Geology of Waterpower Sites on Scenery, Cascade, and Delta Creeks near Petersburg, Alaska

GEOLOGICAL SURVEY BULLETIN 1031-E

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By JOHN CHARLES MILLER

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A preliminary examination of the geologic feasibility of proposed damsites

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GEOLOGY OF WATERPOWER SITES IN ALASKA

GEOLOGY OF WATERPOWER SITES ON SCENERY, CASCADE, AND DELTA CREEKS NEAR PETERSBURG, ALASKA

By John Charles Miller

ABSTRACT

The Scenery Lake damsite is partly in quartz diorite and partly in hornblende-plagioclase gneiss. The Swan Lake and Ruth Lake damsites are in quartz diorite. The bedrock at these damsites is suitable for dams of the height that would be required to achieve the full development of the potential power of the streams. No appreciable leakage from the reservoirs is anticipated.

The tunnel routes from Scenery and Swan Lakes would be in quartz diorite. The tunnel route from Ruth Lake would pass through quartz diorite and diorite gneiss.

The geologic examinations described in this report indicate that the development of the potential power of the streams under consideration is feasible as far as geologic conditions are concerned.

INTRODUCTION

PURPOSE AND SCOPE

This reconnaissance geologic report was made to evaluate the geologic feasibility of the sites for the various structures that would be required for the development of hydroelectric power from Scenery, Swan, and Ruth Lakes. These lakes are on Scenery, Cascade, and Delta Creeks, respectively. The field examinations included the damsites at the outlets of the three lakes, the reservoir sites above these damsites, and tentative tunnel routes from these lakes to powerhouse sites at or near tidewater. The geologic feasibility of the sites under consideration is one of the determining factors in evaluating the waterpower potential of these streams.

The fieldwork on which this report is based was conducted during July and August 1951. The examination of the proposed sites of reservoirs, dams, and tunnels required a total of 29 days on the Scenery Lake and Scenery Creek areas; 21 days on the Swan Lake and Cascade

Creek areas; and 1 day on the Ruth Lake and Delta Creek areas. The author was assisted by J. L. Colbert, hydraulic engineer, who had worked in the area the previous season obtaining control data for the compilation of a topographic map.

This report in essentially its present form and under the same title, was released to open file by press notice No. 90568 dated December 6, 1955.

MAPS AND PHOTOGRAPHS

A special topographic map (U.S. Geological Survey, 1952) of the area served as a base map for the geologic mapping. This map includes an area that extends from Scenery Lake on the north to the Patterson River on the south, and inland 4 to 5 miles from the east shore of Thomas Bay. The map is on a scale of 1:24,000 with a 40-foot contour interval. Included on the same sheet are detailed maps of the Scenery Lake damsite, scale 1:4,800, and Swan Lake damsite, scale 1:2,400; both detailed maps have 10-foot contour intervals. Underwater contours are shown on Scenery, Swan, and Ruth Lakes and on the damsite maps above mentioned. Profiles are shown for Scenery, Cascade, and Delta Creeks. Aerial photographs taken in 1948 were also used in the fieldwork.

ACKNOWLEDGMENTS

Acknowledgment is due to the personnel of the Alaska Communication System for their friendly cooperation and assistance in maintaining radio communications with the field party.

GEOGRAPHY

LOCATION

The area investigated is on the mainland about 20 miles northeast of Petersburg on the east side of Thomas Bay, an arm of Frederick Sound, and is about 100 miles southeast of Juneau. Scenery, Cascade, and Delta Creeks, which flow westward into Thomas Bay, are effluents of Scenery, Swan, and Ruth Lakes, respectively. The location of these lakes and streams is shown on figure 23.

CLIMATE AND VEGETATION

The climate is characterized by moderate temperatures the year round, including mild winters and cool summers, and by heavy precipitation. The mean annual precipitation at Petersburg for the 15 years 1927, 1931–32 and 1938–49 was 111 inches. The runoff records for Scenery and Cascade Creeks indicate that the precipitation in the area of study is greater than at Petersburg.

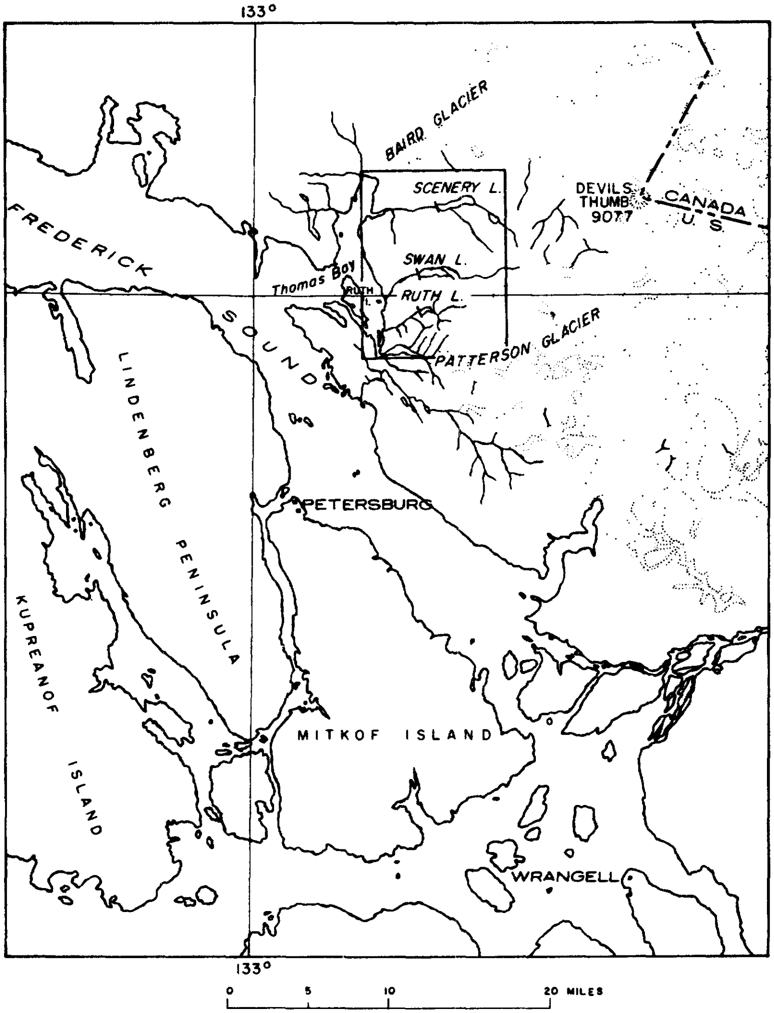

FIGURE 23.—Index map showing location of powersites.

