Geologic Investigations of Proposed Powersites at Baranof and Carbon Lakes Baranof Island, Alaska

GEOLOGICAL SURVEY BULLETIN 1031-B

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By KENNETH S. SOWARD

GEOLOGY OF WATERPOWER SITES IN ALASKA

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A description of the proposed dam, tunnel, and reservoir sites on each lake, with conclusions and recommendations

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GEOLOGIC INVESTIGATIONS OF PROPOSED POWERSITES AT BARANOF AND CARBON LAKES, BARANOF ISLAND, ALASKA

By Kenneth S. Soward

ABSTRACT

The dam, conduit, and powerhouse locations that would be considered in the development of the Baranof Lake powersite are all on or in biotite-quartz diorite that is sound, strong, and suitable as a foundation for such structures. No large scale structural defects are exposed, but on aerial photographs linear features, which are interpreted as faults, can be projected through the damsite and across the adjacent ridge at points 400 and 3,200 feet south of the Baranof Lake outlet. Overburden 1 to 15 feet thick covers much of the area in which a dam would be located, and detailed exploration by drilling will be necessary. Hot springs occur 500 to 1,000 feet east of the lake outlet along the left bank of the Baranof River, between the altitudes of 120 to 154 feet.

The damsite and probable tunnel route of the Carbon Lake powersite are on or in migmatite that is strong and suitable as a foundation for such structures. The penstock and powerhouse sites are on a massive biotite-quartz diorite dike that forms a cliff along the inner shore of Cascade Bay. Overburden covers bedrock on the left (west) abutment and in the stream channel at a possible dam location. A large rock fall is at the toe of the right (south) abutment. Detailed exploration by drilling is necessary in these areas.

INTRODUCTION

The U.S. Geological Survey, as part of its program of classifying public lands with respect to mineral and water resources, is currently making a systematic study and evaluation of the potential waterpower sites in Alaska. This report describes geologic conditions at two proposed powersites on the east coast of Baranof Island, Alaska (fig. 2). The sites were examined to determine their limiting geologic features and to outline the next steps for an orderly and complete geologic investigation. The general term "powersite" is used in this report to include all elements, such as the dam, conduit, powerhouse, and reservoir sites of power development.

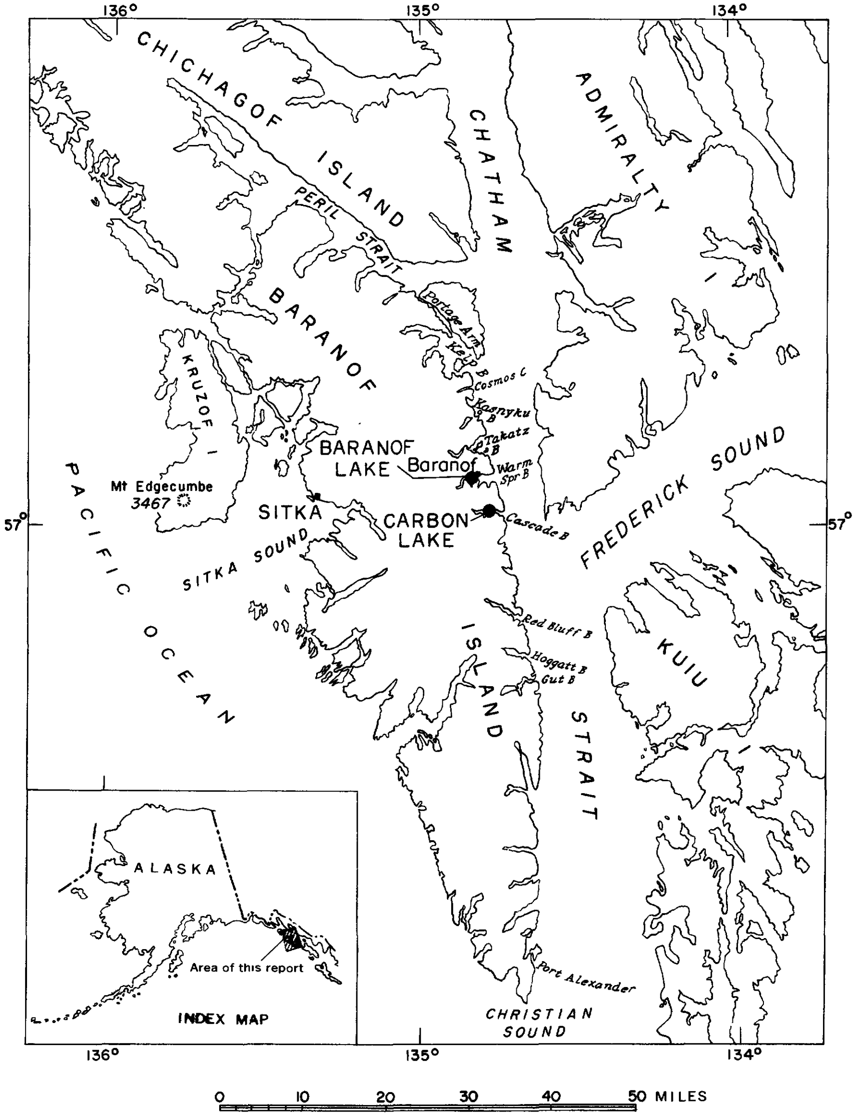

FIGURE 2.—Index map showing location of Baranof and Carbon Lakes.

