Geologic Investigations of Proposed Powersites at Sheep Creek, Carlson Creek, and Turner Lake, Alaska

GEOLOGICAL SURVEY BULLETIN 1031-F

Plafker—POWERSITES AT SHEEP CREEK, CARLSON CREEK, AND TURNER LAKE, ALASKA—Geological Survey Bulletin 1031-F

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By GEORGE PLAFKER

GEOLOGY OF WATERPOWER SITES IN ALASKA

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A description of the proposed reservoir, dam, and tunnel sites at each powersite, with conclusions and recommendations

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1962

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.

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GEOLOGY OF WATERPOWER SITES IN ALASKA

GEOLOGIC INVESTIGATIONS OF PROPOSED POWERSITES AT SHEEP CREEK, CARLSON CREEK, AND TURNER LAKE, ALASKA

By George Plafker

ABSTRACT

Geologic conditions have been investigated at proposed sites for hydroelectric power development at Sheep Creek, Carlson Creek, and Turner Lake. The proposed sites are on the rugged mainland of southeastern Alaska along Gastineau Channel and Taku Inlet near Juneau. Bedrock in the area consists of a coastal strip of northwestward-trending foliated metamorphic rocks with steep northeasterly dips. This belt of rocks is adjacent to the Coast Range batholith on the northeast, and between the main batholith and the metamorphic rocks is a zone, 2 to 3 miles wide, of injection gneiss. Unconsolidated glacial and postglacial deposits of Quaternary age mantle the bedrock over large parts of the area. The valleys of Sheep and Carlson Creeks have been modified by glaciers of Pleistocene age, and Turner Lake occupies a rock basin formed by glacial scour.

There is an excellent site in greenstone bedrock at Sheep Creek for either a concrete or a rock-fill dam. A conduit from the dam to a powerhouse along Gastineau Channel would be on bedrock for most of the distance. Slate bedrock suitable for a powerhouse site is exposed near the mouth of Sheep Creek. To the northwest along Gastineau Channel, bedrock is concealed by a mantle of glacial deposits of unknown thickness. The reservoir is in virtually impermeable bedrock; however, a main haulage adit of the Alaska-Juneau gold mine would probably have to be sealed off to prevent flooding of the mine workings or possible loss of water from the reservoir.

The dam, diversion tunnel, and powerhouse at Carlson Creek would all be fresh injection gneiss bedrock. This rock is well suited as the foundation of a concrete or rock-fill dam, but foundation treatment would be required to seal off closely spaced open joints trending perpendicular to the proposed dam axis. The diversion tunnel would stand unsupported except possibly where it would intersect two zones of closely spaced joints. The reservoir would be in virtually impermeable bedrock.

Both the main dam and auxiliary structure at Turner Lake would be on an excellent foundation of granitic rock (granodiorite). Loose landslide debris would have to be removed at the damsite to expose fresh, sound bedrock. There is a powerhouse site in bedrock along Turner Creek at a stream altitude of 16 feet. Foundation conditions for a powerhouse at tidewater, near the mouth

of Turner Creek were not studied. The conduit would be on sound granitic rock throughout its length, and the reservoir is entirely in relatively tight granitic bedrock.

INTRODUCTION

PRESENT INVESTIGATION

The present investigation was undertaken in furtherance of the Geological Survey's program for systematic study and evaluation of potential waterpower sites in Alaska. A reconnaissance study of the geology at the three powersites described in this report was made during the period from August 22 to September 5, 1954. Base maps used were prepared by the Conservation Division of the U.S. Geological Survey except for the map of the Turner Lake reservoir site, which is from the Taku River (B-6) quadrangle, Alaska. The topography in the vicinity of the tunnel alinement at Carlson Creek was modified from the Juneau (B-1) quadrangle, Alaska. The entire area is covered by vertical aerial photographs taken by the U.S. Navy at a scale of approximately 1: 40,000.

PREVIOUS INVESTIGATIONS

The geology of the area under consideration was the subject of intermittent study, both regional and local in nature, after discovery of gold in 1880 near the present site of Juneau. The entire Juneau gold belt, extending from Port Houghton on the south and northwestward to the boundary of British Columbia, was mapped at reconnaissance scale by Spencer and Wright (1906). Buddington and Chapin (1929) extended this regional study to include most of southeastern Alaska. Detailed surface mapping in the Juneau area has been largely restricted to the "Juneau and Vicinity 1: 24,000" special topographic map, which includes most of Sheep Creek basin and parts of the Sheep Fork and Salmon Fork of Carlson Creek (see fig. 24). Spencer and Eakin (Eakin, H. M., 1922, unpublished data) mapped this area at a scale of 1: 24,000 and subdivided and named the formations described in this report. Subsequent detailed surface mapping in the area by Twenhofel (1952), Sainsbury (1953), and Barker (written communication, 1954), was directed primarily toward completion of unmapped portions of the "Juneau and Vicinity" special map, and refinement of Spencer and Eakin's earlier work. In connection with his study on the correlation of the Mesozoic stratigraphy of Alaska, Martin (1926) assigned tentative ages to the formations in the Juneau area, which are followed in this report. No previous detailed mapping is known in the vicinity of the Carlson Creek or Turner Lake powersites.