The area is within the Tongass National Forest and, except for the steep slopes, is covered with a dense growth of timber consisting of western hemlock, Sitka spruce, western redcedar, and Alaska cedar. From sea level to about 2,000 feet the forests have a dense undergrowth of bushes, mainly salmonberry and huckleberry, and other vegetation including devilsclub. Where there have been slides and on some of the talus slopes, willow and alder form an almost impassable barrier. The best timber is in the well-drained areas on the steep hillsides, but there is a large quantity of poorer grade timber suitable for paper pulp within the drainage areas of the three creeks and in the area bordering Thomas Bay.

ACCESSIBILITY

The three damsites investigated are at the outlets of Scenery, Swan, and Ruth Lakes. Scenery Lake is 3 miles east of the shore of Thomas Bay and 957 feet above sea level; Swan Lake is about 2½ miles east and 1,514 feet above sea level; and Ruth Lake is less than 2 miles east and 1,353 feet above sea level. A development at tidewater on Scenery Cove would be accessible to ocean-going tugs and large vessels. U.S. Coast and Geodetic Survey chart 8210 of Thomas, Farragut, and Portage Bays shows that soundings in Scenery Cove range from 9 to 21 fathoms at mean lower low water. A powerhouse for a development on Swan Lake, if built near the mouth of Cascade Creek and near sea level, would be accessible from Thomas Bay. Also accessible from Thomas Bay would be a powerhouse built at the mouth of Delta Creek. There are no roads in the report area and any road construction would be complicated by the extremely rugged terrain and the consequent occurrence of rockslides or snowslides. The trail up Cascade Creek is well marked to Falls Lake, and it is discontinued at the lake. The trail from Falls Lake to Swan Lake is very steep and indefinite, being obscured in places by snowslides. The U.S. Forest Service maintains a skiff on Scenery and Swan Lakes, but none is available on Ruth Lake. A steep trail is available near Delta Creek for access to Ruth Lake.

PHYSIOGRAPHY

The rugged mountainous character of the area provides excellent topographic locations for the three damsites examined. In the higher altitudes valley glaciers and waterfalls descend from the icecap and the melt water forms streams which enter the lakes. The western slope of the Coast Range has been "* * * deeply dissected by river erosion, modified by the great Pleistocene ice sheet, and sculptured by alpine glaciers of Pleistocene and Recent age." (Buddington and Chapin, 1929, p. 23.) The maximum height of the surface of the Pleistocene ice was probably less than 5,000 feet, as evidenced by the sharp ridges and lack of roundness above altitudes of 4,200 and 4,500 feet. Locally, valley glaciation in Recent and Wisconsin time has resulted in alpine sculpture, but probably the most pronounced glacial erosion was due to the Cordilleran glacier complex in Wisconsin time.

Evidence of the great ice flood of Pleistocene time is found in the fiords such as Scenery Cove, in the three lake valleys, in the occurrence of hanging valleys such as the creek valley on the south side of Scenery Lake and about 1.2 miles from the head of the lake, a similar valley at the head of the drainage southeast of Swan Lake, and others in the region under consideration.

At the mouths of the hanging valleys on the south side of Scenery Lake and southeast of Swan Lake are low rounded transverse ridges, called lips, that roughly span each valley except where the streams flow through the postglacial notches.

There are many cirques in various stages of preservation. The U-shaped tributary valleys contain lateral, medial, and end moraines of preexisting alpine glaciers. The three lakes investigated were formed by glacial action which gouged deep troughlike basins out of the rock. The sharp knife-edged or comb ridges between these glacial lakes are the result of frost wedging, extensive alpine glaciation, and, to some degree, difference in character of the rock—that is, the occurrence of less resistant gneisses within the diorite mass.

In the main creek valleys the cross section is not a simple U and the valleys are not everywhere broad and flat. In some places they show evidence of former successively narrower valleys produced by more than one period of erosion. The loosely consolidated material left by glaciation in the valleys has been modified by normal stream erosion, and gorges have been cut in the rock floor of the valley. The streams emanating from the lakes follow tortuous and precipitous paths to tidewater, and rapids and falls are numerous. The falls on Cascade Creek at the head of Falls Lake are between 60 and 70 feet high. Similar falls were observed near the head of the broad, flat valley of the stream which enters the northeast side of Swan Lake. These falls were probably formed as rock steps produced by the quarrying action of a glacier. The steep walls of the three main creeks are intersected by glacial troughs or by deeply incised valleys of tributary creeks. Most of the topographic features described must be considered when any conduit is planned from the lakes to powerplants near tidewater.

GENERAL GEOLOGY

The limits of the mapping by Buddington and Chapin (1929, pl. 1) extend about 3 miles east of the bay, but their map does not include Scenery Lake and its catchment area. Swan and Ruth Lakes are near the edge of the area previously mapped, but parts of their catchment basins are beyond the area mapped by Buddington and Chapin.

The geology of the area under consideration, shown on plate 8, is based on this field investigation and on the previously published work of Buddington and Chapin. Samples of rock at the damsites, tunnel routes, and reservoir areas were selected for petrographic examination. The engineering geology of each site will be discussed following the description of the geology of the area as a whole.