The geology of Baranof Island has not been investigated in detail. The regional geology is described by Knopf (1912) and Overbeck (1917), and it is shown on the "Geologic Map of Alaska" (Dutro and Payne, 1957). The geology of the island is referred to briefly in the summary report on the geology of southeastern Alaska by Buddington and Chapin (1929). Detailed mineral investigations of small parts of the island, mainly on the west coast, have been made (Guild and Balsley, 1942). The waters from the hot springs at Baranof have been reported on by Waring (1917). Power potential and possible means of development of the lakes were first investigated by Dort (1924, p. 110–116). The sites are also described in a report by the Federal Power Commission and the U.S. Forest Service (1947).

The topographic surveys and the geologic investigations of the Baranof Lake and Carbon Lake powersites were made during July and August 1956.

Baranof Lake and Carbon Lake are shown on the U.S. Geological Survey Sitka quadrangle of the Alaska reconnaissance topographic series, scale 1: 250,000 (1 inch equals approximately 4 miles), contour intervals 200, 250, and 1,000 feet; and on the Sitka A–3 quadrangle of the 1: 63,360 (1 inch equals 1 mile) topographic series, contour interval 100 feet. The lakes and adjacent areas are shown on a river survey map, "Plan and Profile, Baranof Lake and Carbon Lake, Alaska, Dam Sites." On this map the lakes and adjacent areas are shown at a scale of 1: 24,000 (1 inch equals 2,000 feet) with 20-foot contour interval. Underwater contours are shown for the lakes to depths of 60 to 100 feet below lake level with a few spot soundings indicating maximum depth. Maps of the prospective Baranof Lake and Carbon Lake damsites are included. The former is on a scale of 1: 2,400 (1 inch equals 200 feet) and the latter on a scale of 1: 4,800 (1 inch equals 400 feet). Both damsite maps have a 10-foot contour interval. A profile of the mapped reaches of each stream, including the surface and approximate bottom profile of each lake along its centerline, is shown.

Baranof Island is rough and mountainous. Along the east shore the ground surface rises steeply from sea level to altitudes ranging from 1,000 to 2,900 feet. Above these altitudes the slope flattens, but the ground surface continues to rise to altitudes of 5,000 to 6,000 feet in the mountainous interior.

GENERAL GEOLOGY

Baranof Island has been extensively glaciated, and the present topography is the result of ice erosion only slightly modified by later stream erosion. Alpine glaciers flowed down from the central mountains and eroded spectacular glaciated valleys. These valleys often terminate in small fiords that indent the coastline for distances of 0.8 to 6 miles, and they are spaced 2 to 13 miles apart along the straight eastern shoreline of the island. Glacial lakes occupy some of the lower sections of the valleys. The streams in the valleys have high gradients, and many of them cascade into tidewater at the head of the fiords.

The rocks of Chichagof and Baranof Islands lie in broad belts that strike northwest-southeast and conform with the prevailing structural trend of southeastern Alaska (Knopf, 1912, p. 11). The core of the island is made up largely of quartz diorite intruded parallel to the stratified rocks. A large batholith that crosses the northern end of the island is exposed over a distance of 34 miles and a width of 5 to 10 miles. Bordering the batholith on the southwest is a northwestward-trending belt of metamorphic rocks. In turn, this belt is bounded by another composed of graywacke and slate that forms the bedrock on the west side of the islands.

Baranof Lake powersite is in biotite-quartz diorite about 1 mile north of the southern edge of the batholith, as shown on the "Geologic Map of Alaska" (Dutro and Payne, 1957). Carbon Lake powersite is about three-fourths of a mile south of the batholith in an area of metamorphic rock. Bedrock is a migmatite.

An inferred major northward-striking fault lies in Chatham Strait about 9 miles east of Baranof Lake outlet (Wright and Wright, 1908; Martin and Williams, 1924). The estimated length of the fault is 250 miles, extending north from a point about 100 miles south of Warm Spring Bay to Lynn Canal. The Chatham Strait fault is a split or extension of the Denali fault, a great arcuate fault that can be traced from Lynn Canal to Bristol Bay (St. Amand, 1957). Twenhofel and Sainsbury (1958, p. 1435) believe that the Denali fault and probably the Chatham Strait fault are active along their entire length and have been active, at least since early Tertiary.

A large northwestward-striking fault that lies in Peril Strait intersects the Chatham Strait fault about 11 miles northeast of Baranof Lake outlet. Twenhofel and Sainsbury (1958, p. 1435) include this fault as a segment of a large fault, which they call the Clarence Strait lineament and which extends from Clarence Strait to Cross Sound. The Clarence Strait fault may intersect the active Fairweather fault that lies on the southwest side of the Fairweather Range. However, they believe this interpretation may not be correct as the Fairweather fault cuts Tertiary (Eocene) rocks, whereas the Clarence Strait lineament on Kuiu, Kupreanof, and Admiralty Islands is covered by Tertiary (Eocene) rocks and presumably has not been active since that time.

EARTHQUAKES

Although the structural settings, within and adjacent to a major batholith, provide favorable locations for dams and related structures, the earthquake history of southeastern Alaska shows that the area is still seismically active. In the Sitka-Juneau-Skagway area, 16 earthquakes with an estimated intensity of 5 or more on the Modified Mercalli scale have been reported between 1843 and 1956 (Heck and Eppley, 1958, p. 72–78). Between Cape Spencer and Yakutat Bay, 120 to 250 miles northwest of Baranof and Carbon Lakes, 9 earthquakes with intensities between 5 and 10 have been recorded between 1896 and 1946. The Cape Spencer-Yakutat Bay area lies along or adjacent to the Fairweather fault. The relation of nearby active and inactive faults with areas of recorded strong seismic activity makes it prudent that maximum protection against earthquakes be considered in the design of any structure built at the sites. Also, if a powerhouse should front on tidewater, consideration should be given to tsunamis in its design.