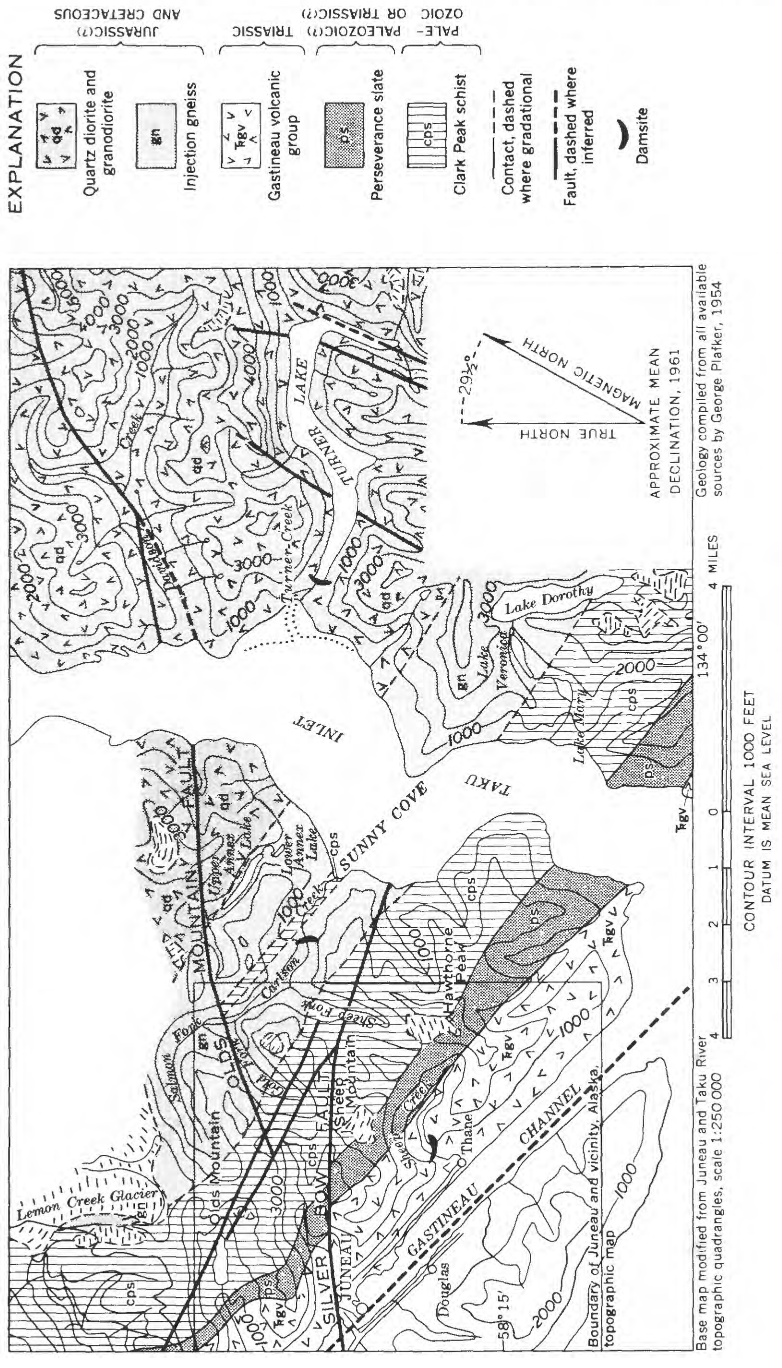

FIGURE 24.—Generalized geologic map of the Juneau-Taku Inlet area, Alaska, showing regional setting of the proposed powersites.

GEOGRAPHY

Physiography.—The area discussed in this report is on the mainland in southeastern Alaska, at approximately lat 58°15′N. and long 134°00′W. in the Juneau and Taku River 1:250,000 quadrangles. The powersites are on streams that drain into Taku Inlet and Gastineau Channel. Within the mapped area shown on figure 24 the mountains rise abruptly from sea level to a maximum altitude of about 5,000 feet, but average local relief is 3,500 to 4,000 feet. In the vicinity of the powersites small patches of permanent ice and snow occur only in sheltered basins above an altitude of 2,000 feet. Northeast of the area shown on figure 24 permanent ice and snow covers the higher peaks and ridges and from these ice caps several valley glaciers extend to low altitude along upper Taku Inlet and the Taku River. One of the most important factors in sculpturing of the present topography was the extensive piedmont ice sheet which, during the Pleistocene epoch, filled all the valleys in this area and spilled over the tops of some of the ridges that lay below a present altitude ranging from 3,200 to 4,000 feet. The ice flowed southwestward throughout most of the area and extended across southeastern Alaska to the Pacific Ocean (Buddington and Chapin, 1929, p. 24).

Below the upper surface of the ice sheet, ridges and mountains are smooth and rounded although on the higher slopes they are locally scarred by cirques. The higher peaks and ridges that stood above the surface of the ice field are serrate and pinnacled, owing to continued exposure to frost action and headward erosion of cirques. The larger valleys in the area are broad, flatfloored, and U-shaped as a result of glaciation which widened, steepened, and straightened the preexisting river valleys. Gouging of the valley floors by these glaciers has produced the deep troughlike basins that now contain lakes or formerly contained lakes now filled with alluvium. Gastineau Channel and Taku Inlet are fiords that probably were former stream valleys deepened below sea level by glacial scouring and subsequently invaded by the sea upon melting of the ice. Following retreat of the glaciers and general uplift of the area relative to sea level, many of the streams cut deep, narrow gorges in the broad valley floors.

Climate.—The climate of the area under study is characterized by rather mild temperatures for the latitude, high precipitation, and generally overcast skies. The temperature and precipitation record at a station near sea level in Juneau over periods of 54 and 56 years, respectively, are summarized below. The average annual snowfall at Juneau is 107.2 inches for a period of 37 years and 239.9 inches at Annex Creek along Taku Inlet (Federal Power Commission, 1947, p. 24). Temperatures drop about 1° F for each 300 feet in altitude, and the precipitation rises correspondingly up to an estimated altitude of 4,000 feet. Above this altitude, precipitation tends to drop off rapidly (Federal Power Commission, 1947, p. 13 and 17). Southerly winds of light to moderate force are the rule in the area studied. At times during the winter months, however, a steep pressure gradient between the high ice caps in northwestern Canada and the relatively warm low eastern portion of the Gulf of Alaska may result in sustained wind velocities of 50 miles per hour, with a recorded extreme velocity of 70 miles per hour at Juneau in February 1923 (Federal Power Commission, 1947, p. 27).

