Final Report

Rock Resource Study
Sand Point, Alaska

Prepared for

City of Sand Point
P.O. Box 177
Sand Point, Alaska 99661

September 1984

Woodward-Clyde Consultants

Consulting Engineers, Geologists, and Environmental Scientists

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Woodward-Clyde Consultants

September 7, 1984

City of Sand Point
P.O. Box 177
Sand Point, AK 99661

Attn: Lamar Cotten,
City Manager

Dear Mr. Cotten:

Sand Point Rock Resource Study

Attached hereto is our final report on the Sand Point Rock Resource Study. The report presents the full basis for our ranking of the various potential rock resource sites on Popof Island. Messrs. R.G. Tart and R.G. Dugan were our Senior Geotechnical Engineer and Project Geologist on this project. We have enjoyed working with you on this challenging study. Please give a call if you have any questions.

Very truly yours,

Howard Thomas

Howard P. Thomas
Project Manager

HPT/rs

Attachment

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1.0 INTRODUCTION

The city of Sand Point is a steadily-growing community along the Alaska Peninsula with an increasing need for a continuing dependable source of good rock for upcoming coastal projects. This report presents the results of a two-phase study to locate and evaluate dependable sources of rock for the city. In this study we have: reviewed available existing data, conducted a field study consisting of aerial and ground inspections of 18 potential sites, obtained rock samples from each site, made petrographic examinations of selected samples, met with Mr. John Sevy to discuss our preliminary results, produced evaluation sheets for each site, rated each site, developed a preliminary site ranking chart, discussed barge feasibility with several contractors, drilled three core borings at Dome Quarry, and prepared this report.

In the following sections of this report the information gathered will be presented, our methods of analysis will be described, results of these analyses will be presented, and our conclusions and recommendations will be presented.

2.0 GENERAL GEOLOGY

Popof Island is located southeast of the southwestern tip of the Alaska Peninsula near the beginning of the Aleutian Chain. It is a member of the Shumagin Island group at 55°20' north latitude and 160°30' west longitude. The island has an approximate diameter of 9 miles with a maximum elevation of 1520 ft above sea level.

The Shumagin Islands are bounded to the north by the Alaska Peninsula and to the south by the Aleutian Trench. Subduction of the Aleutian Trench is the major tectonic force affecting the geology of the region. The area is one of the most seismically active in the world.

A string of active volcanoes occupies the Alaska Peninsula and these are aligned parallel to the Aleutian Trench. Some of the volcanoes

are visible from Popof Island. Older intrusives, the nearest being the Shumagin batholith (Tertiary), form a belt of plutonism midway between the trench and the peninsula (Burk 1965). The region was glaciated during the Pleistocene Epoch and this has modified the uplifted land mass to its present configuration.

Popof Island has varied terrain, with rugged mountains to the east and a broad lowland valley to the west. Most lowland slopes are covered with unconsolidated sediments, brush and tundra; however, bedrock is generally well exposed at higher elevations and along the sea cliffs which bound much of the island.

The island is composed primarily of Tertiary volcanic rocks. The majority of the units are intermediate-to-mafic andesite flows and flow breccias which dip southwesterly and overlie a sequence of welded tuff-breccias. Some units are significantly altered. Occasional small domes and other intrusive structures composed of andesite, basalt or dacite have intruded the slightly-older volcanic units (Gallagher 1984).

Tertiary sedimentary rocks of the Stepovak formation outcrop on the northwest portion of Popof Island.

3.0 SAND POINT ROCK REQUIREMENTS

To estimate the quantity of rock that the City of Sand Point could require for the next ten to twenty years, plans for major projects were discussed with Mr. Sevy. The Runway Realignment/Extension Study conducted by USKH and the Preliminary Master Plan for Sand Point Harbor Facility prepared by R&M/TAMS were reviewed. Where estimates of others were not available, we developed our own approximate quantity estimates.

We understand that the runway extension and the proposed improvements to the harbor facility are the top priority items for future capital improvements at Sand Point. Other future uses of rock and gravel

include expansion of the road system and construction of building pads in areas with poor in-situ soil conditions.

Four categories of rock or embankment materials were established to aid in defining the requirements and to help classify the rock sources identified. The following table defines these categories.