BARANOF LAKE POWERSITE

LOCATION AND ACCESSIBILITY

Baranof Lake damsite is at the outlet of Baranof Lake, 0.3 mile from the point where Baranof River discharges into Warm Spring Bay. (See pl. 5.) Baranof is a small settlement at the upper end of the bay. It is a popular port of call for fishing boats and yachts because of its protected harbor and nearby hot springs. Waters from the springs are used in one small public bathhouse and a number of tubs in cabins. In 1956, there was weekly airmail service and weekly boat service for mail and freight between Baranof and Juneau. The proposed dam and powerhouse sites are easily accessible by trail from Baranof.

TOPOGRAPHY AND VEGETATION

Baranof River and Lake are in a deep, narrow, U-shaped glacial valley. The lower end is now occupied by a fiord, Warm Spring Bay, which is 2.4 miles long, and Baranof Lake, which is 3.0 miles long. The lake, with a water surface at altitude 145 feet, is retained by a low rock ridge that extends north for 3,600 feet across the valley. The highest point on the crest of the ridge is at an altitude of about 325 feet. The lake outlet is within 1,500 feet of tidewater as is also a point on the lakeshore 1,400 feet south of the outlet. (See pl. 5.) A small hill west of the south end of the ridge rises to an altitude of 500 feet. A saddle crosses the ridge about 3,200 feet south of the lake outlet at the point where the ridge joins the main valley wall. The maximum altitude of the ground surface in the saddle is about 240 feet above sea level, or 95 feet above the lake level. Another smaller saddle with ground surface near altitude 235 feet is along the north valley wall about 450 feet north of the lake outlet.

Baranof River crosses the ridge about 600 feet south of the north valley wall and in one-third mile descends 145 feet to the bay. From the lake outlet to a point 700 feet downstream, through the proposed damsite, the river falls 8 feet.

The damsite is immediately downstream from the lake outlet. (See pl. 5 and figs. 3 and 4.) Near the possible axis line of the dam shown in section *A–A′* (pl. 5) the valley is 110 feet wide at the river surface at altitude 145 feet; 150 feet wide at 150 feet; 790 feet wide at 200 feet; 1,040 feet wide at 240 feet; and about 2,300 feet wide at 300 feet.

A heavy growth of vegetation covers much of the damsite area. The left (north) abutment has been burned over and now supports a thick growth of lodgepole pine, hemlock, and grass. On the right (south) abutment the soil layer on top of bedrock is thin and tree growth is sparse. However, bedrock is concealed in many places by a heavy growth of grass and light brush, and small peat bogs have developed in the undrained depressions on bedrock. Natural terraces with bogs have been built on some slopes. Wherever the soil layer is thick enough, there is a heavy stand of timber.

GEOLOGY

BEDROCK

All rock exposed at the damsite is classified from megascopic examination as biotite-quartz diorite or a closely related rock type. The rock is light to dark gray and medium to fine grained and has crystals that range from 1 to 4 mm in length. The biotite crystals are wavy and many of the quartz and plagioclase crystals are slightly crushed or granulated. Occasional garnet crystals or masses 0.5 to 2.0 mm in diameter occur. Rocks of more dioritic composition occur in small exposures at the footbridge, 100 feet south of the rapids between altitudes of 135 and 116 feet, and near the mouth of Baranof River.

STRUCTURAL FEATURES

The only structural features exposed at the site are a few small faults and joints. The faults range from partings with slickenslides to thin seams with as much as 2 inches of broken rock and gouge along them. Their general strike is to the north, and 3 of 4 fractures with crushed rock along them are in a set that strikes N. 12°–30° W. and dips 80°–88° SW. The other faults fall into sets with the following attitudes: strike N. 8° E. and N. 7° W., dip 68° and 79° E.; N. 27°–45° E., 26°–40° SE.; and N. 25°–27° W., 41°–63° NE.

Two major joint sets include 56 percent of the joints on which observations were taken. Of the remainder, 23 percent fall into 5 sets that have 2 to 4 joints per set, and 21 percent are fractures with

FIGURE 3.—East end of Baranof Lake. Outlet of lake is slightly left of center of view.

FIGURE 4.—View southwestward across lower end of Baranof Lake. Lake outlet in lower left center of view.

random orientations or have strikes and dips that are close to those of the sets. The two major sets have the following attitudes: strike N. 20°–45° E., dip 16°–40° SE., and N. 20° W.–N. 19° E., 66°–89° E. The minor sets have the following attitudes: strike N. 27°–43° W., dip 36°–57° E.; N. 25°–28° W., 84°–89° SW.; N. 50°–55° W., 82°–85° NE.; and N. 72°–82° E., 80° SE. to 85° NW.

On the aerial photographs covering Warm Spring Bay and Baranof Lake, three sets of strong linear features stand out prominently. Linear features are straight or gently curving physiographic features, and these are interpreted as faults or fault zones. The bearing of one set is N. 16° W. to N. 15° E. This direction correlates with one of the major joint sets and one of the minor fault sets. A second set strikes N. 37°–65° E. and partly overlaps the other major joint set and a minor fault set. The third set strikes N. 31°–60° W. and correlates roughly with two of the minor joint sets.