Average monthly temperature and precipitation at Juneau, Alaska

[Data from U.S. Weather Bureau, 1955, p. 184, 186]

Month	Temperature	Precipitation	Month	Temperature	Precipitation
January	29. 5	8. 0	September	51. 8	10. 49
February	29. 9	5. 78	October	44. 0	13. 03
March	34. 4	6. 43	November	36. 2	10. 38
April	40. 4	5. 73	December	30. 8	7. 73
May	47. 8	5. 14			
June	54. 5	4. 13			
July	56. 0	6. 04	Yearly average	42. 65	90. 25
August	55. 9	7. 37			

Vegetation.—The combination of high precipitation and rather mild temperatures encourages a luxuriant growth of vegetation below an altitude of about 2,000 feet. Above this general altitude an alpine flora prevails. The forest is predominantly western hemlock and spruce with small amounts of cedar. A wide variety of berry bushes, devilsclub, and other shrubs is present as a dense undergrowth, and a carpet of moss 6 inches or more in thickness, generally covers much of the forest floor. Most talus slopes, alluvium, and landslides are covered by thickets of thorny brush; young alluvial soils support a tangled growth of alders with some cottonwood and willow trees. All this area is in the Tongass National Forest.

REGIONAL GEOLOGY

BEDROCK

Bedrock in the area consists principally of a coastal band of northwestward-trending metamorphic rocks dipping steeply to the northeast. This band is adjacent to an extensive complex of granitic rocks to the northeast, and between the granitic and metamorphic rocks is a zone, 2 to 3 miles wide, of injection gneiss (fig. 24). The belt of metamorphic rock is part of the Wrangell-Revillagigedo belt (Bud-

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dington and Chapin, 1929, p. 49) that occurs along the southwest flank of the Coast Range batholith throughout southeastern Alaska. The metamorphic rocks in the area were subdivided by Spencer and Eakin (Eakin, H. M. 1922, unpublished data) into (a) Clark Peak schist—unfossiliferous varieties of foliated quartz-andesine-biotite-hornblende schist and a few thin calcareous beds, (b) Perseverance slate—unfossiliferous black graphitic slate, possibly 3,000 feet thick, and (c) the Gastineau volcanic group—andesitic greenstone and greenstone tuff and minor amounts of limestone and fossiliferous calcareous slate. In this report the Coast Range batholith is subdivided into a border facies of injection gneiss consisting largely of quartz diorite that shows prominent foliation and many relatively thin "screens" and remnants of schist; and a massive quartz diorite and granodiorite with relatively few schist remnants. The contact of the injection gneiss with the Clark Peak schist to the southwest and with the massive more homogeneous granitic rocks to the northeast is gradational over a broad zone. Away from the shores of Taku Inlet the contacts are only very approximately located.

Structure.—The prevalent dip of bedding, slaty cleavage, and foliation in the crystalline rocks is 60°–80° NE. All the metamorphic rocks are apparently conformable, but there is some uncertainty as to the structure of this section and whether it is right side up or overturned. As these considerations are not relevant to the present engineering geology study they will not be discussed in this report.

Stratigraphy.—Martin (1926, p. 94) states that "there is no conclusive evidence on the age of any of the rocks at Juneau, except for the slate in the Gastineau volcanic group, which has yielded characteristic Upper Triassic fossils. The other beds have yielded no fossils, and there is only indirect and inconclusive evidence on their age." However, on the basis of the scanty fossil evidence from slate within the Gastineau volcanic group, long range correlations with rocks in adjacent areas to the southeast and northwest, and on the assumption that the section is overturned, Martin considers the Perseverance slate to be Triassic or older and the Clark Peak schist to be Paleozoic with possibly some infolded Triassic rocks (1926, p. 93). Martin's tentative age assignments for these formations are followed in this report, but it should be borne in mind that the age of only part of the Gastineau volcanic group is satisfactorily determined. In considering the age of the granitic rocks of southeastern Alaska and the bordering zone of injection gneiss, Buddington (Buddington and Chapin, 1929, p. 253) concludes "that all the Mesozoic intrusive rocks may be of Lower Cretaceous age, but the data given for adjacent territory suggest that they may be in part of Upper Jurassic and in part of Lower Cretaceous age."

Faults.—The major faults in the vicinity of Juneau are shown on figure 24. The best known of these, the Silver Bow fault, has been mapped on the surface and underground in this area. The Silver Bow fault has a general easterly trend and dips steeply to the north. The north side is displaced about 1,400 feet downward and 2,000 feet westward in the vicinity of Juneau (Eakin, H. M., 1922 unpublished data); further east near Carlson Creek, there is 3,500 feet of horizontal displacement (Sainsbury, 1953, p. 18). The faults postdate the Upper Jurassic or Lower Cretaceous granitic rocks and the mineralization in this area. Although no displacement of glaciated surfaces has been reported or can be detected on the aerial photographs, it is possible that there may have been relatively recent movement. The sheared zones along the faults are readily susceptible to frost plucking. Thus, surface traces of the faults are commonly steep-sided cuts, in part filled with talus; the fault traces generally stand out prominently on vertical aerial photographs.

UNCONSOLIDATED DEPOSITS

Glacial scouring during the Pleistocene epoch removed any weathered and unconsolidated material that may have been present in the area. All of the unconsolidated deposits that now mantle the crystalline bedrock are glacial or postglacial in age. They can be classified in five main groups as follows: (a) a relatively thin veneer of ground moraine deposited on the lower slopes in the area by glaciers of Pleistocene age; (b) ground moraine, end and lateral moraine, and outwash, deposited by post-Pleistocene glaciers; (c) alluvial deposits along the streams and in the Form of deltas built out into lakes and fiords; (d) deposits of marine mud in the tidal zones; and (e) unstratified coarse talus and landslide debris found at the base of the steeper slopes.

