.

Transportation by running water tends to reduce the size of rock fragments by the grinding of one piece on another and to round the sharp edges and corners of angular pieces. It also sorts the fragments according to size and specific gravity and moves them greater or less distances in accordance with this sorting and the swiftness of the currents. Material that has undergone such treatment makes up the flood-plain gravels of the streams, the lake or quiet water deposits, and the bench or terrace gravels of the Nabesna district. Such deposits occupy the lowland areas and valley floors and in many places are so intermingled with morainal deposits and so obscured by vegetation that no attempt is made to differentiate them on the geologic map.

Some kind of water deposit, ranging from beds of fine silt and sand to coarse, rudely stratified gravel, is formed by practically every stream or lake. Low gravel terraces border most of the stream courses and many lake shores and are commonly overgrown with timber or other vegetation. Conspicuous high benches that were formed at a time when the glaciers were more extended and active than at present occur in various localities, particularly at the head of Suslositna Creek and the south fork of Cheslina Creek. The high benches of Cheslina Creek, which slope downstream at a slightly steeper grade than that of the present stream bed, were formed in part through the erosion of the bedrock by glacial ice, but they bear deposits of gravel and morainal material on their surfaces. The high benches of Suslositna Creek were formed by water from the Copper River basin that spilled over the divide at the head of the creek and flowed through Suslota Pass to the Little Tok River. The surface of these deposits slopes gently downstream with practically the same grade as the stream bed and 150 feet above it in places. High gravel terraces of somewhat similar origin and age were formed where streams were impounded by the ice at the margin of the glacier. The best example of this mode of origin is at the west end of the canyonlike valley leading from the head of Suslositna Creek to the southern headwater tributary of the Little Tok River, where benches more than 200 feet high occupy the entrance to the valley.

The Nabesna River and other streams flowing from the east side of the Wrangell Mountains transport great quantities of rock debris, which they receive from the glaciers at their heads and move gradually from the mountain area to the broad, open valley of the upper Tanana River. There they spread it out over the lowlands more rapidly than they can remove it, thus building up the land in this part of their courses while lowering it in their headwater regions. This process has gone on for a long time and has resulted in burying the bases of some of the isolated hills of the lowland area with gravel, so that their lower slopes meet the gravel plain at an angle instead of in the usual gentle curve.

The lowlands are poorly drained, dotted with lakes, and crossed by wandering stream channels. Apparently the deposits there are all of the fluvial or glaciofluvial kind. Possibly the ice at the time of its greatest advance may have moved out onto the lowlands from valleys like that of the Nabesna River and left morainal deposits. Although such deposits may exist, they were not seen by the writer, as the route of the Geological Survey expedition did not cross that part of the country.

A kind of unconsolidated deposit that is of relatively little importance as compared with the deposits laid down by water and ice consists of fine material transported by the wind. These wind-laid deposits are formed chiefly near the broad flood plains of the larger glacial streams, such as the Copper and the Nabesna Rivers, where the air currents pick up the dust from the gravel bars and whirl it away till they lose the power to carry it farther. Deposits of this kind, consisting of dust and fine sand, make up a considerable proportion of the river bluffs at Slana. Probably they also form part of the soil of the lowland areas, for some of the fine dust is carried for long distances by the air currents. Such deposits may have been more abundant at a former time, when the glacial streams were larger and carried more load than at present and wider floodplains were exposed to the wind.

No unconsolidated deposits of preglacial age were recognized. Doubtless they existed at one time, but seemingly they were swept from the valleys as the ice advanced from the high mountain areas and were either incorporated in the lowland deposits or were carried away by the streams. At the time of maximum glaciation the valleys must have been devoid of all preglacial unconsolidated deposits.

The Recent deposits began to be formed when the retreat of the ice began. They occupied the land as it was freed from the covering of ice and followed the front of the ice as it withdrew into the valleys. Their existence is temporary, and from a geologic point of view they should be thought of as taking part in a continual migration toward the sea, a migration that is interrupted repeatedly and for long periods of time but that will be completed eventually.