The linear features may be related to structural features of greater size and extent than any exposed at the damsite. In the set that bears N. 37°–65° E. they are continuous and pronounced. One of the linear features can be projected along the draw that is 400 feet south-southeast of the lake outlet, and its extension to the east-northeast would lie in the river channel. However, no structural feature that can be related to it is exposed in the area. Any fault or shear zone striking through the draw would have to be less than 2 or 3 feet wide, because closely spaced bedrock outcrops near the river about 250 feet northeast from the point where section *A–A′* crosses the draw would expose a wider fault zone. Another linear feature that falls in this set extends through the narrow saddle at the south end of the ridge. No structural features are exposed, but a sharp small reentrant is present in the east face of the ridge northeast of the saddle. At altitude 190 feet, rock outcrops are 100 feet apart on either side of the reentrant, and a fault or shear zone as much as 20 to 30 feet wide could be concealed.

A prominent line on the photographs that bears N. 6° W. crosses the damsite area. Any structural features related to it should crop out in the south bank of Baranof River 300 to 400 feet upstream from the footbridge. Apparently the line reflects only minor structural features, because in this area two small faults and some joints are exposed. The faults, which have thin zones of broken rock 1 to 2 inches thick along them, strike N. 17° and 30° W. and dip 84° SW. The joints that parallel the line strike N. 10°–15° W. and dip 77°–84° NE.

A prominent linear feature that bears N. 35° W. extends through a small indentation in the shoreline 1,500 feet south of the lake outlet. There are no exposures of any structural feature related to it.

UNCONSOLIDATED DEPOSITS

Throughout most of the damsite area, a thin layer of unconsolidated material overlies bedrock. Alluvium consisting of boulders, gravel, and sand is exposed in a few places along the left river bank from the lake outlet downstream for 600 feet. Sand and silt are exposed on the lake bottom near the outlet and along the shore. In the draw north of the lake outlet from 200 to 800 feet east of the rock outcrop at the bend in section *A–A′* (pl. 5), and in the small draw to the west of the outcrop, there are boulder-strewn areas with subangular boulders 2 to 3 feet and a few as much as 7 or 8 feet in diameter. Soil, gravel, and silt are exposed between the boulders. Over much of the remainder of the site, topsoil and a heavy growth of grass, brush, and timber conceal the underlying deposits.

Although the ridge alined across the lake outlet is a glacial feature, no till is exposed in it. A thin layer of soil and rocks that may have been derived from till is exposed along the edge of the lake in the small cove about 1,500 feet south of the outlet. In the draw northeast of the lake outlet, till may be at depth, but no exposures were found. At Baranof, impervious boulder clay is exposed in a small drainage ditch around one of the cabins at the foot of the north valley wall.

HOT SPRINGS

Baranof hot springs are on the north side of the Baranof River 500 to 1,000 feet east (downstream) from the lake outlet. The springs are between altitudes of 120 and 154 feet or from 25 feet below to 9 feet above the surface altitude of Baranof Lake. Four of the ten springs found are 2 to 9 feet above the lake level. All the springs issue from unconsolidated deposits of quartz diorite boulders, gravel, and silt, but spring 3 (see pl. 5) is only a short distance from the bedrock outcrop.

The hot springs have been discussed by Waring (1917, p. 27–32). As closely as possible, the numbering of the springs shown on plate 5 follows that given on his sketch map. Spring 9 in the river channel was not noted in this survey, and its location is from Waring's map. Springs 10 and 11 are minor seeps not shown on his map.

Waring classified the water from the springs as sodium carbonate type, of moderate total mineral content, with silica making up an unusually large proportion of the total. He concluded that the springs appear to be in a locality of some crustal movement, and may possibly be ascribed to fault fissures that allow the upward escape of deep-seated waters.

The analyses of Baranof hot springs, are comparable to those of siliceous geyser waters given by Clarke (1924, p. 197). However, the mineral content of the geyser waters is much greater, and the percentage of chloride ions in all but one analysis is 4 to 12 times greater than that of the Baranof waters. Although Waring attributes the waters to a deep-seated source, the low mineral content and small percentage of chloride ions indicates that the magmatic waters are being diluted by metoric water.

A number of the springs are along two lines that bear N. 52° E. and N. 82° E. These bearings fall in or close to a major set of linear features observed on the aerial photographs and may reflect fractures along which the water could rise. To the southwest these lines would intersect the lake basin, but if they do, the openings must now be sealed.

DEVELOPMENT SCHEMES

Development of the Baranof Lake powersite could be accomplished by the construction of a dam at the lake outlet of sufficient height to obtain the required storage for regulation of the streamflow. The water could be conveyed by a conduit from the resulting reservoir to a powerhouse located either on the shore of Warm Spring Bay about 250 feet south of the mouth of Baranof River or on a tidal lagoon 2,100 feet south of the river mouth (fig. 5). The conduit would be either a pipeline or tunnel, or a combination of both. If the powerhouse were located at a point about 250 feet from the mouth of

FIGURE 5.—Shore of Warm Spring Bay south from mouth of Baranof River. Note lagoon in upper left part of view.

Baranof River the conduit (pipeline) would cross the bench in the cleared area above the river on the right side of the view in figure 5. If the powerhouse were located on the lagoon, water would be conveyed to it from the lake by a tunnel through the ridge shown in the upper right part of the view.