EARTHQUAKES

Earthquakes of moderate intensity are felt frequently in the Juneau-Taku Inlet area. The strongest earthquake recorded at Juneau was on February 11, 1934, with a magnitude of 5 on the Gutenberg-Richter scale. This earthquake caused "some cracked plaster and other slight damage to buildings" (U.S. Coast and Geodetic Survey, 1947, p. 80). The epicenters of earthquakes felt at Juneau are grouped in three distinct zones: (a) along the west side of Chichagof Island, (b) in the Glacier National Monument area, and (c) in a strip from Skagway to Kluane in Canada. Earthquakes of the intensity that have previously been recorded in the area would probably cause relatively little damage to structures of the type that are discussed in this report.

SHEEP CREEK

Sheep Creek empties into Gastineau Channel 0.4 mile southeast of Thane, 4.1 miles by road from Juneau at lat 58°15.5′ N., and long 134°19.4′ W. Sheep Creek heads in a steep-walled amphitheater southwest of Hawthorne Peak, and in its middle course flows at a low gradient in a U-shaped basin, which trends in a broad arc from northwest to west to southwest. From the site of the proposed dam to sea level, a distance of 1 mile, the creek falls 600 feet through a steep-sided, narrow postglacial canyon. The drainage area of Sheep Creek is 6.0 square miles with 4.6 square miles draining to the damsite (Juneau and Vicinity special map scale 1:24,000, 1950 edition). Small cirque glaciers and snow fields drain into Sheep Creek at the head of the valley, but provide only a small percentage of the total runoff.

According to Johnson and Colbert (written communication, 1959) power development on Sheep Creek would be accomplished by the construction of a dam at about mile 1.0, conveyance of water from the resulting reservoir by a tunnel or pipeline to a powerhouse located on tidewater at or near Thane. A reservoir with a maximum surface altitude of about 800 feet would be required to attain adequate regulation of the streamflow. The field investigation of the reservoir site and damsite were, therefore, based on the assumption that the maximum reservoir surface altitude would be limited to 800 feet.

Much of the Sheep Creek basin is patented mineral land, mill sites, and valid mining claims, none of which were being worked in 1956. There is an existing power development on this creek which consists of a low log crib diversion dam immediately above the proposed damsite (pl. 10). A 2,486-foot long timber flume and a 2,687-foot penstock conduct the water to a powerhouse located 400 feet from the creek mouth at tidewater. In 1956 no power was being generated at this site because of breaks in the flume. Approximately 7,100 feet of the Annex Creek to Juneau transmission line is within the reservoir area and would have to be rerouted if Sheep Creek is developed. The relative values of mineral resources and power must be assessed before development of Sheep Creek is undertaken.

A good trail leads from the road at Thane to the damsite, and from the damsite along the Annex Creek to Juneau transmission line into the upper Sheep Creek valley. The location, topography, and geology of the Sheep Creek powersite is shown on plate 10.

RESERVOIR SITE

As pointed out in the previous section the maximum reservoir surface altitude is assumed to be 800 feet. At this altitude the reservoir would extend upstream from the dam for a distance of about 1¾ miles. The reservoir would occupy a broad, U-shaped basin whose profile is due to widening and steepening by a valley glacier during the Pleistocene epoch. The reservoir area is underlain by the Gastineau volcanic group, a bedded sequence of slightly metamorphosed massive fine-grained greenstone, thin-bedded fine-grained greenstone tuff, and black graphitic slate. Upstream from the reservoir area the Sheep Creek valley is underlain by the Perseverance slate, which is apparently conformable with the Gastineau volcanic group. The beds strike northwest and dip 60°–75° NE. The bedrock areas generally support a scattered growth of hemlock and spruce.

A thin discontinuous veneer of talus mantles the lower slopes of areas shown as bedrock on plate 10. The talus consists of poorly sorted coarse angular debris derived from the steep valley walls. These deposits were not delineated on the map of the reservoir area. Alluvium with subordinate amounts of talus forms the valley floor within the reservoir area. Along Sheep Creek the alluvium is moderately well sorted clean subangular to rounded sand, granules, pebbles, cobbles, and boulders. There is a gradual decrease in average grain size from the upstream end of the valley toward the damsite. Along the base of the steep valley walls small talus cones and sheets consisting of poorly sorted coarse angular material grade into, and are mapped with, the alluvial deposits. The thickness of unconsolidated deposits is not known. A sparse growth of cottonwood, willow, and hemlock trees is found on the alluvium, and the talus is in general covered by a dense growth of devilsclub, alders, and berry bushes.

DAMSITE

Bedrock.—The Sheep Creek damsite is a narrow steep-walled notch at the outlet of the broad Sheep Creek basin (pl. 10). Bedrock at the damsite is predominantly thin- to thick-bedded slabby greenstone tuff but includes minor amounts of fissile black graphitic slate. All gradations between the tuff and slate are found. The greenstone tuff is a moderately hard, tough rock that breaks into thick, irregular slabs and small blocks. The slate cleaves readily into flat slabs generally less than 2 inches thick, and the fresh surfaces have a silky sheen.

In thin section the greenstone is seen to consist primarily of green chlorite flakes as much as 0.2 mm long, and idioblastic prisms of yellow epidote as much as 0.08 mm long in a colorless groundmass, probably largely albite. Minor constituents are sharply crystallized octahedra of magnetite 0.1 to 0.4 mm in diameter, granular clusters of sphene, and irregular patches of idioblastic calcite. Phenocrysts and amygdules in the original rock are drawn out into elongated streaks owing to shearing. The slaty rocks are composed of grains generally less than 0.04 mm in diameter, which consist of finely divided white mica flakes, xenoblastic quartz and albite, dusty opaque graphite, and prisms of pale-yellow epidote and accessory magnetite octahedra and sphene.

Bedding and foliation of the rock at the damsite strikes N. 40°–75° W. and dips 60°–75° NE. There is a strong set of joints spaced from 4 inches to 5 feet apart, which trends N. 55°–75° E. and dips 60°–85° SE. Poorly developed joints include a nearly horizontal set, and one having the same strike as the major set, with a near-vertical dip.

Unconsolidated deposits.—At the damsite the lower slopes are mantled with loose talus debris probably less than 25 feet thick. This material consists of poorly sorted loose angular slabs and blocks of greenstone tuff and slate, generally less than 4 feet across. The talus is overgrown with a tangled growth of alders, devilsclub, and salmonberry bushes.