GEOLOGIC HISTORY

Present knowledge permits only a brief account of the geologic history of the country shown on the geologic map. Furthermore, this account includes only a few such outstanding events as have left understandable evidence of their occurrence and probably omits equally important events for which the evidence is lacking or is not recognized and understood.

The story begins with the deposition of the Devonian sediments that are exposed on Buck and Cheslina Creeks. These deposits indicate that the sea then covered the land and continued to occupy it for a long time, during which thick beds of shale, sandstone, fine conglomerate, and limestone were formed. The beds appear to indicate an absence of volcanic activity in the area at that time, for they are not known to include tuffs and lava flows as do the Devonian sedimentary beds of the Yukon-Tanana region.

Clear evidence of the relation of the Devonian rocks to the Permian and of the events that occurred during most of the Carboniferous period is lacking. The absence of any deposits belonging to this intervening time may indicate either that the land was above the sea or that if it were submerged and deposits were formed they were removed by erosion before the Permian epoch began. Probably the Devonian beds were folded and were above sea level during part of earlier Carboniferous time. At any rate they are more metamorphosed than the younger rocks. Some intrusion by igneous rocks probably occurred in this time also.

The Permian was a time of exceptional volcanic activity, which was accompanied by the extrusion of a great thickness of lava and the eruption of tuffaceous material. It also was a time when marine sediments were deposited. These sediments are chiefly limestone and limy tuffs, which nearly everywhere are somewhat fossiliferous and in places contain the remains of marine invertebrates in great abundance. The intermingling of volcanic rocks and sediments suggests that part of the lavas may have been poured out in the sea. Yet the pillow structure, which is sometimes formed when lavas are erupted under water and which would be considered as good evidence for submarine extrusion in this district, was not found. The evidence that is afforded by neighboring districts seems to indicate that the Permian epoch began with volcanism and ended with it.

Lower and Middle Triassic rocks are not certainly known in Alaska, and it is probably true that their absence indicates that most of the land was above the sea in that part of Triassic time. The Permian and Mesozoic rocks are in contact all the way across the area shown on the geologic map, but part of this contact is a fault contact, which increases the difficulty of determining the depositional relation of these groups of rocks. However, it is believed that the laying down of the earliest Mesozoic beds began when the land was submerged after a long period of erosion in Lower and Middle Triassic time, during which lavas may have been erupted but no sedimentary beds were formed.

The Upper Triassic limestone and the overlying thin-bedded shaly limestone were formed in a sea that probably was warm at first but later, for reasons that are not understood, became colder, as is shown by a change in the types of animals that lived and died there. So far as is known from exposures in this area, the Upper Triassic deposits include only limestone and shaly limestone. Although the Upper Triassic limestone of the Chitina Valley is overlain by shale known as the McCarthy shale formation, no corresponding shale was recognized in the Nabesna district, notwithstanding the fact that the typical fauna of the McCarthy shale is present in the limestone. Absence of the shale in one locality may indicate only that it has been removed by erosion and not that it was never present there.

The events of Mesozoic time following the deposition of the Upper Triassic limestone, like those following the deposition of the Devonian rocks, are obscure. The limestone was folded by mountain-building forces and was raised above sea level; then it underwent a long period of erosion during which much of it was removed. Whether this folding and erosion preceded or followed the deposition of the Upper Jurassic shale or whether it both preceded and followed it is not yet determined, but without doubt it preceded the deposition of the Lower Cretaceous beds, which are much less deformed. The most probable interpretation appears to be that the limestone was strongly folded and subjected to prolonged subaerial erosion and then depressed below the sea and covered in part or wholly by deposits of mud and sand in Upper Jurassic time. Lower Cretaceous beds were then laid down on the Jurassic beds. A minor period of erosion, during which the sea again invaded the land, may have intervened between these two periods of submersion and deposition of sediments. Conclusive evidence for this supposition is not at hand.