DAMSITE

The most favorable location for a dam, based on topographic considerations, is immediately downstream from the lake outlet. This location is indicated by section *A–A′* (pl. 5). Along this section, bedrock crops out occasionally or is covered by unconsolidated deposits, estimated to be as much as 10 to 15 feet in depth. However, at two places the depth to bedrock may be greater. A narrow, deep channel or slot could be concealed between the rock outcrop on the right (southeast) bank 50 feet downstream from section *A–A′* and the next rock outcrop 265 feet to the northwest. Similarly, between the north end of the section and the first outcrop 150 feet to the south, the depth to bedrock may be more than the estimated 10 to 15 feet. Immediately north of the section, the valley wall rises at a steep angle for 200 feet, and bedrock is at shallow depths.

A fault or shear zone may be concealed in the low area about 400 feet south of the outlet where the linear feature that strikes N. 57° E. crosses section *A–A′*. About 660 feet south of the outlet the ground surface rises to above altitude 250 feet, and from that point to the south end of the section, scattered bedrock outcrops extend through a thin cover of topsoil, some alluvium, and a small amount of talus.

The saddle about 3,200 feet south-southeast from the lake outlet must be considered in any plan of development which would raise the maximum lake altitude an appreciable amount. The ground surface in this saddle is at an altitude of 240 feet, which is 95 feet above normal lake level. The saddle area is covered by soil and a heavy growth of grass and some brush. The bedrock surface is estimated to be as much as 30 to 40 feet or more below the ground surface. There are a number of large angular blocks of talus, some of which are 15 feet in diameter, at the foot of the south valley wall. A strong linear feature extending through the saddle probably indicates a fault or shear zone. Corrective measures such as grouting or a cutoff wall may be required to prevent serious leakage through the fault or shear zone.

The exposed rock in the damsite area is biotite-quartz diorite that is light to dark gray and medium to fine grained and has crystals 1 to 4 mm in length. This rock has a high crushing strength and low permeability. It is suitable as a foundation for a concrete dam of any height that would be considered for this site.

APPURTENANT WORKS

CONDUIT ROUTES TO POWERHOUSE SITES

A conduit to a powerhouse site on the lagoon would include a tunnel and penstock. The tunnel would be in biotite-quartz diorite for its entire length (*B–B′*, pl. 5). No major defects are exposed along the route, but two linear features previously mentioned, cross the line. The linear feature that bears N. 35° W. and lies along the northeast side of the high rock knob west of the ridge might intersect a tunnel driven at lake level near the portal and would intersect a tunnel driven at a lower altitude within 150 to 200 feet of the portal. The fault or shear zone related to the linear is not exposed, and detailed exploration is required to determine its size and effect upon a tunnel. The second linear feature bears N. 6° W. and crosses section *B–B′* 1,000 feet east of the lake. Only small faults and some joints are exposed where the north extension of the linear feature crops out in the south bank of Baranof River. These small structural features would intersect *B–B′* at angles of 50° to 70° and would cause no trouble during excavation of a tunnel. The rock along section *B–B′* is strong and sound, and will probably not require support during tunnel excavation except possibly at the intake portal.

A pipeline could be used to carry the water to an alternative powerhouse site 250 feet south of the river mouth. The first 400 feet of the pipeline could be placed in a shallow opencut excavated along the draw 400 feet south-southeast of the lake outlet. Downstream from the intersection of the draw and the river, the pipeline could be carried for about 750 feet on a bench excavated into the river bank. Geologic conditions will cause no construction difficulties along the opencut and bench. If part of the lake basin were to be used for live storage, a tunnel might be necessary. If so, two possible defects would have to be avoided: the tunnel line should be moved southeast of the draw away from the fault or shear zone that strikes along it, and any fractures that contain hot water would have to be located and sealed off from the tunnel.

At both powerhouse sites the penstocks could be placed either on the surface or in tunnels in strong, sound biotite-quartz diorite.

POWERHOUSE SITES

Both of the powerhouse sites considered are in strong, sound biotite-quartz diorite.

EXPLORATION

Adequate exploration of the site should be possible by drill holes. To insure that no narrow slots eroded along faults or shear zones are missed, angle drill holes should overlap in rock beneath the unconsolidated deposits along the proposed axis. If any zones of hydrothermally altered rock are found additional exploration will be necessary, because extensive correctional work might be required. To determine if the fissures along which the hot water rises extend to the damsite, a comparison could be made between the flow of the springs under normal conditions and during water-pressure tests in the holes drilled along the axis of the dam.

At the south end of the ridge, angle drill holes are required to explore the saddle for a narrow slot eroded along the fault that might be concealed there.

CONSTRUCTION MATERIALS

Sand and gravel are lacking in the vicinity of the damsite. A limited amount of aggregate for concrete may be available on the left abutement, in the river channel, and on the lake bottom near the outlet. However, the main source of aggregate is the outwash deposit in the valley upstream from the lake. At the point where Baranof River flows into the lake, there is a large exposure of subround to tabular gravel that has a maximum diameter of 6 inches and an average of 3.

The composition of the gravel is 50 to 60 percent biotite-quartz diorite, 35 to 45 percent fine-grained quartzite, 5 percent argillite, and a small amount of chert. In the biotite-quartz diorite the biotite has worn or weathered out, so that most of these rocks now have a pitted surface.

A large amount of fine sand and silt is exposed on the shore north of the mouth of the river.