Rock Type	Size	Use
1	3 ft +	Armor Stone
2	1-3 ft	Armor Underlayers/Select Core
3	1 ft	Crushed Aggregate/Select Core
4	Soil	Fill/Core

Of the four rock types, Type 1 material is the most limited at Sand Point. This is the size armor currently in place protecting most of the existing harbor breakwaters and the present runway. This rock would be equivalent to a 3 ft cube weighing about 2.5 tons or larger. The largest armor stone that we observed was protecting the south end of the runway and was approximately equivalent to 5 ft cubes or 11 ton rock. The maximum armor requirement presented in the USKH report was 6.5 tons or rock cubes with side dimensions slightly over 4 ft. It appears that rock sizes 3 ft or larger would provide adequate armor stone for most anticipated upcoming projects.

Rock smaller than 3 ft and larger than 1 ft could be used for armor stone underlayers and for select core. This size material is more available and larger quantities would be required.

Rock sources with competent rock smaller than 1 ft in size could be used in fill, to make crushed aggregate, and for core materials.

Soil sources consist of sites with low-quality rock which would degrade quickly or sites consisting of gravel-size or smaller

materials. These types of sites appeared to be relatively abundant and were not evaluated during this effort.

Considering the foregoing, we felt that finding adequate quantities of Types 3 and 4 rock would be no significant problem for the city, especially if suitable sites for Types 1 and 2 could be identified. We estimate that the dock will require at least 40,000 cu yds of Type 1 rock and 80,000 cu yds of Type 2 rock. From the USKH report, we estimate that the new runway will require about 60,000 cu yds of Type 1 rock and about 70,000 cu yds of Type 2 rock. Thus, the city will probably be able to operate into the foreseeable future with a rock source that can provide about 100,000 cu yds of Type 1 rock and 150,000 cu yds of Type 2 rock. Most of this rock will be for shore protection and, for this reason, should be resistant to abrasion, seawater alteration or weathering, and freeze-thaw cycling.

4.0 METHOD OF INVESTIGATION

4.1 Literature Review

Our investigation began with a review of available geologic maps and literature concerning the geology of the Shumagin Islands. We also reviewed the reports, test results, and files of the U.S. Army Corps of Engineers (COE) pertaining to construction of Humboldt Harbor and discussed the project with COE materials section personnel who were familiar with Sand Point.

We discussed the geology of Popof Island with several government and private exploration geologists who had previous field experience there related to mineral exploration, seismicity, and geologic mapping.

4.2 Air Photo Interpretation

Prior to going to the field, we searched for and obtained aerial photography of Popof Island. This included high-altitude BLM false-color infra-red (IR) photos at an approximate scale of 1 inch =

1 mile, color 1 inch = 1000 ft photos printed with the permission of Resource Associates of Alaska, and black and white 1 inch = 500 ft photos obtained from North Pacific Aerial Surveys. These photos provided complete stereo coverage of Popof Island at scales of 1:63,000, 1:12,000, and 1:6000, respectively.

Geomorphic features suggestive of resistant igneous rocks such as domes, lava flows, dikes and volcanic rocks were delineated on the overlays of the high-altitude photographs by stereoscopic photo-interpretation. These volcanic landforms (mostly intrusives) typically offer the best possibility of yielding the hardest, most massive rock since they are generally denser, have cooled slowly forming more widely-spaced joints, and are fresher or less altered than the older rocks that bound them. These delineations were the primary targets for further investigation in the field.

We utilized the color 1:12,000 scale photos in the field to more accurately delineate candidate bedrock sources and their associated talus slopes. Coastal areas with large concentrations of armor-size talus boulders were evident on the color photography. These areas were indicative of favorable bedrock sites and were further checked in the field. The limits of the available talus and bedrock at each site were traced on the color photo overlays and were used to aid our volume estimates.

4.3 Field Investigations

4.3.1 Inspections of Potential Sites

Our Phase I field investigation of Popof Island rock sources was conducted from May 21-26, 1984 by a two-man team consisting of an experienced geotechnical engineer and a geologist. This team field checked geomorphic features identified from the airphotos and investigated existing material sites adjacent to the Sand Point road system. Locations of the sites evaluated are located on Figure 1.

Potential sites on the west side of the island were checked on the ground. Rented trail bikes were used to the degree practical to reach these various locations. The south coast of Popof Island that extends east of the runway was traversed for a distance of two miles on foot. An aerial reconnaissance of all of Popof Island was made from a Cessna 206 fixed-wing aircraft. Potential sites marked on the airphotos were reviewed and photographed during these two flights.