Alluvial deposits consisting of moderately well sorted subrounded to rounded sand, granules, pebbles, and cobbles have filled in the area behind the existing diversion dam above the proposed damsite. The alluvium supports a sparse growth of hemlock, cottonwood, and willow trees.

POWERHOUSE SITE

The powerhouse site would be at tidewater between Thane and the mouth of Sheep Creek. Black graphitic slate bedrock is exposed at the creek mouth and along the road for a distance of about 650 feet to the west of the creek mouth. West of the area of slate outcrop bedrock is concealed by a veneer of mixed unconsolidated glacial deposits and rockslide debris of unknown thickness. The glacial deposits are not exposed in place in this area. East of the mouth of Sheep Creek probably similar material is well exposed in a roadcut, and consists of poorly sorted angular to subrounded sand, granules, pebbles, cobbles, and scattered boulders in a clayey silt matrix. The area is heavily timbered, mainly with hemlock.

DIVERSION ALINEMENT

The diversion alinement would depend upon the location of the powerhouse. Any alinement in this area, however, would be on the same type of bedrock and structure as that described at the damsite. Locally, bedrock may be mantled by a thin discontinuous cover of talus or glacial material.

CONCLUSIONS AND RECOMMENDATIONS

Reservoir site.—Several small mine workings and one large drift lie within the proposed reservoir site. None of the smaller workings would be sources of leakage from the reservoir. The Sheep Creek adit, however, has its portal at an altitude of about 720 feet at the Portal Camp (pl. 10), and extends northward about 10,000 feet to the workings of the "Perseverance ore body" in the Alaska-Juneau gold mine. This adit would have to be sealed off in order to prevent flooding of the mine workings, and possible loss of water from the reservoir. The remainder of the reservoir is in bedrock or bedrock mantled with unconsolidated deposits which would be virtually impermeable.

Damsite.—Bedrock in the damsite is well suited as a foundation for either a concrete or rock-fill dam. The narrow valley at this site would be ideal for a concrete arch structure. However, the loose talus, probably less than 20 feet thick, would have to be removed from the abutments to expose fresh, sound bedrock. Bedrock is exposed at creek level on either side of the creek, and it is unlikely that stripping in the creek bed would involve more than removal of a few feet of loose material. The joints and bedding planes are relatively tight so that seepage and foundation treatment would be at a minimum. The abutments are well suited for driving tunnels for either diversion or outlet structures. Tunnels through these abutments would intersect the steeply dipping beds approximately at right angles, which is the most favorable alinement for tunneling. Lining or support would not be necessary except possibly at the portals.

Construction materials.—It may be possible to obtain suitable natural concrete aggregate from the alluvial deposits along Sheep Creek. The alluvium should be sampled by dug pits or auger holes to determine the quality and volume of potential aggregate available. Crushed aggregate and dimension stone could be obtained from the massive fine-grained greenstone that crops out on both sides of Sheep Creek valley upstream from the damsite. Although some clay for the impervious core of a rock-fill dam may be obtained from the glacial deposits along Gastineau Channel it is unlikely that large sources of suitable material could be found in these deposits.

Powerhouse and conduit sites.—The shortest alinement for conducting water from the dam to a powerhouse at tidewater in the vicinity of Thane would be along section *A–A′* (pl. 10). Along line *A–A′* the conduit and penstock would be on sound bedrock most of the way with a local cover of talus or glacial deposits that has an estimated average thickness of 10 feet. A powerhouse site in the vicinity of Thane would be underlain by glacial deposits of unknown thickness. Before a powerhouse is located in this area the thickness of the unconsolidated material should be ascertained by either drilling or geophysical exploration to determine if the structure could be founded on bedrock.

Slate bedrock exposed at the mouth of Sheep Creek and along the road for a distance of 650 feet west of the creek mouth would be an excellent foundation material for a powerhouse. Location of a powerhouse in this area would require an increase of about 200 feet in the length of the penstock. This may be offset by a somewhat lower slope along the penstock alinement which would minimize the possibility of disruption by landslides and snowslides. The conduit and penstock would cross virtually the same type of material as that along line *A–A′*.

CARLSON CREEK

Carlson Creek discharges into Sunny Cove on the west shore of Taku Inlet at lat 58°18.4′ N., and long 134°08.5′ W., a distance of 20 miles by sea from Juneau (fig. 24). Carlson Creek is formed at the confluence of its tributaries, Salmon Fork and Gold Fork, on the west flank of Olds Mountain. From this point the creek flows with a steep gradient to its junction with Sheep Fork which heads between Sheep Mountain and Hawthorne Peak. Carlson Creek then flows eastward at a low gradient across a flat-floored basin for slightly over 1 mile before plunging through a narrow, northeastward-trending canyon half a mile long. After emerging from the canyon the creek turns sharply southeastward, and flows on a slightly meandering course for 1⅜ miles to its mouth at Sunny Cove. The drainage area of Carlson Creek is 26.7 square miles, of which 23.3 square miles drains to the proposed dam site. The creek is clear with only a small proportion of melt water derived from isolated ice and snow patches in the drainage basin. See figure 25 for aerial view of part of Carlson Creek valley.

A good trail leads from Sunny Cove to the Alaska-Juneau Gold Mining Co. cabin, a distance of about 1½ miles. Above the cabin the trail continues up Carlson Creek and Sheep Fork along the transmission line from Annex Creek to Juneau, but in this area it is largely grown over with brush. A little more than 2 miles of the transmission line would have to be relocated if the Carlson Creek project is developed.

The development of power on Carlson Creek according to Johnson and Colbert (written communication, 1959) would be accomplished by the construction of a dam at either mile 1.8 or mile 2.3, conveying the water from the resulting reservoir by tunnel and penstock to a powerhouse at or near tidewater near the mouth of Carlson Creek. In this report only the damsite at mile 1.8 is considered. It was assumed that the maximum reservoir altitude would be about 500 feet requiring a dam 250 feet high with crest length of 900 feet.