RESERVOIR SITE

Baranof Lake is 3 miles long and 1,000 to 3,800 feet wide. The lake completely fills the U-shaped valley bottom, and from the shoreline the valley walls rise in steep slopes. Baranof River valley extends for about 4 miles upstream from the lake, gradually narrowing from 2,000 feet to 600 feet. At the upper end the steep walls of the central mountain range rise to altitudes above 5,000 feet.

The lake bottom descends on a moderate slope, and 600 feet south and 300 feet west of the outlet, it is at altitude 30 feet or 115 feet below the lake surface. About 1,900 feet southwest of the outlet, the lake bottom is 135 feet below sea level, or 280 feet below the lake surface. At the deepest point, 2.1 miles from the outlet, the lake has a depth of 303 feet.

The entire lake basin is in igneous rock. Most of the rock is biotite-quartz diorite similar to that at the damsite, but some diorite was noted at the upper end. Glacial outwash covers the floor of the valley upstream from the lake.

The rock in the walls of the reservoir is sufficiently impermeable that only minor water losses will occur.

CARBON LAKE POWERSITE

LOCATION AND ACCESSIBILITY

Carbon Lake powersite is on the first large drainage south of Warm Spring Bay and Baranof River (fig. 2). The damsite is on Coal Creek, at the outlet from Carbon Lake, about 4.5 miles south-southeast of Baranof, and 1 mile west of Cascade Bay. The powerhouse site, at the head of Cascade Bay, is easily accessible by boat, but the damsite and conveyance route are accessible only on foot. For the first 3,000 feet from the bay, the easiest route to the damsite is along the south side of the valley. For the last 2,000 feet, the easiest route is along the valley wall between the altitudes of 250 and 400 feet.

TOPOGRAPHY

Coal Creek, with a reported flow slightly larger than that of Baranof River, heads in the high mountains and glaciers near the midsection of Baranof Island. The creek, like Baranof River, falls into tidewater at the head of a bay or small fiord that makes a reentrant of 0.9 mile in the relatively straight east coast of the island.

Coal Creek valley has been glaciated, but erosion has not been as great as in Baranof River valley, as is shown by the narrower, more irregular valley, and the smaller fiord. The downstream 3 miles of Coal Creek valley is 400 to 1,000 feet wide and fairly irregular. The upper 3 miles is 2,000 to 3,000 feet wide and quite straight.

Carbon Lake fills the valley bottom from a point 1 mile west of the bay to 3.5 miles upvalley. The lake ranges from 250 to 2,100 feet in width and has a surface area of about 400 acres. On August 16, 1956, the altitude of the lake surface was 211.4 feet. The lake is impounded on the east by a northward-trending ridge that extends 1,200 feet north from the south valley wall. The ridge is 400 to 550 feet wide, and on the east side drops off in an almost vertical cliff 75 to 100 feet high (fig. 6). On the west or lake side, the slope is gradual, and the 150-foot contour, which is under water, is 350 feet west of the lakeshore. There are two high points on the ridge: one at altitude 331 feet 700 feet north of the south valley wall, and the other at altitude 284 feet 200 feet from the south wall (pl. 5).

FIGURE 6.—Rock ridge at east end of Carbon Lake. Lower end of Carbon Lake in left edge of view. Unnamed lake in upper right part of view drains into Coal Creek 650 feet downstream from Carbon Lake outlet.

Between the two knobs, the ground surface descends to within a few feet of the lake surface, and during periods of high water, a small stream flows through the saddle. Between the lower knob and the south valley wall, the ground surface is 5 to 6 feet above lake level. Water has not flowed through this saddle recently.

About 3,500 feet west of the lake outlet a saddle at an altitude of 295 feet separates Carbon Lake from two small unnamed interconnected lakes about one-half mile north of the lower part of Carbon Lake. These lakes, which are at an altitude of 246 feet, are drained by a small stream that flows into Coal Creek, 650 feet downstream from the outlet of Carbon Lake.

About 1,500 feet downstream from Carbon Lake a small, rounded, glaciated point, which rises to altitude 300 feet, extends out from the south valley wall. The point produces a narrows in the valley and a fall of 25 feet in the river. East of the point the valley is 600 to 1,000 feet wide. The fairly level floor, which is near altitude 100 feet, extends to within 300 feet or closer to the bay before it drops off in a steep cliff to tidewater.

Coal Creek has a fall of 12 feet in a distance of 450 feet downstream from the outlet of Carbon Lake. In the next 700 feet, the stream descends 75 feet to altitude 125 feet in a series of rapids and small falls. For 1,000 feet below these rapids, the stream is wide and slow flowing. Below this it falls 25 feet to another wide, lakelike reach 0.7 mile long at an altitude of 98 feet. From this section the river cascades over a rock ledge into the bay.

GEOLOGY

BEDROCK

The entire powersite area is underlain by metamorphic rocks that are migmatites or composite gneisses, resulting from intimate penetration of magma into country rocks. From a megascopic examination it appears that sedimentary rocks, originally either impure quartzite or a graywacke high in quartz, have been intensely metamorphosed and intruded on a large scale by biotite-quartz diorite. The intruding biotite-quartz diorite is in sheets or dikes that at the damsite are as much as 10 feet thick, and in the reservoir and downstream from the damsite are as much as 150 feet thick. Most of the rock is foliated, slightly schistose, with layers of fine- to medium-grained granulated quartz grains and thin layers of wavy biotite. The texture of the intruding biotite-quartz diorite is generally granitoid, but in some places the crystals have been granulated and some small masses of the rock have been drawn out slightly. The quartz diorite probably was intruded over a considerable range of temperature, pressure, and time, and the earlier intrusions have been dynamically modified.