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IGNEOUS ROCKS

The predominant rocks of the mainland of southeastern Alaska and of the area involved are hornblende-quartz diorite of the composite Coast Range batholith, the Coast Mountains geanticline of Payne (1955), and gneisses and schists of the metamorphic-complex belt lying adjacent to the batholith. The intrusive quartz diorite is reported by Buddington and Chapin (1929, p. 61) to be contaminated in varying degrees with inclusions, remnants, or assimilation products resulting from the breaking up or disintegration of schist. In the area under consideration, particularly along the valley of Scenery Creek, the intrusive sheets of quartz diorite appear to contain very few assimilation products. Some increase in the mafic mineral content, mainly hornblende, was observed along Cascade Creek and a marked increase was evident along Delta Creek farther south. This rock is referred to in this report as diorite.

Dikes of aplite or felsite are more common in the Swan Lake basin than in the Scenery Lake basin. The dikes range in width from a few inches to tens of feet.

The texture of the diorite ranges from fine to coarse and the fabric is equigranular, although locally it has a slightly porphyritic appearance. From north to south across the area an increase in the content of ferromagnesian minerals in the diorite was observed and locally the country rock resembles gabbro. The area of quartz diorite which comprises the western part of the Coast Range batholith is 3 to 15 miles wide in southeastern Alaska and is considered to be of Late Jurassic or Early Cretaceous age.

METAMORPHIC ROCKS

The metamorphic rocks are crystalline schists and injection gneisses, and the main belt of these rocks, 13 miles wide in the Thomas Bay region, roughly parallels on the southwest the Coast Range batholith. In places the linear flow structure and the roughly parallel orientation of hornblende, give the diorite a more or less gneissic appearance. This type of structure in the intrusive bodies is more prevalent in the southern part of the area. The gneisses are predominantly hornblende-plagioclase gneiss, but mica and garnet occur in some of them. These gneisses and schists in general show various stages of injection and occur as blocks, stringers, or as infolded masses locally intercalated with beds of limestone or marble, which are in places as much as 10 feet thick. The gneisses and schists, however, may be regarded as members or integral parts of the larger and more common occurrences of hornblende gneisses.

In several localities it was difficult to determine the boundary between diorite and gneiss because the exposures vary from feebly metamorphosed diorite gneiss to highly metamorphosed hornblende-plagioclase gneiss and garnetiferous mica schist—for example, on the northeast side of Swan Lake where the limits of the metamorphic rock are in doubt, in part owing to forest cover and topographic relief. The boundary shown between diorite and gneiss is to be regarded as indefinite, but it delimits the area of predominantly metamorphic rocks which, however, may not be of the same age or origin in different parts of the area mapped. On plate 8 the rocks are classified broadly under four types of interest to construction engineers. The age of these metamorphic rocks probably ranges from Ordovician to Jurassic or younger.

UNCONSOLIDATED ROCKS

In the broader valleys and in the valleys that enter Thomas Bay, deposits of glacial boulders and gravel are exposed. The valleys of the streams entering Swan and Scenery Lakes contain deposits of sand in limited amounts. The streams have carried glacial debris toward Thomas Bay, although a large part of the deposits in these valleys must have been left by recession of the valley glaciers of Quaternary age. The glacial debris has been reworked locally and Recent stream deposits consist of a large amount of reworked morainal material. Some forested areas in the broader valleys entering Thomas Bay are underlain by outwash from glaciers which occupied the area. Proglacial streams from the broad lobe of Baird Glacier deposit a large volume of sand and gravel which is added to morainal material left by recession of the glacier and by older glacial streams. These streams also carry rock flour and silt which is discernible for several miles out in Thomas Bay.

STRUCTURE

The damsites investigated are near the western edge of one of the major geologic features of southeastern Alaska, the Coast Range batholith of the mainland. This batholith is included in the tectonic element designated by Payne (1955) as the Coast Mountains geanticline. The Prince of Wales geanticline of Payne (1955) is 50 miles or more west of the mainland, and between this anticlinorium and the mainland lies the Juneau synclinorium (Buddington and Chapin, 1929, pl. 22), or the Seymour geosyncline of Payne (1955), striking northwestward roughly parallel to other major structural elements. The beds in this synclinorium are overturned to the southwest. On the mainland, however, in the area between Delta and Scenery Creeks, the strike of the foliation, which is generally north to northwest parallel to the western border of the Coast Range batholith, is locally interrupted by beds of gneiss or schist that cut across the regional strike. The structures observed are probably residual from sedimentary rocks existing prior to intrusion of the magma.

Many shear zones are found within the area, but any appreciable displacement which might have occurred is masked by forest growth and rockslides. Jointing is commonly steep (75° to vertical), generally in a northeast and northwest direction, rather widely spaced, and generally cutting across the lineation. Among the many structural patterns in evidence on aerial photographs, a well-defined line extends from a point near the triangulation stations Boulder and Land as shown on the special topographic map of the area (U.S. Geological Survey, 1952), to a point about 2 miles to the east near the headwaters of the South Fork of Scenery Creek. A most pronounced system of joints or fractures that was observed on aerial photographs extends northwestward parallel to the synclinorium. This lineation is intersected by another one trending northeastward. Several lineaments shown on plate 8 were located after an examination of aerial photographs by George Plafker of the Geological Survey. Overturned isoclinal folds in the gneiss occur sporadically, but in general the structure near the western margin of the batholith is not complex. Several main divides or sharp ridges consist of gneiss. Whether their occurence is due to the tectonics of the region, resistance to erosion, or to glaciation was not determined.

SEISMIC ACTIVITY

According to a seismic probability map of the United States (U.S. Coast and Geodetic Survey, 1950), these damsites are on the edge of what is designated as zone 2, an area in which structures are reported to have been moderately damaged one or two times. The adjoining zone 1 to the east is a region of minor damage by earthquakes but no structural change. In the explanatory note accompanying the map cited, it is stated that:

> A compilation of records shows that between 70 and 80 percent of earthquakes occur in the same general regions, although not necessarily at the same epicenters, where previous earthquakes have occurred and that these regions are generally within fairly well-defined zones or belts. * * * At present there are not sufficient data available to prepare a general seismic probability map of the country based on surface geology. The zone limits shown on this map are based almost entirely on earthquake history and represent the general combined opinions of a number of scientists.