The location, topography, and geology at the Carlson Creek powersite is shown on plate 11.

FIGURE 25.—Aerial view of part of Carlson Creek basin looking upstream (west) from a point over the mouth of Carlson Creek. Damsite is in gorge cut through ridge in foreground. Trend of creek at the damsite and parallel gullies on the ridge in foreground define prominent northeastward-trending joint set. Creek in lower right corner of picture defines trend of the foliation. Flat-floored basin above the damsite is an alluvium-filled lake.

RESERVOIR SITE

Development of waterpower from Carlson Creek would require a storage reservoir with a maximum estimated altitude of about 500 feet. The reservoir would cover a portion of the Carlson Creek and Sheep Fork valleys (pl. 11).

As shown on plate 11 the reservoir site is underlain predominantly by injection gneiss consisting largely of foliated quartz diorite and minor amounts of schist. Along the Sheep Fork the ratio of schist to gneiss increases to approximately equal amounts of each. In this area thin beds of marble interbedded with quartz-andesine-biotite schist and quartz-andesine-biotite-hornblende schist are found. Both the schist and gneiss are cut by light-colored dikes of aplite and pegmatite. Bedrock areas are characterized by growth of hemlock, spruce, and cedar.

Overlying the bedrock are unconsolidated deposits of talus consisting of unsorted to poorly sorted angular boulders and cobbles and interstitial sand and gravel. The largest deposits are delineated on plate 11 although most of the areas shown as bedrock on the map are also concealed by a thin discontinuous veneer of talus. The talus slopes are generally covered with a dense growth of brush. The flat-floored basin upstream from the damsite (fig. 25) is interpreted to be a former glacial lake that was filled with alluvium. The alluvium supports a tangled growth of alders.

DAMSITE

Bedrock.—The damsite area is underlain by fairly massive quartz diorite injection gneiss. This rock is medium-grained mottled black and white foliated quartz diorite with widely spaced partings and inclusions of gray to black schist. The schist "screens" are generally less than 6 inches in thickness and are planes of weakness along which the rock cleaves readily. In thin section the more massive rock is seen to range from 0.5 to 3 mm in grain size and to average about 30 percent shreds of brown biotite and ragged laths of hornblende, 45 to 50 percent subhedral andesine, 15 to 20 percent anhedral quartz, and minor amounts of accessory apatite, sphene, zircon, and calcite. The biotite is locally altered to chlorite, plagioclase is partly sericitized, and slender rods of epidote are found intergrown with the hornblende. Protoclastic texture in some sections is indicated by bent biotite, granulated and drawn out plagioclase, and bent plagioclase twin lamellàe. The schist remnants in the injection gneiss average 1 mm or less in grain size, and are composed of virtually the same minerals as described above, with a higher percentage of well-oriented biotite and correspondingly less hornblende. A band of thinly bedded schist crosses the lower end of the damsite and probably extends southeastward along Carlson Creek to Sunny Cove as shown on plate 11. The schist in this band is dark colored, fine to medium grained, and consists mostly of quartz-andesine-biotite and quartz-andesine-biotite-hornblende. Some of these schists contain considerable amounts of muscovite, and in others diopside is abundant. Minor accessory minerals are magnetite, pyrite or pyrrhotite, apatite, and sphene. Both the schist and injection gneiss are cut by dikes of light-colored potassium-rich granite-pegmatite and aplite. Hemlock interspersed with sparse amounts of cedar grow in areas where bedrock is near the surface.

Foliation of the rock in the damsite area trends uniformly N. 25°–50° W. and dips 65°–80° NE. The rocks are cut by a major set of joints spaced 6 inches to 4 feet apart which trend N. 60°–85° E. and dip 65°–85° SE. The course of Carlson Creek at the damsite follows the strike of this prominently jointed zone (fig. 25). The combination of northwestward-trending foliation, northeastward-trending major joints, and a relatively minor set of flat-lying joints, all tend to cut these rocks into rectangular rocks which are elongated parallel to the foliation.

Unconsolidated deposits.—The lower slopes at the damsite area are mantled with loose talus derived from injection gneiss. This material consists of poorly sorted or unsorted angular cobbles and boulders, some of which are as much as 25 feet across. The talus debris is mantled with a tangled growth of devilsclub and berry bushes.

POWERHOUSE SITE

A powerhouse could be located in bedrock on the south bank of Carlson Creek about 3,200 feet upstream from the mouth, at a stream altitude of 20 feet. Below this point a very small increase in head could be obtained at the expense of markedly increasing the overall tunnel or conduit length. The powerhouse site would be in injection gneiss bedrock similar to that described for the dam foundation. At this site a steep gully is cut along a zone of closely spaced northeastward-trending joints similar to those which control the course of Carlson Creek at the damsite.

TUNNEL ROUTE

An approximate tunnel alinement for diverting water from the reservoir to the powerhouse is shown on plate 11. The exact type and alinement for this diversion would depend upon the minimum surface altitude of the reservoir. Assuming this to be 450 feet, the tunnel would be about 4,250 feet long with a penstock—above or below ground—about 200 feet long. The tunnel would be in fresh, massive injection gneiss similar to the foundation rock at the damsite and powerhouse site. The rock is foliated almost parallel to the tunnel alinement, and is cut by the same major set of northeastward-trending joints with high angle southeasterly dips as found at the damsite (fig. 25). Two zones of closely spaced joints indicated by distinct linear depressions would be crossed by a tunnel with an alinement as shown on plate 11 (section *A–A′*).

CONCLUSIONS AND RECOMMENDATIONS

Reservoir site.—The floor and walls of the reservoir would be composed of bedrock or bedrock mantled with unconsolidated deposits, which is sufficiently tight to insure minimum water loss through leakage.