The services of a local commercial fisherman, Stanley Mack, were engaged to permit us to evaluate sites impractical to reach by land from Sand Point. We circumnavigated the island in his boat and made numerous landings to take samples and ground check potential sites. Samples were obtained from all sites we were able to access. Numerous photographs were also taken.

During the ground reconnaissance of each site, we observed, took notes on, and photographed each site. The information obtained at each site was summarized on the Field Site Description summaries presented in Appendix A. Rock quality was evaluated according to our modified Uniform Rock Classification System (URCS) according to weathering, strength, joint spacing and density. Based on the surficial evidence, we made estimates of the volume of varying rock sizes each site was likely to produce. Access was evaluated according to distance from existing Sand Point roads. Depth of overburden was estimated and recorded since this is a cost factor in developing the site. Current use of the area by wildlife was noted as a measure of environmental sensitivity.

We identified three principal volcanic rock types for sites considered in this study: basalt, andesite, and dacite. These identifications were based on a visual classification with the aid of a hand lens, confirmed in a few cases by petrographic analysis (see Appendix B). All rock sources considered in this study were closely-related volcanic rocks composed of feldspar and varying amounts of ferromagnesian minerals. The distinctions we have made between andesite and basalt are based primarily on color and texture. The

basalts are darker, finer grained, contain olivine, and are less porphyritic than andesite. Dacite is lower in ferromagnesium minerals than basalt or andesite and may contain quartz which is not common in basalt or andesite.

4.3.2 Dome Quarry Core Drilling

As a second phase of our work, we conducted a limited core drilling program at Dome Quarry. The coring began on June 20 and continued through June 23. Three coreholes were drilled to 100 ft, 66.5 ft and 34.5 ft, respectively, using a 43-hp BBS-25 direct-drive rotary drill rig (1500 ft capability) equipped with a Bean 35 (35 gal/min) pump, NX wireline casing and Christiansen diamond-impregnated bits. The location of these borings is shown on Figure 2. Water was used as the drilling fluid and was supplied by the City of Sand Point with a trailer-mounted 400-gal tank. The drill was moved with a privately-owned hydraulic boom truck and a bulldozer owned by the City of Sand Point. Results of this drilling are presented in Section 7.0.

4.4 Laboratory Testing

Several rock samples were brought back to our Anchorage laboratory for specific gravity, density and expansion breakdown testing. Bulk specific gravity tests were performed on eleven samples to determine the relative rock density at several different sites. Weights of the tested samples were between 0.25 and 2.5 pounds. The tests were a modified version of ASTM Method C 127-80.

The samples were weighed dry, then immediately immersed in water and reweighed while submerged. The bulk specific gravity was calculated as the dry weight of the sample divided by the volume of the water displaced. Densities were then calculated by multiplying the specific gravity value times the unit weight of water (see Table 2).

Rock samples from nine sites were tested for expansion breakdown. This test is a means of detecting the susceptibility to weathering by immersing the rock sample in ethylene glycol, a chemical which has the

effect of accelerating the weathering process. The samples were split in two, and one half was immersed in glycol while the other half was used as a control. After three weeks, the samples that had been immersed were dried and compared to the control half. Evidence of degradation was noted as susceptibility to weathering (see Table 4).

4.5 Petrographic Analysis

Thin sections of selected samples from nine sites were made for petrographic analysis in order to identify the mineral composition and textures of the rocks. In addition, the degree and nature of alteration, intensity of microfracturing, and susceptibility to weathering were determined. A report detailing results of this work is presented in Appendix B.

5.0 CRITERIA FOR RATING SITES

Eighteen potential sites have been identified as potential sources of rock. These sites are shown on Figure 1, the Site Location Map. Some of these sites are remote, some are very large, and others are currently producing rock for Sand Point projects. In developing rating criteria we attempted to include all aspects that would be considered in selecting a site. Our rating criteria have been broken into two major categories, geologic and non-geologic. A total of twelve factors have been assessed, six of which are related to physical characteristics determined through the geologic interpretation of the site. Each criterion is assigned a numerical rating in which the highest number indicates the most favorable condition for that criterion. In the following paragraphs, we have discussed each criterion and the bases we used to establish the rating scales used.

5.1 Geologic Factors

Six geologic criteria were evaluated for each site. These were: weathering, strength, joint spacing, density, available volume, and

alteration potential. With the exception of volume and alteration potential, each of these aspects can be evaluated using the basic procedures defined in the Uniform Rock Classification System (URCS) which we modified slightly to make it more useful in classifying rock sources that could be used for armor stone. The Modified URCS is presented in Table 1. Each geologic criterion is discussed separately in the following subsections.