Even though the prospective damsites, tunnel routes, and powerhouse sites are located in an area of only moderate to minor probable damage from earthquakes, the possibility of more severe earthquakes and greater damage should be considered in the location and design of structures.

GEOLOGY OF POSSIBLE POWERSITES APPLIED TO WATERPOWER DEVELOPMENT

The general plans or methods by which power would be developed in this area are described by F. A. Johnson (1962). Any plans for power development will require the creation of storage to equalize the pronounced irregularities in streamflow, and conveying the water from the storage sites to powerhouse sites at or near tidewater. Opportunity for storage exists in three lakes—Scenery Lake on Scenery Creek, Swan Lake on Cascade Creek, and Ruth Lake on Delta Creek. Storage development could be accomplished on Scenery and Swan Lakes by the construction, in each instance, of a dam at the lake outlet to raise the lake surface above its natural level, or by drawing the lake below its natural level, or by a combination of the two methods. Ruth Lake is comparatively shallow and has a small capacity below lake level so any storage development would require the construction of a dam at the lake outlet. To utilize the full potential head, the powerhouse sites would be as near tidewater as practicable and, in general, would be near the mouths of the creeks under consideration. It would also be possible to convey the water from Swan Lake to a powerhouse site at the mouth of Scenery Creek, thus using the water from both Scenery and Swan Lakes in a single powerhouse. The fieldwork was directed toward the examination of damsites at the lake outlets and the suitability of the lakes as reservoir sites, and examination of tunnel routes from each of the three lakes to possible powerhouse sites near the creek mouths and from Swan Lake to a powerhouse site near the mouth of Scenery Creek. Only tunnels were considered as a means of conveying the water from the storage sites to the head of the penstocks leading to the powerhouse sites. Owing to terrain as well as climatic conditions, the use of canals or pipelines was considered impractical. The water-surface elevation in the reservoirs may range from 100 to 150 feet. Consequently, any tunnels considered will have to withstand the hydraulic pressure equivalent to the maximum range in the elevation of the reservoir surface.

The character of the rock beneath the surface is more or less inferred on the basis of field investigation and samples obtained on or near these tunnel courses, and because the dioritic intrusions are recognized as part of the Coast Range batholith. The rock to be penetrated is competent to maintain the tunnel openings and to withstand the hydraulic pressures expected. The surface profiles along the tunnel courses were drawn from the topographic map. The locations of the penstocks were determined by inspection of the topography, and their courses were selected to provide a minimum cover of 100 feet of rock in place.

The engineering geology of each damsite and tunnel site discussed in the following pages is the result of reconnaissance work in these areas. More detailed examination, aided by drill-hole data, will be necessary prior to the planning of any construction. The three reservoir sites are in relatively impervious rock, and no structural or other geologic conditions were observed which might cause appreciable leakage from the reservoirs. Rock-fill or concrete dams of either gravity or arch type could be constructed at all sites.

SCENERY LAKE POWERSITE

TOPOGRAPHY

The catchment basin above Scenery Lake which receives the melt water from two valley glaciers terminating near the unnamed lake east of Scenery Lake (pl. 8), has steep walls probably carved by a more extensive glacier in Pleistocene time. Scenery Lake is a glacial lake and its steeper slopes are barren of vegetation, but most of the rockslides and alluvial fans at the foot of some of the slopes are covered with alder and brush. The floor of the valley above Scenery Lake has a minor amount of relief, and is partly covered by trees and partly by alder and brush. Some spots are poorly drained, and swamps caused by beaver dams or by snowslides that dam drainage courses with rock and debris are common.

The valley bottom of Scenery Creek for the first mile upstream from the head of Scenery Cove is about half a mile wide and of relatively low relief. Fallen timber and large blocks of rock are common near the edges and on the adjoining slopes.

GEOLOGY

Rock types.—The basin of Scenery Lake has been gouged out of solid rock which is almost entirely hornblende-quartz diorite. The basin walls both above and below the lake outlet were sampled at intervals of about a quarter of a mile in order to discover any changes in the wallrock or country rock that might be obscured by forest growth. Occasional samples were also taken at intervals in the upper valley of Scenery Creek as far as the lake and about 1½ miles eastward. Changes in the content of the ferromagnesian minerals, principally hornblende, were noted in a few localities where the diorite became gneissic.

At the outlet of the lake a contact between hornblende-plagioclase gneiss on the southwest and quartz diorite on the northeast crosses the damsite area diagnonally, as shown on plate 8. Both the diorite and the gneiss are firm rocks which do not weather deeply and possess low porosity. The jointing in the diorite is about vertical, rhomboidal, and widely spaced. Individual layers of gneiss are as much as 2 to 4 feet thick. About 200 feet downstream from the lake outlet in the canyon wall on the right bank the ferromagnesian minerals in the gneiss appear to increase, probably owing to a segregation. However, this was not examined closely because it was difficult to reach. The lake outlet is a V-shaped notch caused by plucking of gneiss. Aplitic dikes and sills are common in the diorite.

Structure.—Evidence of geologic structure is provided by the occurrence of infolded crystalline schist or gneiss which has been included as bands, blocks, and stringers in the hornblende-quartz diorite. The foliation or the separate layers dip northward at 57° and strike about N. 60° W. at the damsite. Although it was not followed for the entire length of the outcrop, the gneiss zone apparently extends in the line of strike northwestward to a point about 1,500 feet north of Scenery Creek and about 1 mile northwest of the outlet of Scenery Lake. It is not known whether the gneiss was completely assimilated in the diorite northwest of this point.

A well-defined shear or fault zone appears on the aerial photographs beginning at a point 2.7 miles north of the mouth of Cascade Creek on Thomas Bay and extends more than 2 miles in an eastward direction. In the absence of good exposures the direction of movement was not determined, but the trace of this zone on the aerial photographs indicates a southward dip of the plane of fracture. As this line of weakness does not extend through the Scenery Lake damsite or reservoir site and probably becomes nonexistent east of the South Fork of Scenery Creek, it was not traced beyond this point. A tunnel from Swan Lake to Scenery Creek, however, would cross this zone about 2 miles south of the point where South Fork flows into Scenery Creek. In addition to this shear zone, several lineaments are shown on plate 8 which were located by examination of aerial photographs.