Although the petrologic history is quite complicated, the resulting gneiss is strong and very capable of supporting a concrete dam and related structures and tunnels.

STRUCTURAL FEATURES

Throughout the powersite area the attitude of the foliation varies widely, often within short distances. The strikes range from east to N. 60° W., and the dips range from 20° to 70° north and west. At the damsite the strike of the foliation ranges from N. 30° E. to N. 45° W., and the dips range from 29° to 70° W.

Only minor faults were found in the dam, reservoir, and tunnel areas. However, on the aerial photographs there are strong, extensive linear features, some of which may be topographic expressions of large structural features. At the damsite the low saddle across the ridge (*C–C′*, pl. 5) is controlled by a narrow fault that strikes N. 34° E. and dips 34° SE. The fault has a zone of broken and crushed rock ½ inch to 4 inches thick. A related slip that strikes N. 23° E. and dips 34° NW. also has a zone of crushed rock a few inches thick along it. Two other minor faults, with attitudes of N.

2° E., 55° NW., and N. 37° W., 36° SW., have zones of crushed rock ½ inch to 3 inches thick along them.

On the aerial photographs a strong linear feature follows the small draw 1,000 feet east of the damsite. A careful search of the draw disclosed a fault with a 2½-foot zone of closely jointed rock with a few thin seams of crushed rock. The attitude of the fault is N. 30° W., 38° SW., and slickensides show that the hanging wall has moved to the southeast. Near altitude 325 feet a 4-foot-thick quartz diorite dike lies along the fault.

A few minor faults undoubtedly are concealed by the surficial deposits, but no major fault is suspected in the dam or tunnel areas.

The bedrock is cut by a few long, continuous joints.

UNCONSOLIDATED DEPOSITS

Surficial deposits at the damsite and on the valley walls include thin, patchy layers of organic material, soil, silt, sand, gravel and talus. Upstream from Carbon Lake the valley bottom is covered by an extensive deposit of outwash material, but downstream from the lake only thin deposits of alluvium overlie bedrock.

DEVELOPMENT SCHEME

Development of Carbon Lake powersite could be accomplished by construction of a dam at the lake outlet of sufficient height to obtain the required storage for regulation of streamflow. The water would be conveyed by a pressure conduit from the resulting reservoir to a powerhouse located on the shore of Cascade Bay. An auxiliary dam would be required in the saddle west of the lake outlet if the flow line is above altitude 295 feet.

DAMSITE

The control of Carbon Lake would in addition to a main dam on Coal Creek require two auxiliary dams in the saddles described on page 58. If the lake is raised to an altitude of more than about 280 feet, these three dams would be connected and become a single structure with an overall length of about 950 feet. The main dam would be located 300 feet downstream from the lake outlet. The geologic conditions along the axis of the main dam as well as of the two additional dams are shown by section *C–C′* (pl. 5). The left (west) abutment is formed by a hill that rises to altitude 1,095 feet. The right (east) abutment for the main dam would be formed by the rock knob that rises to altitude 331 feet. (See fig. 7.)

The foundation and abutments are believed to be suitable for a concrete dam to a height that would develop the required reservoir

FIGURE 7.—Carbon Lake outlet. Probable axis for dam would cross channel at upper end of rapids. Unnamed lake in upper center part of view drains into Coal Creek 650 feet downstream from Carbon Lake outlet.

capacity. Along section *C–C′*, bedrock is exposed or is covered by a thin layer of overburden, except at two places where there is an estimated 20 to 30 feet of unconsolidated material. One of these areas extends from the right (east) bank of Coal Creek to the left (west) abutment up to about altitude 280 feet. There is an estimated 10 feet of alluvium in the river channel and as much as 20 feet of mixed talus, topsoil, and silt on the left bank. The second area extends from the toe of the south valley wall near altitude 215 to altitude 270 feet. A rock slide has occurred here, and large blocks as much as 20 feet in diameter are stacked at the base of the slope. The depth to bedrock may be as much as 30 feet, and possibly more if the toe of the rock slope has been undercut. On the valley wall above the slide from an altitude of 270 to 360 feet, there is a thin layer of overburden and talus. Bedrock is exposed from an altitude of 360 to 400 feet. The rock face on the south valley wall and the rock face on the right (east) side of Coal Creek at section *C–C′* are controlled by the dip of the foliation.

Permeability of the rock appears to be low. Water losses will occur mainly along fractures such as the minor faults, joints, or partings parallel to the foliation. Although the grains of the rock have been granulated, the minor fractures probably are limited in extent and are not interconnected. Metamorphism has greatly reduced the original porosity in the rock, and small or no water losses are expected because of percolation through the pores.

If a limited exploration program is undertaken, the first work should be concentrated in the stream channel, the lower part of the left abutment, and on the lower part of the right (south) abutment.

SADDLE DAMSITE

This site is in a saddle that trends north-northeast from Carbon Lake. The low point is at an approximate altitude of 295 feet, and between the 300-foot contours the saddle is 80 to 100 feet wide over most of its length. The right abutment rises at a gradual slope of about 20°, and the left abutment rises in a series of steps at an average slope of 35°.

The right (east) abutment has a thin, patchy cover of topsoil, silt, and sand. On the left (west) abutment the steps between the rock cliffs are covered by an estimated 10 to 15 feet of talus mixed with topsoil, silt, and sand.