The scarcity of fossils in the beds overlying the Upper Triassic limestone, together with the absence of beds that are readily recognizable from place to place, and consequently an imperfect knowledge of the stratigraphic section, prevent the forming of a clear picture of the events that took place in Jurassic and Cretaceous time. The evidence seems to indicate that the Upper Jurassic beds may be less widely distributed than the Lower Cretaceous beds and that like the Upper Triassic limestone they are absent, or at least do not appear, in places where they should intervene between the Permian and Lower Cretaceous rocks. This may be interpreted as evidence that the Upper Jurassic beds were not laid down in part of the area, that they were partly removed by erosion, or that they were faulted in such a way as to be hidden from sight. Some facts to support each supposition might be cited, but the determination of which interpretation is correct will require further investigation.

The Lower Cretaceous beds were deposits in a sea that must have covered a large part of Alaska, for deposits of this age are widespread and many thousand feet thick. Although the character of the material indicates rapid accumulation for much of it, the mass of the deposits and their composition are evidence that the sea covered the land for a long time, although a nearby land mass must have existed to furnish the material for the beds.

At some time after the Lower Cretaceous beds were formed they and the older formations were intruded by dikes and sills of diorite and related igneous rock. This intrusion, or possibly series of intrusions, cannot yet be referred to a definite period. It may have taken place during the time of mountain building that deformed the Lower Cretaceous beds and raised them above the sea, that is, in the late Cretaceous or early Tertiary time. Possibly it was somewhat later and contemporaneous with the extrusion of some of the lavas of the Wrangell Mountains. The chief interest in these intrusives lies in the fact that they are probably connected with the mineralization of this district, just as similar dikes and sills are related to mineralization in the Chitina Valley.

In late Cretaceous time, as has just been stated, a great change took place. A period of mountain building began, the Cretaceous beds were folded and brought above the sea, and a cycle of erosion was started which has continued to the present, for so far as is now known, all of Alaska except some of the marginal areas has been a land mass throughout Tertiary and Quaternary time. Even by early Tertiary time much of the land had attained a mature topography, with rounded hills and swampy lowland areas, but the relief was yet considerable. Under these conditions a great thickness of fresh-water deposits including clay, sand, conglomerate and beds of peat accumulated. No large deposits of this kind are known to have been formed in the Nabesna district, although it is probable that an examination of the base of the lava flows of the Wrangell Mountains would reveal thin beds of clay or conglomerate in places.

At this point in the geologic history of the region the extrusion of the younger lavas of the Wrangell Mountain area began, ushering in the first period of extensive volcanism affecting this district since that of the Permian epoch. Part of the lava that covers the area came from well-defined vents, such as the vent of Mount Wrangell and those of the other volcanic peaks of the group, but some of it welled up through complex fissures in the country rock, from which it flowed out over the surface in successive sheets. In places volcanic tuff and breccia accompanied the lava flows. They were thrown out with explosive violence and in their turn were covered by the later flows of lava, yet fragmental material seems to make up only a minor proportion of the volcanic deposits. This period of volcanic activity affected directly only a small part of the area shown on the geologic map, for although the Tertiary lava beds occupy the southwest corner of it they do not appear elsewhere.

Extrusion of the lava was not a continuous process. It probably took place intermittently and required much time for the building up of the beds as they appear now. The process may still be going on; Mount Wrangell is not yet extinct and emits steam and showers of dust from time to time.

Under the operation of mountain building forces and of weathering and erosion in Tertiary time the pattern of the principal highland areas and valleys gradually took on a form that corresponded closely to the arrangement of the present mountain ranges and valleys. Even the Tertiary lava flows of the Wrangell area were deeply trenched, and much of their material was removed by the streams. However, this long-continued process was interrupted by a variation in climate, which changed the balance between the rate of snowfall and the rate of melting and brought about a gradual accumulation of ice and the beginning of a local glacial period.