5.1.1 Weathering

The degree of weathering refers to chemical weathering. In this report, it is an estimate of the state of decay of the rock by chemical action based on our visual observations of discoloration or mineral alteration. Thus, the ratings for the five degrees of weathering can be summarized from Table 1 as:

	Rating
Fresh	5
Slightly weathered	4
Moderately weathered	3
Highly weathered	2
Completely weathered	1

5.1.2 Strength

A reasonable estimate of specimen strength can be made by striking the sample, rock core, or outcrop with the round end of a hammer. The resulting characteristic impact reaction indicates a range of unconfined compressive strengths. The rock specimen or outcrop is struck several times to determine uniformity of response. A quality rating is assigned based on the distinct reaction at the point of impact.

From Table 1 the ratings for strengths are:

	Rating
Highest Strength	5
High Strength	4
Moderate Strength	3
Low Strength	2
Very Low Strength	1

5.1.3 Joint Spacing

Joint spacing refers to any directional weakness in a rock mass, such as bedding planes, joints, cleavage, foliation or flowbanding that control block sizes obtainable from a site. From Table 1, the ratings for joint spacing are:

	Rating
Massive	5
Widely Spaced	4
Medium Spaced	3
Closely Spaced	2
Crushed	1

5.1.4 Density

Density is a useful indicator of rock quality. The lower the density, the more susceptible the rock is to abrasion loss and shifting under heavy attack by waves. It is also a parameter in weight-volume relationships used in haul cost estimating. Sites visited on the ground were sampled and bulk densities were measured on selected samples in our laboratory. Results of these tests are presented in Table 2.

From Table 1, density ratings are categorized as follows:

	Rating
Very High Density	5
High Density	4

Medium Density	3
Low Density	2
Very Low Density	1

5.1.5 Volume

As discussed in Section 3 of this report, a site or sites capable of producing 100,000 cu yds of Type 1 (3 ft plus) rock will probably be able to supply most of the rock resource required by the city of Sand Point for the foreseeable future. In Table 3 we have presented our estimates of the volume of rock available at each of the 18 sites based on our interpretation of the surficial geology. To estimate the quantity of material at each site, we estimated the extent of the usable rock at the ground surface by pacing the sites and/or scaling the site area from aerial photography. The depth of the formation was estimated by examining the relief of the exposed rock or the topographically-implied relief of the exposed rock. We assigned confidence levels to our estimates based on how much rock was visible at each site. In addition, we attempted to make our estimates conservative by keeping the dimensions used to calculate the volumes well within the apparent contacts we identified. To each confidence level developed we attached a percent range of volume variation that we expected. Thus from Table 3 we expect that the volume of material at Dome Quarry could range from about 180,000 cu yds to about 420,000 cu yds (up to 40 percent variation).

The numerical ratings assigned to each site based on the estimated volume of Type 1 material available are given in the following table.

Estimated Quantity of Type 1 Material	Rating
Greater than 500,000 cu yds	5
300,000 to 500,000 cu yds	4
100,000 to 300,000 cu yds	3
20,000 to 100,000 cu yds	2
Less than 20,000 cu yds	N

Sites with less than 20,000 cu yds of Type 1 material were not included in the ranking and, as shown above, were given an N rating rather than a numerical rating.

5.1.6 Alteration Potential

Volcanic formations are notoriously variable in rock quality. In recent Sand Point projects, some quarry sites selected have produced rock that degraded to silty to clayey soil much faster than anticipated and other sources, primarily the Dome Quarry, have produced consistently good materials. These differences could not be related to visibly-detectible features of fresh rock samples from the various sites. For this reason, we have performed expansive breakdown tests and petrographic analyses on selected samples from some of the sites rated.

Results of the petrographic analyses and expansion breakdown tests are summarized in Table 4. The complete petrographic report is presented in Appendix B.

These tests and analyses have generally shown that fresh rock samples from the potential quarry sites have only a moderate alteration potential or susceptibility to weathering. However, the sample from Popof Head, tested for expansive breakdown in ethylene glycol, showed visual evidence of breakdown after three weeks. Hence, susceptibility to weathering is not a major concern at any site where fresh rock will be mined except at Popof Head where the expansive breakdown test indicates that this rock could weather rapidly. For this reason the "Alteration Potential" rating for Popof Head was dropped one below that determined from the petrography alone.