Bedrock at this site is similar to that at the Carbon Lake outlet. West of the lowest part of the draw the strike of the foliation ranges from N. 20° to 80° E. and dip ranges from 32° to 55°NW. Southeast of the low point along section *D–D′* (pl. 5), the strike of the foliation ranges from N. 65° to 70° W., and the dip ranges from 64° to 88° SW.

A small fault, with an approximate strike of N. 30° E., probably cuts through the low spot in the saddle. Another fault, with a somewhat more northerly trend, also cuts through the saddle and probably joins the first one in the north part of the map area. Although there are no exposures of these faults, the latter one apparently controls the rock slope at the edge of the lake at the south end of the map area. If so, the approximate strike is N. 10° E., and the dip is 78° NW. The estimated width of crushed rock along the fault is 6 to 18 inches. Along the lake shore about 100 feet west of the map area, another fault, with about 12 inches of crushed rock along it, crops out. The strike is N. 21° E. and the dip is 74° NW. Similar faults combined with the foliation probably produce the steps on the west abutment.

The majority of the rock exposed in the saddle is sound and strong, and the site is suitable for a concrete dam. An overflow spillway could be constructed on a dam if the broken rock along the narrow fault zones were protected from scour.

APPURTENANT WORKS

CONDUIT ROUTES TO POWERHOUSE SITES

A conduit from the reservoir site to a powerhouse site on Cascade Bay could be either a pipeline, part pipeline and tunnel, or all tunnel. Dort (1924) suggested a part tunnel and part pipeline. In this plan the tunnel would extend for 2,000 feet from the reservoir to the east side of the rounded point that is 1,500 feet downstream from the damsite (*E–E′*, pl. 5). From here a pipeline would follow the hillside to a point above the small cove 1,700 feet south of the mouth of Coal Creek and then join the penstock leading to the powerhouse. An alternative route is possible if a low pressure pipeline can be placed on the relatively flat valley bottom. From the end of tunnel line *E–E′* the line would descend to the valley floor and run to a powerhouse site in the steep cliff 500 to 600 feet south of the mouth of Coal Creek. The line would be slightly shorter than one to the cove and much easier to build.

Line *E–F* (pl. 5) shows a suggested all-tunnel route about 1 mile long leading to the powerhouse site in the cove (Arthur Johnson, written communication, Oct. 13, 1958).

GEOLOGY

The rock along line *E–E′* is a migmatite similar to that at the damsite. Biotite-quartz diorite has been intruded into a slightly schistose impure quartzite or a graywacke high in quartz to produce a massive gneiss. A dike 150 feet thick of medium-grained biotite-quartz diorite is exposed on the west side of the downstream point. In other places near the possible tunnel route, thin veins and sheets of biotite-quartz diorite have been intruded generally parallel to the foliation.

The attitude of the foliation differs considerably from place to place. The strikes range from N. 55° E. to N. 60° W. and the dips range from 21° to 70° W.

No large faults are known or suspected along line *E–E′*. A small fault, described previously, is exposed near altitude 250 feet in the draw 1,000 feet east of the lake. The rock point downstream from the damsite is separated from the main valley wall by a small saddle that may reflect some structural defect, but overburden covers the area.

ANTICIPATED ROCK CONDITIONS

The rock along a possible tunnel line at section *E–E′* (pl. 5), is sound and of high strength. It probably would stand without support both during and after construction of a tunnel. From the intake area to the dike or for approximately the first 70 percent of its length, a tunnel would be in migmatite; the next 10 percent would be in a dike of massive biotite-quartz diorite, and the remaining 20 percent in migmatite. Along the last part of the tunnel line, the strike of the foliation intersects the line at a small angle, and the dip is at a low angle. As a result, a small amount of overbreak can be expected along this reach. The tunnel probably would need a concrete lining in order to prevent water and pressure losses along joints and fractures in the rock. However, if the rock cover overlying the tunnel is thick enough or the distance from the tunnel to the valley wall is great enough, a concrete lining might not be needed.

Along line *E–F* (pl. 5), the geology of the first 1,150 feet is similar to that along *E–E′*. The remainder of the line was not mapped, but the rock probably is a migmatite. Aerial photographs show that a linear feature lies about 100 to 200 feet south of the last 1,600 feet of the line.

POWERHOUSE SITE

Along the inner part of Cascade Bay, a steep rock cliff rises from the water surface to altitude 100 feet and extends from the mouth of Coal Creek 1,700 feet south-southeast to a small cove. The cliff is formed by a thick, massive dike of quartz diorite that offers an excellent rock foundation for a powerhouse and tunnel penstock. The small cove has been suggested as a powerhouse site, as it offers a small amount of protection against the storms that sweep into the bay (Dort, 1924).

RESERVOIR SITE

The reservoir site is surrounded by steep rock walls except at the upper end where it widens out to a U-shaped gravel-filled valley. The rock is a migmatite similar to that at the damsite.

Outwash deposits at the upper end of Carbon Lake are the best source of aggregate in the area. Extensive deposits of silt and fine sand occur, but along the river channel above the lake, there is some gravel that may be suitable for aggregate. The gravel is composed of about 70 percent biotite-quartz diorite, 20 percent quartzite, and 10 percent miscellaneous rock types that include pyroxenite and some fine-grained igneous rock high in pyrite.

No leakage can occur from the reservoir outside of the damsite area.

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