DAMSITES

In this report two possible locations for a dam below the outlet of Scenery Lake are considered. These are shown on plate 9 as *A–A′* and *B–B′*. Johnson (1962) indicates that a dam of a height of more than 90 feet above the lake surface would be required to develop the requisite storage for equalization of the streamflow.

The first site, *A–A′*, is located about 50 feet downstream from the actual outlet and the geology at this site is shown in map view and section on plate 9. The left abutment and the section across the channel would be in a hornblende-plagioclase gneiss. The remainder of the section and the right abutment would be in a hornblende-quartz diorite. The gneiss forms a natural weir through which the lake water flows; consequently, no waterborne deposits exist at that point.

The slopes of both abutments are stable. On the right or north wall the abutment would be in the nearly vertical wall of diorite which rises toward a knoll about 200 feet above the lake. This slope presents no serious problem. The slope of the abutment on the south side, however, is largely bare gneiss with a minor amount of brush and timber, particularly in the upper slopes. The slope is as much as 60° over short distances but averages about 45°, and rock loosened by ice and frost action could slide toward the dam. Snow building up on the upper slopes of this hill could slide toward this abutment, carrying rock and timber with it.

A dam at the first site would have a crest length of about 900 feet and a maximum height of about 130 feet above the channel in order to raise the lake level about 90 feet. The bedrock at this site is suitable for a flexible fill or masonry type of dam of the height required.

The second site considered is designated as *B–B′* on plate 9. A section along this line is also shown on plate 9. This will require a main dam (lower northward-trending solid line, from *B*) across the channel and an auxiliary dam (upper northward-trending solid line to *B′*) across the saddle to the north. The main dam would be located about 300 feet downstream from the lake outlet. This site would be entirely in the metamorphic rock or hornblende-plagioclase gneiss, the individual layers of which range in thickness from 2 to 4 feet and in general dip at an angle of 57° N. and strike N. 60° W. This foliation persists between the site and the lake outlet and beyond, probably for several miles to the southeast. This crystalline gneiss offers a satisfactory foundation for a dam of the height considered, although probably as much as 10 feet of rock might have to be scaled from the steep high wall on the south side of Scenery Creek to reach firm rock for the abutment in that bank. It is doubtful whether any grouting between layers of gneiss would be required. This dam would be about 140 feet in height above the stream channel and would have a crest length of slightly less than 300 feet. The main dam (lower solid line, from *B* on fig. 3) would not be subject to slides on the right bank, but the left bank would be subject to the same slide conditions described for site *A–A′*.

The auxiliary dam (upper solid line, to *B′* on pl. 9) mentioned in the preceding paragraph, is located about 900 feet west of the lake outlet across the saddle on the north bank. A dam at this site would have about the left one-third of its length and the south abutment in gneiss and the right two-thirds of its length and the north abutment in quartz diorite. It would have a height of about 35 feet above present ground level and a crest length of about 250 feet. Foundation and abutment conditions are satisfactory for any type of dam that might be selected for this site.

The area between the main dam in the channel and the auxiliary dam in the saddle, represented by the westward- and northwestward-trending lines (pl. 9), is well above the maximum assumed flow line of 1,050 feet and is all in plagioclase gneiss. This barrier is relatively impervious and would serve as a natural dam. The area along the auxiliary damsite is covered with brush, timber, and muskeg. The slope at the south abutment is gentle and no slide problems would be experienced. The slope at the north abutment (*B′*) of the auxiliary dam, however, consists of massive quartz diorite boulders which may be the remnants of a lateral moraine of the valley glacier, or which may have been moved down from higher altitudes north of these cliffs by normal erosion processes.

Whether the dam is the overflow or the nonoverflow type, erosion of the channel of Scenery Creek by water from the spillway or spillway apron would be a minimum as the gneisses in the area are firmly crystallized and probably sufficiently resistant to dissipate the effects of hydraulic friction and cavitation.

RESERVOIR

The reservoir is almost entirely in hornblende-quartz diorite but a minor area of hornblende-plagioclase gneiss is exposed near the damsite. Both types of rock are relatively impermeable, and in the absence of pronounced faulting or continuous openings which might provide channels for escape of water impounded by the dam, no appreciable leakage from the reservoir is anticipated.

The steep slopes on the borders of the lake show evidence of snowslides at several points. The principal creeks entering the north and the south sides of Scenery Lake thread through debris cones, and during flood stages they carry some detrital material to the lake. A negligible amount of silt may be carried into the lake on such occasions, but it is clear at all times. Moreover, this debris is relatively stable, and even if rockslides occurred they would constitute no serious impediment in the reservoir.

Timber and brush cover the swampy area drained by the upper part of Scenery Creek at the east end of the lake, but some of the steep to nearly vertical slopes around the lake support no timber. The damsite area north of the creek, however, is timber covered.

TUNNEL

A tunnel for conveying water from Scenery Lake to a powerhouse at or near the head of Scenery Cove could be located on either side of the Scenery Creek valley. The field investigations were directed primarily toward a south bank location but the valley walls on the north side of the creek were also examined at intervals. With the exception of the occurrence of plagioclase gneiss, the wallrock on the north side was essentially the same as on the south side of the Scenery Creek valley.

For illustrative purposes in this report a tunnel route was assumed on the south side of the valley, shown in map view as *C–C′* on plate 8 and in section on plate 9. As shown on plate 9 the tunnel diverts from the lake at an altitude of 900 feet. In actual development this may range from as low as 800 feet to as high as 950 feet. The geologic conditions, as nearly as can be inferred from the available information are essentially the same within this range in altitude. The tunnel alinement, as shown on plate 8, is based on an assumed altitude of 900 feet at the diversion from the lake and an adequate cover of rock, about 100 feet, where the alinement crosses the several creek valleys.