It is not known at present whether the history of Pleistocene glaciation in this part of Alaska parallels that of Canada and the northern United States in being made up of several periods of advance during which ice occupied the land, separated by interglacial periods in which the ice retreated or disappeared altogether. Yet evidence for at least one earlier period of glaciation was found by Capps[22] on the White River, and the presumption is that conditions similar to those which brought about glaciation in Canada and the United States may have produced contemporaneous, local glaciation in Alaska. The glacial stage that is looked on as corresponding to the most recent, or Wisconsin, stage of glaciation in the United States is the one to which the following statements refer.

Doubtless the first glaciers appeared in the high mountain areas, where the average temperatures were low, and, advancing from different centers, slowly pushed down the valleys and out into the open lowlands. The Wrangell Mountains constituted a principal center of accumulation of snow and glacial ice and have remained so to the present time. From there and from other centers the ice streams moved outward in all directions. Eventually so great a mass of ice had accumulated that the lower mountain tops in the Copper River Basin were covered, and the depth of the ice at the borders of the basin had reached several thousand feet. Probably the whole basin was filled. On the other hand, conditions on the Tanana River side of the mountains were strikingly different. Although all the larger valleys tributary to the Tanana Valley were occupied by ice, the ice streams do not appear to have moved far out over the lowlands, as

[22] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, pp. 63-67, 1916.

they did in the Copper River Basin, or if they did invade those areas the evidence has been removed or has not been recognized.

Maximum extension of the glaciers was reached, and the positions may have been held for a considerable time till finally the processes that led to the invasion were reversed, the melting of the ice became more rapid than the accumulation, and the glaciers disappeared, probably as gradually as they came. The evidence that confirms this story of geologic events is found chiefly in land forms that are characteristic of all strongly glaciated mountain areas and may be seen on every hand in the Nabesna district. Outstanding among these are cirque basins, the U-shaped cross section of the valleys, straightened valley walls, truncated spurs, rock benches on the mountain sides that mark temporary but long-maintained positions of the ice, morainal deposits, abandoned stream channels on mountain slopes or across divides, washed gravel on flat mountain tops, diverted drainage, and others, all of which are found within the area.

The advancing ice swept the unconsolidated sand, gravel, and other loose material from the valley floors and carried them away from the mountain area to the lowlands of the Tanana and Copper Rivers, where much of them remains to the present. On the other hand, retreat of the ice permitted the formation of new deposits, which were laid down as heterogeneous material, either unsorted just as it was freed from the melting ice or as imperfectly sorted and more or less water-worn gravel, sand, and silt in the stream and lake beds. It also bared the mountain sides to weathering and a renewal of the common processes of erosion. Yet in general the changes that have been brought about in this way since the ice disappeared have not been great. All the more recent changes in the topographic form of mountain and valley are perhaps less noteworthy in their effect on the eye than the change in the landscape caused by the renewal of vegetation that took place as new soil suitable for plant growth was formed.

MINERAL RESOURCES

The part of the Alaska Range under consideration does not now produce gold, copper, or any of the other valuable metals, but some sections of it are mineralized and may possibly yield such metals at a future time. This statement assumes a somewhat arbitrary geographic boundary between the Alaska Range and the Wrangell Mountains, which excludes the property of the Nabesna Mining Corporation, situated on White Mountain between Jack and Jacksina Creeks, from the areas of mineralized rocks to be mentioned. A detailed topographic map of a small area including the Nabesna mine was made by T. W. Ranta in 1938 and will furnish a base for future geologic surveys, but inasmuch as a careful study of the geology of the mine has not been completed by the Geological Survey an adequate description of the ore body and its occurrence cannot yet be given. The following statements therefore apply chiefly to the mineralized areas that lie east of the highway and north of the Nabesna River.