Damsite.—Bedrock in the damsite area is suitable as a foundation for either a concrete or rock-fill dam as much as 350 feet high. Section *B–B′* (pl. 11) is in the vicinity of one of the more favorable alinements. At this site the loose talus debris, probably less than 15 feet in maximum thickness, would have to be removed to expose fresh, sound injection gneiss bedrock. Only a thin mat of vegetation and organic soil would have to be stripped from the bedrock. The foundation rock has sufficiently high compressive and shear strength to support the contemplated load.

The foundation rock itself is virtually impermeable and insoluble. However, the major joints, which trend parallel to the creek and are perpendicular to the dam axis, would be natural seepage channels under the proposed dam. These joints are closely spaced, and are open near the surface owing to water seepage and frost action along them. They would have to be sealed with a grout curtain along the proposed dam alinement. The depth to which grouting would be required could be determined by pressure tests from drill holes along the axis of the dam.

Construction materials.—Satisfactory crushed aggregate or dimension stone could be produced from the injection gneiss in the damsite area. Natural aggregate may be available from the alluvium along Carlson Creek upstream from the damsite. This alluvium along the creek consists of subrounded to rounded sand, granules, pebbles, and cobbles, and minor amounts of interstitial silt. Away from the creek channel the flood plain is mantled by a surficial layer of micaceous silt of unknown thickness. The average grain size of the alluvium increases gradually upstream and it may be possible to produce a well-graded aggregate by blending of material from pits at selected points along the creek. Washing would probably be required to remove the silt. Test pits should be dug on a grid within the alluvial deposits to determine whether suitable aggregate is available in the required quantity. The only fine-grained material available for an impervious core would be the glacial rock flour deposited in the tidal zone at Sunny Cove. The physical characteristics of this material should be determined if a rock-fill dam is contemplated for this site.

Powerhouse site.—The fresh injection gneiss would be an excellent foundation material for the proposed powerhouse at the site shown on plate 11, or along the south side of Carlson Creek and Sunny Cove to the east of this site.

Tunnel route.—Except for the two joint zones which cross the tunnel alinement (pl. 11), bedrock is fresh, sound, and tight. Gullies have been eroded along these zones of closely spaced joints, and they could be the source of considerable ground-water seepage during tunneling. Observations on a similar jointed zone exposed at the lower end of the damsite area, indicates that the joints are probably 6 inches to 4 feet apart. Away from the portals the rock can be expected to stand unsupported for an indefinite period, although some support may be required in the closely jointed zones.

A diamond-drill program should be undertaken prior to selection of the final tunnel alinement in order to determine the nature of the jointed zones at depth and inflow of ground water to be expected during tunneling.

TURNER LAKE

The outlet of Turner Lake is at lat 58°18.3′ N. and long 133°56.1′ W. The lake has an approximate area of 2,900 acres (Federal Power Commission, 1947, p. 69), and on August 14, 1952 it had a surface altitude of 73.2 feet. Turner Lake discharges into Turner Creek, which flows half a mile northwestward to its mouth on the west shore of Taku Inlet, 22 miles by sea from Juneau (fig. 24). The creek drops through a series of rapids to an elevation of 16.1 feet within 500 feet of the lake outlet, and from there it flows on a gentle gradient to sea level. The width of the lake ranges from a quarter of a mile just above the outlet to a maximum of three quarters of a mile near the center portion, and is 8½ miles in length. The general trend is easterly with a 2-mile long southward-trending arm at the east end of the lake, and a small southward-trending embayment near the middle part of the lake.

Glacier-fed streams drain into the lake at the head of the southward-trending arms, and one large stream drains into the east end of the lake. Several smaller clear water and glacial streams empty into the lake at various points along its length. The total drainage area is approximately 52 square miles.

A well-maintained forest service trail slightly over half a mile long leads from tidewater at the mouth of Turner Creek to Turner Lake. There is a forest service cabin and boathouse on the point south of the lake outlet, and a shelter cabin is located near the mouth of the creek that drains into the east end of the lake. See figure 26 for aerial view of lower end of Turner Lake.

According to Johnson and Colbert (written communication, 1959) the development of power at Turner Lake would be accomplished by the construction of a low dam and auxiliary structure to raise the surface altitude of the lake to approximately 116 feet or 43 feet above normal lake level, a powerhouse located on Turner Creek 450 feet downstream from the lake outlet or near the mouth of Turner Creek at tidewater, and a penstock or combination conduit and penstock to conduct water from the reservoir to the powerhouse.

FIGURE 26.—Aerial view of Turner Creek and lower end of Turner Lake looking east from over Taku Inlet. Note steep-sided glaciated valley occupied by Turner Lake. Large scar on steep slope to left of the lake outlet (light area) is probable source of rockslide debris at the damsite. Light-colored area at creek mouth is tidal mud flat.

RESERVOIR SITE

The reservoir site is a glaciated valley with a steep-sided U-shaped profile up to about 1,500 feet altitude, a broad V-shaped profile from about 1,500 feet to 4,000 feet altitude, and steep-sided ragged ridges and peaks above an altitude of 4,000 feet (fig. 26; pl. 12). The basin occupied by Turner Lake was scoured out of bedrock by a westward-flowing valley glacier. The lake bottom falls off sharply from shore, and has been sounded to a depth of 682 feet by the field party that made the survey of the damsite at the lake outlet. Because of the extremely steep slopes surrounding Turner Lake, the lake area would be increased only slightly by the maximum practicable raising of the lake surface.

The entire lake basin consists of hard fresh massive granitic rock (hornblende-biotite granodiorite). The bedrock is concealed in places by small alluvial fans which are being built out into Turner Lake at the bend 2 miles from its head, and at the heads of the two southward-trending arms. The gentler slopes are in part mantled with talus and small landslides. Morainal deposits, probably of Recent age, occupy small cirques on the higher slopes in the area.