As shown on plate 8, a tunnel route on the south side of the valley would have a total length of nearly 20,000 feet and would be in hornblende-plagioclase gneiss for about the first 1,200 to 2,000 feet from the lake with the remainder in quartz diorite. A location on the north side of the valley would be in quartz diorite for about the first half mile from the lake, then would pass through a zone of hornblende-plagioclase gneiss for 1,500 to 2,000 feet with the entire remaining part in quartz diorite.

The character of the rock to be penetrated, whether on the south or north bank, assures stability in openings of the tunnel throughout most of its length. However, one or more zones of weakness appear on the aerial photographs along the proposed tunnel route near the South Fork of Scenery Creek and these zones should be drilled prior to location of the tunnel or the penstock. No other unfavorable geologic conditions are believed to exist along the tunnel routes that would most likely be considered from Scenery Lake to Scenery Cove.

CONSTRUCTION MATERIALS

A concrete or fill type of dam could be built at the Scenery Lake damsite. Coarse aggregate for concrete could be obtained by quarrying and crushing rock in the vicinity of the site. There are scattered gravel bars along Scenery Creek, particulary near mile 1.0. An inexhaustible supply of relatively clean fine to coarse sand and gravel is available at the north end of Thomas Bay in the broad outwash plain below the Baird Glacier. This deposit is 1½ miles north of the entrance to Scenery Cove and is accessible to boats of shallow draft. Small deposits of sand and gravel occur in the valley of Scenery Creek above the lake and in creeks entering the lake. There is some doubt as to the availability of the necessary fine materials for a fill type of dam.

SWAN LAKE POWERSITE

TOPOGRAPHY

The north and south boundaries of the Cascade Creek drainage basin are marked by comb ridges. The catchment basin above Swan Lake is characterized by evidence of both past and present glacial action. Streams descending from valley glaciers and from the icecap flow into the lake. The cirques or minor basins which contribute their drainage to the lake directly are probably the work of alpine glaciers. The creek which enters the northeast part of the lake is fed by the melt water of the icecap and two valley glaciers several miles east of the lake. This creek flows through a broad relatively flat valley about 1 mile long, from the upper end of which falls descend about 60 feet to the valley floor.

Cascade Creek, which flows out of Swan Lake, descends about 350 feet in the first half mile. A falls at the head of Falls Lake is about 80 feet high. After leaving Falls Lake through a narrow gorge the stream gradient is steeper, and in the next mile the creek follows a straight course and descends about 850 feet. In the last half mile to the coast it falls about 250 feet and flows through a narrow rock-walled valley. The steplike character of the upper streambed is shown on the profile of Cascade Creek on the topographic map. As its name implies, there are many rapids and cascades throughout the length of Cascade Creek.

The side slopes of the lake in general are not quite as precipitous as those of Scenery Lake and are covered in large part by forest growth.

GEOLOGY

Rock types.—The rock in the reservoir area is generally gneissic in character, particularly on the south side of the lake, and in comparison with the Scenery Lake area, it exhibits a definite increase in content of mafic minerals. There may be two sheets of intruded batholithic material in this area, one of which crosses the outlet of the lake. One of these intrusive sheets may be classed locally as gabbro and the other as hornblende-quartz diorite. These rocks have not been mapped separately and in detail because they are part of the same batholithic intrusion in which quartz diorite predominates.

The massive gneiss layers on the south side of the lake consist of hornblende and plagioclase with quartz, garnet, biotite, and epidote as accessory minerals. The hornblende crystals are parallel to the foliation. Aplitic dikes 6 inches to 3 or 4 feet in thickness were observed, and although southeast of the lake the aplitic zone may be very much thicker, it is probably of lenticular shape. Small light-colored dikes are numerous and conspicuous around the lake and they intersect each other at various angles. Beds of marble or crystalline limestone ranging from a few inches to 4 or 5 feet in thickness were observed in the gneiss north of the lake outlet, also southeast of the lake, and between this point and the falls on the creek which enters the lake on the northeast side. The marble is pure white and in places medium to coarsely crystalline; some thin stringers are pure calcite.

Deposits of glacial sand and boulders occur in the valleys of the creeks on the east end of the lake. Angular boulders and reworked glacial debris occur at the mouths of drainage channels at or near lake level. Cascade Creek below the gorge at the outlet of Swan Lake flows through cobbles and boulders before dropping over the falls at the head of Falls Lake.

Around Falls Lake the country rock and the ledge which forms the falls are hornblende-quartz diorite. Sampling at intervals along Cascade Creek to the coast revealed no abrupt change in the composition of the bedrock, although the content of hornblende appears to increase westward and the rock becomes definitely gneissic in character.

Structure.—Near the east end of the lake the layers of hornblende-plagioclase gneiss in a small exposure strike N. 55° W., and dip 47° NE. At the contact with the hornblende-quartz diorite near the west end of the lake the gneiss contact trends northwestward. However, along the creek entering the northwest side of the lake near the lake outlet and about 500 feet higher than the lake, calcareous gneiss is exposed in a small sharp isoclinal fold about 75 feet across. This calcareous gneiss zone extends over the divide beyond the headwaters of the South Fork of Scenery Creek and trends slightly west of north. There appears to be a shear zone on both sides of Swan Lake roughly following the creeks that enter the lake near the outlet. The creek on the south side of Swan Lake east of the lake outlet, however, roughly follows the contact of the hornblende-plagioclase gneiss and the quartz diorite. In the lower part of the South Fork of Scenery Creek the calcareous gneiss was absent but was observed about 1 mile above the main creek.

The slightly incised valleys near each abutment site and transverse to the axis of the proposed dam, between 800 and 1,000 feet to the north and south of the lake outlet, so far as could be determined by field examination, are not faults but probably are joint fractures which eroded more easily than the neighboring rock. These localities should be drilled to verify this supposition as it was not possible to inspect these points closely because of forest growth.

The straight course of Cascade Creek southwestward from Falls Lake for a distance of about 4,000 feet, its abrupt turn at that point southeast for about 1,000 feet, and another right-angle turn southwestward toward the coast are evidently the result of the structural pattern of the area. This might affect the stability of a tunnel from Swan Lake to a point near the mouth of Cascade Creek.