So far as is known at present the rocks of the area shown on the geologic map that are mineralized and that have attracted the attention of prospectors lie inside the boundaries of the Devonian and Permian areas, with the exception of one locality near the border of the Mesozoic area. If future prospecting tends to confirm this suggested distribution, there would seem to be evidence for assuming that there was a period of mineralization in pre-Mesozoic time. On the other hand, the deposition of ore minerals may have been controlled by the depth of cover or other factors at the time the mineral-bearing solutions were circulating in the rocks, and the time of deposition may be late Mesozoic or Tertiary, and possibly equivalent to that of the intrusion of the dikes and sills that invaded the Mesozoic slates and sandstones. Whether or not these younger intrusives played a part in the deposition of gold and other metals, it is certain that they are connected in some manner with the staining of the slate and sandstone by iron oxide, which has already been mentioned.

The district has not attracted a large number of prospectors, yet prospecting has been carried on persistently for many years by a few men, particularly Mr. Carl F. Whitham, who searched for minerals in all parts of the area and finally achieved success by discovering the mine at Nabesna. As a result of prospecting by Mr. Whitham and others, placer gold was found in the gravel of Cheslina Creek and Trail Creek, lode gold was found on a small gulch north of the highway near mile 80, and deposits of molybdenite were discovered at the head of Rock Creek. The work that has been done so far on these different prospects has not shown that either gold or molybdenite is present in sufficient quantity to be mined profitably; consequently the descriptions that follow are of interest chiefly as showing the way in which the minerals occur.

MOLYBDENITE

The occurrence of molybdenite in the Nabesna district has been known for a long time. It appears to have been first brought to the notice of white men by the natives of Batzulnitas, who probably discovered it on some of their hunting expeditions. The mineral has been reported from several localities, but only a deposit at the head of Rock Creek has received special attention from those interested in the metal molybdenum.

Rock Creek is a small stream crossing the highway at mile 84. It is a tributary of Tanada Creek, which in turn is a tributary of the Copper River. The stream has been known by two names. The lower part, where it crosses the old Nabesna trail, has long been called Caribou Creek. The upper part, to which the name Rock Creek applies, is one of several small streams that drain the south slopes of the mountains between the highway and upper Suslota Creek.

These mountains are high and rugged near the head of Rock Creek but become lower and show smoother outlines to the northwest, where, about 10 miles from Rock Creek, they finally give place to the lowlands. They include a small area of Mesozoic limestone, shale, and sandstone but are made up chiefly of Permian lava flows and intruded granitic rocks. Both the lava flows and granitic rocks are somewhat metamorphosed, and in them the molybdenite mineralization occurs.

The molybdenite prospect is on the border of a large mass of light-gray diorite and is slightly less than 4 miles in a direct line from the highway and almost 2,000 feet higher, or at an altitude of approximately 5,100 feet. It may be reached by a trail suitable for pack horses that starts from the highway at mile 84½ and follows the north bank of the creek to the camp in the upper valley, which is a little more than half a mile from the prospect and 700 feet below it. Thence the trail ascends a minor northeastward-trending branch of the stream for the remaining distance. The last part of the climb from the camp to the prospect is up the bottom of a steep, narrow gulch into which the snow comes early and in which it lies till late in the spring.

About 100 feet below the outcrop of molybdenite the gulch divides into two steep, narrow branches, which widen out above the outcrop, assume a lower grade, and finally end in a cirque basin at the head of the valley. The outcrop of molybdenite is on the nose of the spur between these two branches of the gulch and has been explored by several open cuts and a prospecting tunnel.

The slopes of the mountain below or to the west of the tunnel are composed of dark, considerably altered basaltic rock, which consists partly if not wholly of old lava flows intricately interlarded with lighter-colored granitic dikes. Above the tunnel are granitic rocks. They entirely displace the lava flows in the gulch above the prospect and still higher on the mountainsides. In places the granitic rocks are too fine-grained to show individual minerals, in places they are coarse-grained, rusty-weathering, and gneissic, and in places they are pegmatitic. Near the mouth of the tunnel and a few feet below the principal exposures of molybdenite, light gneissic and dark micaceous rocks appear in bands, which range in thickness from 6 inches to more than 1 foot and resemble the beds of a sedimentary formation. This structure seems to be characteristic of the border zone between the granitic intrusive and the dark basaltic flows in this vicinity. Higher on the spur to the northeast, the border phases of the intrusive give way to fresh-looking dark-gray and light-gray granitic rocks, which show easily recognized crystals of hornblende and striated feldspar and which are cut by fine-grained dikes with no noticeable dark minerals. The granitic rocks vary in appearance and composition but in general are probably more nearly related to the diorite than the granite end of the series.