The granite rocks are cut into large blocks generally more than 5 feet across by several well-defined sets of joints. The traces and attitudes of the major joints are shown on plate 12. All of the joints examined in the field were tight with no detectable weathering along them. Six high-angle northeastward-trending faults or probable faults occur within the reservoir area as shown on plate 12. These structural features show up clearly on the vertical aerial photographs as distinct linear depressions generally filled with talus. The fault planes could not be seen in the field because of their tendency to be concealed by talus owing to accelerated frost action along the shattered zones. None of the faults can be traced for more than a few miles in either direction from the lake, and it is probable that they actually represent relatively minor fractures between the major westward- and northwestward-trending faults of southeastern Alaska. One of these major faults intersects Taku Inlet a few miles north of Turner Lake near Davidson Creek (fig. 24). The faults are probably inactive as indicated from lack of displacement of smooth glaciated surfaces and absence of seismicity in the area.

DAMSITE

Bedrock.—The damsite area is underlain by hornblende-biotite granodiorite. Bedrock is exposed in the point just south of the lake outlet, along both shores of the lake upstream from the outlet, and as small riblike outcrops at the outlet and along Turner Creek (pl. 12). The rock is generally medium grained, light colored, and mottled with black ferromagnesian minerals. Locally, there is a tendency toward a faint foliated or gneissic structure, with thin dark-colored clots of fine-grained material and prisms of hornblende or plates of biotite defining the plane of foliation. In thin section the rock is seen to be hypidiomorphic granular in texture with an average grain size of 2 to 4 mm. It consists of about 50 percent subhedral zoned andesine (An_{30-35}), 20 percent anhedral quartz, 18 to 20 percent subhedral brown biotite and green hornblende, and 6 to 10 percent anhedral orthoclase. Sphene in crystals as much as 2 mm long, anhedral magnetite, and euhedral apatite and zircon constitute the remaining 2 to 4 percent of the rock. The minerals are in general fresh with only minor sericitization of the plagioclase cores, chloritization of biotite and hornblende, and replacement of hornblende by rods and granules of epidote.

Rockslide deposits.—Near the lake outlet and along Turner Creek a jumbled mass of loose angular unsorted blocks, some of which are 40 feet or more across, overlie the granodiorite bedrock. This mass of loose rock is interpreted to be a landslide that came down the slope north of the lake outlet from a cliff at an altitude of about 1,000 feet (fig. 26), and filled most of the valley now occupied by Turner

Creek. The landslide debris is extremely permeable and Turner Creek probably was able to maintain its course by flowing through the many openings within the mass. A part of the landslide debris has been cleared from the channel by the creek, but much of the creek course is still choked with large blocks and some water flows through openings in the debris on the south side of the lake outlet.

Landslide debris supports a dense growth of devilsclub and berry bushes and a few small hemlock and pine trees.

Talus deposits.—A veneer of talus mantles the base of the steep slope southwest of the damsite. This talus consists of poorly sorted angular to subangular granules, pebbles, and cobbles, and scattered boulders in a silty sand matrix. Most of the talus fragments are of granodiorite, but a small percentage is schist and chert. These fragments of metamorphic rock may be derived from metamorphic inclusions within the granodiorite or could be ground or glacial moraine deposited on the slope. The thickness of the talus is not known.

The growth of large, straight hemlock trees on the talus deposit indicates that it has been fairly stable for a long period of time. There is a moderately dense undergrowth of devilsclub and berry bushes.

CONCLUSIONS AND RECOMMENDATIONS

Reservoir site.—All the reservoir area is in bedrock overlain by a relatively thin mantle of overburden, which is sufficiently tight to insure minimum water loss through leakage.

Damsite.—The foundation at the lake outlet consists of granodiorite bedrock largely concealed by blocks of landslide debris. The small outcrops of granodiorite at the outlet, as shown on plate 12, were distinguished from large, loose blocks of the same material by comparing the foliation and joint planes to those in nearby exposures of undoubted bedrock. Another distinguishing feature of the bedrock is that it is the only lithologic unit on which cedar trees grow in this area. All of the landslide debris and surficial organic matter would have to be removed to expose fresh rock at the damsite. The foundation rock here is excellently suited for a concrete or rock-fill dam. From surface indication the joints are sufficiently tight to insure a minimum of seepage through the foundation. It may be necessary to erect a diversion wall on the steep north abutment of the damsite to prevent slide rock from falling on the dam.

Auxiliary dam.—There is a saddle about 200 feet southwest of the lake outlet, the low point of which is just under 100 feet in altitude. On the assumption that the maximum reservoir altitude would be 116 feet it would be necessary to build an auxiliary dam across this saddle.

Such a dam would be about 20 feet high and about 250 feet long. This saddle is in granodiorite bedrock and foundation treatment would probably require only stripping of the surficial organic matter and soil, which is less than 3 feet thick.

Spillway site.—The low divide at 136 feet altitude west of the auxiliary damsite (pl. 12) may be suitable as a natural spillway. The saddle is filled with talus that probably is less than 15 feet thick. An open cut in the saddle down to the estimated reservoir level of 116 feet would have to be only 25 feet deep at the maximum. A test hole should be put down in the saddle to ascertain the depth to bedrock and permit an estimate of the relative amounts of common and rock excavation that would be required.

Construction materials.—Granodiorite in the damsite area would be excellently suited for crushed aggregate to be used in a concrete dam or as dimension stone for a rock-fill dam. There is no suitable natural aggregate in the vicinity of the damsite. The only fine-grained material in the area that may be used for an impervious core for a rock-fill dam would be the marine glacial rock flour from the mud flats near the mouth of Carlson Creek. Physical tests of this material should be made to determine its suitability for this purpose.

Powerhouse site.—One of the possible sites for a powerhouse would be near the base of the rapids along Turner Creek 500 feet downstream from the lake outlet. At this location granodiorite bedrock is exposed, which would be an excellent foundation for a powerhouse. The other site would be at tidewater near the mouth of Turner Creek. No examination of this area was made during the present investigation, but aerial photograph interpretation indicates that there is a possible powerhouse site on bedrock immediately north of the creek mouth.

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Geology of Waterpower Sites in Alaska

GEOLOGICAL SURVEY BULLETIN 1031

This bulletin was printed as separate chapters A–F

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1962

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

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