DAMSITE

The narrow gorge immediately downstream from the outlet of Swan Lake presents favorable topography for the location of a dam. The bedrock in this gorge consists entirely of hornblende-quartz diorite. The south or left wall of the gorge is practically bare for more than 100 feet above the altitude of Swan Lake. The north or right side of the gorge is covered with thick brush, trees, and large boulders and blocks of diorite. Within the narrower part of the gorge large blocks of diorite, 10 to 20 feet in maximum dimension, line the stream channel and to a lesser extent form the outlet of the lower part of the channel. There are two small incised valleys, one on each side of the gorge, roughly parallel to Cascade Creek and several hundred feet higher than the altitude of Swan Lake. Examination of these localities furnished no evidence of faulting, either active or dormant, and it was concluded that jointing was solely responsible for these incised valleys. Exploratory drilling to verify this should be included as part of any detailed investigation of this site.

The right or north side of the gorge, because of the cover of trees and brush and the large irregular boulders, should be reasonably free from slides. The left or south wall might be susceptible to slides, however, as it is practicaly bare and is steeper.

The most likely location for a dam would be at the narrowest part of the gorge (*D–D′*, pl. 9) which is about 500 feet downstream from the lake outlet. A dam at this site should have a crest length of 300 feet. The waterpower report by Johnson (1962) shows that a dam that would raise the lake level about 100 feet would be required at this site to attain the desired regulation of outflow from the lake. The foundation and abutment conditions are satisfactory for the construction of either a masonry or rockfill type of dam of the height indicated. The rock conditions in the channel downstream from the dam would effectively withstand the erosion from any spillway discharge.

RESERVOIR

The rock surrounding Swan Lake includes, in addition to hornblende-quartz diorite, a large amount of hornblende gneiss, diorite gneiss, and calcareous gneiss that contains beds of marble. With the exception of the gneiss containing marble, near the west end of the lake, none of the rocks observed would be susceptible to rapid weathering. The location of these calcareous gneisses near the lake would not promote leakage, and permeability is lacking in other rocks in the reservoir. No faults, joints, or openings were observed that might cause water losses. However, the two notches on each side of the lake outlet previously described should be core drilled.

The reservoir rock supports a good growth of timber over much of the lake basin and, with the exception of a few areas subject to snowslides, the slopes can be considered stable.

An increase in elevation of the lake surface would flood some timbered areas. The valleys of the two creeks that enter the upper part of the lake are covered with alder and brush.

Water from Swan Lake could be diverted to a powerhouse site at or near the head of Scenery Cove (*C–E*, pl. 8) or to a site at or near the mouth of the Cascade Creek (*F–F′*, pl. 8). Sections along these routes are shown on plate 9. In this figure the tunnels have been shown as diverting at lake level. If the storage were utilized in the absence of a dam by drawing the lake below its natural level, these tunnels could be about 125 feet lower than indicated. Judging from the information available, geologic conditions would be virtually the same at either altitude considered, lake level or 125 feet lower.

TUNNELS

Swan Lake–Scenery Cove tunnel.—The tunnel route from Swan Lake to Scenery Cove, *C–E* as considered in this report, would follow a course roughly parallel to the creek that enters the northwest end of the lake and parallel to the South Fork of Scenery Creek (pl. 8). Reconnaissance of these creek valleys discloses that gneiss containing white marble or crystalline limestone bands and stringers is continuously exposed from a point about 150 to 200 feet above Swan Lake to the divide between the Scenery Creek and Swan Lake drainage. Although detailed information is lacking, this gneiss zone apparently is continuous northward beneath the snow and icecap to a point on the South Fork of Scenery Creek about 1½ miles below the divide. Whether these infolded or included blocks and stringers of gneiss exist at the depth of the probable tunnel grade—below an altitude of 1,500 or possibly 1,375 feet—is not known, but this can be determined by diamond drilling.

Reconnaissance along this tunnel route discloses that the first sizable outcrop of marble occurs about 600 feet above lake level at an altitude of about 2,100 feet. A conclusion based solely on this observation is that a tunnel grade at an altitude of 1,500 feet or lower would probably not find the calcareous gneiss, particularly if the tunnel were driven west from the outlet of Swan Lake west of the South Fork of Scenery Creek through the quartz diorite along a course approximating that indicated by the line on plate 8. This tunnel would intersect a shear zone, which apparently extends eastward from the bay about 1,000 feet south of triangulation station "Land" to a point about 2 miles south of Scenery Cove, as shown on plate 8. In addition to this zone, six lineaments are shown which may indicate fracture zones that could affect tunneling operations along the route indicated.

The total length of this tunnel would be about 3½ miles, and the length of the penstock would be about 2,500 feet.

Cascade Creek tunnel.—The tunnel route from Swan Lake to a powerhouse site at or near the mouth of Cascade Creek was selected for consideration in this report on the north side of the Cascade Creek valley, and is designated as *F–F′* on plate 8. The alinement indicated was based on topographic considerations so that there would be an adequate rock cover over the tunnel at all points. A course on the south side of the valley was not considered as desirable because of the presence of several reentrants resulting from Recent and Pleistocene erosion and glaciation. Sampling at intervals between the lake and the bay along Cascade Creek showed that the tunnel route as indicated would be in hornblende-quartz diorite throughout its entire length. Four shear zones may be intersected by the proposed tunnel. A section along the route is shown on plate 9. The tunnel would be about 2¼ miles long. If the powerhouse site were at the mouth of Cascade Creek on Thomas Bay a penstock over 4,000 feet long would be required. If a satisfactory powerhouse site could be had at a point along the shore about 3,500 feet north of the mouth of Cascade Creek the penstock length could be reduced to about 2,000 feet or less.