Molybdenite, which is a sulphide of molybdenum, containing 60 percent molybdenum and 40 percent sulphur, occurs in flakes, blebs, and veinlets in shattered, light-colored, fine-grained intrusive and in the pegmatitic phases of the intrusive where it is associated with quartz, feldspar, and black mica. The shining, bluish-gray molybdenite occurs chiefly in the more shattered parts of the bedrock and in the pegmatite, but small flakes are scattered through some of the fine-grained parts of the intrusive where fracturing is less developed. It was not seen in the banded gneissic and micaceous rocks at the mouth of the tunnel, but it occurs in both types of rock in the spur above the tunnel. The tunnel discloses no ore, and the open cuts above were filled with loose material that had sloughed in from above, so that little of the mineralized bedrock in place could be seen. No evidence was found to indicate whether the mineralization follows a fault or shear zone or whether it represents a border phase of the intrusion near the contact with the host rock where the pegmatite was formed and the mineralizing solutions or vapors were abundant and in circulation.

The mining claims that include the molybdenite deposit were staked in September 1936, by George B. Todd, William Frame, Vernon Horn, and Lawrence DeWitt. They cover the contact of the basalt and granitic rocks on both sides of the tunnel and extend eastward across a depression in the ridge between Rock and Little Jack Creeks. The original development work done by the owners consisted of open cuts, which exposed the surface at several places on different claims. In 1937 an arrangement was made by which the Kennecott Copper Corporation received an option on the claims and undertook to prospect the ground. In the winter of 1937 and the early summer of 1938 a tunnel 160 feet long was driven below the outcrop of the molybdenite-bearing rocks in the expectation of reaching a mineralized zone. No molybdenite was found in the tunnel, and the work was abandoned. This ended the development work in

1938. Whether or not the owners of the claims intend to continue the exploratory work was not learned, but it is suggested that more thorough investigation of the surface exposures along the contact line might be as useful as work underground and that deep exploration might be delayed until the extent of the surface mineralization is known.

GOLD

The occurrence of gold is reported from three localities in this district. Placer gold was found in the gravels of Cheslina Creek and of Trail Creek many years ago and was the subject of investigation for a time. Lode gold was discovered before the World War at a third locality in the same group of mountains as that in which the molybdenite deposit occurs, but after considerable development work had been done, further exploration was suspended until the fall of 1938, when a new owner made preparations for resuming work on the claims.

Although the results of explorations at these three localities have been unfavorable so far, the history of the discovery and development of the gold lode at Nabesna raises the hope that future prospecting may meet with greater success.

CHESLINA CREEK

The first prospecting on Cheslina Creek appears to have been done by Carl Whitham. He discovered gold in the gravel of the branch that heads in the divide opposite the mouth of Buck Creek and thus gave the incentive for later prospecting. About 1933 R. D. Adams, Frank J. Cotter, and others prospected on the same creek but met with so little success that they gave up the project.

This branch of Cheslina Creek lies in a broad depression between two highland areas. Its chief drainage comes from the south side of the diorite ridge that bounds the Devonian rocks on the north, but it also receives water from the area of Mesozoic rocks on the south. The stream keeps to the north side of the valley, crowding closely against the foot of the mountains. Its upper part flows through an open canyon cut into the broad, high divide between the drainage areas of Cheslina Creek and the Tetling River. The lower 2 miles of its channel is in the open valley where the land slopes down gently from the south but steeply from the north and the water is confined between low gravel terraces without bedrock exposures other than a few ledges of limestone.