CONSTRUCTION MATERIALS

Because of the scarcity or absence of appropriate fine materials, a fill type of dam would not likely be considered at the Swan Lake damsite. Coarse aggregate for a concrete dam could be obtained by quarrying and crushing rock in the vicinity of the site. A limited supply of sand and gravel may be available in the small creek valley 1,000 feet southeast from the outlet of Swan Lake. A substantial quantity is available in the creek valley upstream from Swan Lake. If this source is unsatisfactory or inadequate the outwash plain below the Baird Glacier (p. 116) could be considered.

RUTH LAKE POWERSITE

TOPOGRAPHY

The north wall of Ruth Lake is nearly vertical, but the south wall is less steep and covered with trees. The channel out of the lake is 2 to 5 feet deep, probably owing in part to the accumulation of boulders, after which Delta Creek enters a narrower channel. The north bank, less than 200 feet from the outlet, is almost vertical to a height of 60 to 70 feet above stream level but the south bank slopes more gently, and large blocks of quartz diorite have accumulated from the outcrop of bedrock about 50 feet above the stream. Delta Creek is slightly more than 2 miles long and follows a more circuitous course than Scenery Creek or Cascade Creek.

GEOLOGY

Rock types.—The exposed north wall of the lake contains many dikes that have penetrated the hornblende-quartz diorite in the same manner as at Scenery and Swan Lakes to the north, and the diorite forms a similar reservoir of smaller dimensions. The joints in the intrusive masses also govern minor drainage to some extent. Samples were taken on the north and south banks. The lower 50 feet of the north wall was identified as hornblendite and apparently is a segregation, but the quantity of hornblende diminishes in the upper part of this wall and the rock seems to change to a gabbro. Farther downstream the right bank is hornblende-quartz diorite. Rock of the south bank is virtually the same type where exposed. In general, the bedrock along Delta Creek toward the bay contains increasing amounts of ferromagnesian minerals and is gneissic in several localities. Within ½ to ¾ mile of Thomas Bay the bedrock is entirely hornblende gneiss.

Structure.—The foliation of the schist and massive gneiss within half a mile of the coast dips generally eastward, although this foliation may be from overturned beds of the Juneau synclinorium (Seymour geosyncline of Payne). In the gneiss zone near the coast dips as high as 70° E. were noted. The foliation becomes less distinct eastward and the bedrock is essentially a part of the diorite mass. Without a boat little opportunity was afforded to examine the structure of the reservoir, but so far as could be determined from the outlet of the lake and from aerial photographs no faulting or folding has affected the reservoir area; at least no unfavorable conditions were apparent. The reservoir area seems to be a part of the main mass of hornblende-quartz diorite.

DAMSITE

The Ruth Lake damsite shown on plate 9 was not surveyed but is an enlargement of that part of the special topographic map of the area (U.S. Geol. Survey, 1952).

Delta Creek, immediately downstream from Ruth Lake, flows through a very narow canyon section about 600 feet in length. About 200 feet downstream from the lake outlet the right or north bank is very steep and the first 60 or 70 feet above the stream is practically vertical. The left or south bank is also very steep but not quite as steep as the north bank. The bedrock through the canyon section consists mainly of hornblende-quartz diorite although there is an increase in mafic mineral content as compared with the area examined along Cascade and Scenery Creeks to the north. The slopes on both sides of the canyon, at the most probable site for a dam, seem to be stable.

Waterpower studies (Johnson, 1962) indicate that it would be necessary to raise the level of Ruth Lake as much as 215 feet to obtain the desired regulation of the outflow. The required dam would be about 245 feet high and have a crest length of 400 feet. The rock conditions in the canyon are satisfactory for the construction of either a masonry or rockfill dam. Rock conditions in the channel downstream from the dam location would withstand the erosion from spillway discharges.

RESERVOIR

The country rock at the lake outlet is hornblende-quartz diorite; locally, however, it approaches the composition of a gabbro. From the brief field observation made and from examination of aerial photographs, it is concluded that the entire reservoir is this type of rock. No faults or continuous openings which might permit escape of impounded water were observed, and the lack of permeability of the bedrock indicates that the probability of any appreciable leakage from the reservoir is remote. A small area of unconsolidated sediments is present in the stream valley at the upper end of the lake.

The slopes of the reservoir seem to be stable throughout, although minor snowslides and rockslides might occur on the north side of the lake from the bare slopes and in the stream valleys.

The north wall is steep to vertical for a height of more than 500 feet above the lake and supports little timber. The south border of the lake supports a good growth of timber.

TUNNELS

Plans for the utilization of the water from Ruth Lake would require diversion by tunnel along one of three different routes: (a) from Ruth

Lake to a point at or near the mouth of Delta Creek on Thomas Bay; (b) from Ruth Lake to a point at or near the mouth of Cascade Creek on Thomas Bay; and (c) from Ruth Lake southwestward to some point in the Patterson River valley. The first two are designated as *H–H′* and *F–I* on plate 8; the third route is not shown.

Observations along the foot trail in the Delta Creek valley indicate that the quartz diorite rock in the valley is locally gneissic in character and becomes entirely gneiss as the coast is approached—that is, toward the west. A tunnel from Ruth Lake to the mouth of Delta Creek would be mainly in the quartz diorite, except in the area from one-half to three-quarters of a mile from the coast where it would be in gneiss.

Rock conditions along the route to Cascade Creek were observed only in the vicinity of Ruth Lake and at the mouth of Cascade Creek. The rock in both these areas was quartz diorite and it is believed that the entire route would be in the diorite.

No observations were made in the Patterson River valley, but it is assumed, based on aerial photographs, that a tunnel route from Ruth Lake that terminated in this valley would find essentially the same rock conditions as were observed at Ruth Lake; that is, quartz diorite and gneiss.

CONSTRUCTION MATERIALS

Conditions at the Ruth Lake damsite are about the same as at the Scenery Lake and Swan Lake damsites, in that the necessary fine materials for a fill type of dam are not available. Coarse aggregate could be obtained by quarrying and crushing rock in the vicinity. A limited supply of sand and gravel may be available in the valley upstream from the lake. Other sources for sand and gravel would be the Patterson River delta or the outwash plain below the Baird Glacier.

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