The highland area of the divide at the head of the creek is above the timber line and supports only a sparse vegetation, including grasses, low shrubs, and a few small willows. The well-drained gravel benches near the forks of Cheslina Creek, however, are covered with a fine growth of spruce (pl. 5, *A*), which would be a valuable asset to any mining venture.

The gravel deposits on the lower course of the creek appear to be fairly deep. They accumulated where the diminishing grade of the stream bed reduced the power of the water to move its load, and they include much morainal material, some of which can be identified as coming from the Mesozoic shale and sandstone area, as well as gravel that is postglacial and consists of such material as weathering and stream erosion are producing now.

The stream was staked for a distance of about 2 miles from the forks, and prospecting appears to have been restricted to this stretch. Several holes were sunk near the creek on the benches of different claims, but all were filled with water at the time they were visited and could not be examined. It is apparent that the ground was frozen so that thawing was required, but whether this was because of permanent frost or winter temperatures was not learned. All the shafts show a thick deposit of muck or silt at the surface. The dumps contain more or less angular material that evidently was ice-borne and has undergone little wear by water. A thin veneer of glacial material such as furnished these angular rock fragments covers all the valley floor between the mountains, so that gravel derived from it is to be expected in the stream deposits.

No indication of the source of whatever gold may be contained in these gravel deposits was found. The deposits are within the area of Devonian rocks, but they are derived in part from Devonian rocks, in part from Mesozoic rocks, and in part from diorite intrusives of unknown age, anyone of which may include the source of the gold, although evidence from other localities appears to favor the older rocks as the source of some of it.

Up to this time prospecting in this area has done no more than show that gold is present in the gravel. It remains to be seen whether future prospecting will show it to be present in sufficient quantity to be mined profitably.

TRAIL CREEK

Trail Creek is a tributary of Jack Creek, heading in the same mountains from which Suslota Creek flows. It crosses the highway near mile 92 and joins Jack Creek less than 1 mile below Jack Lake. Its valley furnishes a possible route between the highway and the upper Suslota Valley that can be used by horses, although the pass between the two valleys is high and the ascent to it is steep on the south side.

The headwaters of Trail Creek are in the Mesozoic shale, sandstone, and conglomerate area where the melting ice from two small glaciers furnishes much of the water in the stream. Near the head of Trail Creek the two main upper branches of the stream unite, one branch coming from the direction of the pass to Suslota Creek, the other from the larger of the two glaciers, which is a mile or more east of the forks. The water from this glacier has built up a broad gravel fan extending up the valley from the mouth of the stream to a point not far from the glacier where the canyon walls approach each other. The boundary between the Permian and Mesozoic beds crosses Trail Creek near this fork, so that both of the branches are within the area of the Mesozoic rocks and in a part of the area where dikes and sills of intrusive rock are most abundant. It is plain, both from the composition of the fan deposits and from the manner of their formation, that most, if not all, of the gravel is from the shale-sandstone area. Presumably the gold it contains is from the same area, although the proof of this is lacking, since so far as is known to the writer no other evidence of lode gold has been found there.

The ground was staked by N. P. Nelson and E. G. LaBell in 1931, and the first prospecting was sufficiently encouraging to justify further work in the following winter. This undertaking was a disappointment, however, and the owners gave up the search, for the gold content proved to be less than was anticipated. Since then no other prospecting appears to have been done on the creek.

LODE PROSPECT

The prospect that was cited as a possible source of lode gold is in a small valley north-northeast of mile 80 on the highway and about 4½ miles west-northwest of the molybdenite prospect on Rock Creek. This prospect lies within the area of Permian basaltic lava flows and intrusives and is far from any known younger rocks. It was not visited by the writer, but it is known that the outcropping of the mineralized lode was discovered many years ago and that development work was done by the discoverer with the intention of applying for patent. The coming on of the World War interfered with this plan, and interest in it was not revived when the war ended. This was the situation till the fall of 1938, when a new owner took in food and supplies to be used in continuing the exploratory work after the winter set in. The success of this work has not been learned.

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