The results of the petrographic analyses were used to develop an "Alteration Potential" rating. The criteria used for this rating are presented in the following table.

Petrographic Weathering Susceptibility Index from Appendix D	WCC Alteration Rating
1	5
2	4
3	3
4	2
5	1

If dual indices were suggested in the petrographic analysis, the higher index was used to determine our rating.

5.2 Non-Geologic Factors

In addition to the geologic factors evaluated, the following other factors were assessed: proximity to Sand Point, land access, sea protection, water depth, environmental sensitivity, and ownership. Our methods for developing ratings for these factors are presented in the following sections.

5.2.1 Proximity

For a specific project, transportation can add a large increment of cost to rock materials. To put this item in as a separate rating, we classified sites according to their respective distances from the village itself or the airport, the two most-likely locations for future projects requiring rock. The following table presents the proximity rating system we used.

Distance from Village or Airport	Rating
Within 1 mi	5
Within 2 mi	4
Within 3 mi	3
Within 4 mi	2
More than 4 mi	1

5.2.2 Land Access

Although it is closely related to the proximity rating factor, we felt that a separate rating was appropriate for evaluating the land accessibility of a site. The key factor in this rating is the relative cost of constructing a road to the site as measured by the distance of the site from an existing road. In several conversations with contractors familiar with conditions in the area, all said that land-accessible sites would be much less costly to develop than sea-accessible sites because of the potential for significant weather delays at the sea sites and the high mobilization costs for appropriate equipment. The criteria used to develop the land access ratings for the sites are presented below.

Adjacent to existing road	5
Within 1 mi of existing road	4
Within 2 mi of existing road	3
Within 3 mi of existing road	2
More than 3 mi from existing road	1

5.2.3 Sea Protection

To evaluate each site's sea accessibility, the amount of protection provided at the site and the water depth at the site were both rated. Exposure of a given coastal site depends on the prevailing wind direction, the fetch and the configuration of the coast at that point. The prevailing wind direction at Popof Island is from the southwest. However, the southwestern side of the island is sheltered by Unga Island. The most exposed area of the island is Popof Head at the extreme southern tip of the island. As a first approximation, sea protection was rated by estimating the exposure of the site in degrees of open water at the shoreline where the site is located. For example a site with an open beach would have about 180 degrees of exposure and a harbor site could have 90 degrees or less exposure. The following ratings were used to evaluate sea protection.

Exposure in Degrees	Rating
Not on coast	4
Less than 90	3
90 to 180	2
More than 180	1

5.2.4 Water Depth

The second factor in sea access rating was water depth close to shore. This again was given only a 3 maximum rating to reflect the relative undesirability of a sea site.

Water Depth	Rating
Greater than 3 fathoms	3
1 to 3 fathoms	2
Less than 1 fathom	1
Not on coast	0

5.2.5 Environmental Sensitivity

Development of any coastal site would probably have an impact on sea life in the area. With the exception of the terrain disturbance and the development of access for more people, the impact of site developments on shore should have little impact on the environment. Based on the observations we were able to make in the field, we have made a comparative rating system for environmental sensitivity. Because even the most sensitive of the sites observed appeared acceptable for development from an environmental standpoint, we have not given these ratings high numerical values.

	Rating
No signs of wildlife	3
Coastal	2
Obvious rookeries or sea life	1

5.2.6 Ownership

In the following table we have given ratings for types of ownership that we believe may affect development of a site. We have been unable to confirm ownership of any of the sites but we believe that most are owned by the Aleut or Shumagin Village corporations. The Aleut Native Corporation reportedly owns the mineral rights to most of Popof Island. The ratings are intended to give the most easily and economically obtainable sites the highest numerical value.

Type of Ownership	Rating
City	5
Individual	3
Native Corporation	2
Fish and Wildlife Service	1

5.3 Site Rating Table

Utilizing the rating system discussed above, Table 5 was developed which gives numerical ratings to each site for comparison. From this chart, one can see how we made our evaluations of each site. The values can be adjusted for different importance factors or if new information reduces the subjectivity in the ratings and importance factors we selected. In the second column of this table, we present "Importance Factor" and, as a first approximation, we assigned each of the 12 items evaluated equal Importance Factors. When sites are chosen for future quarries, other information may be available and different importance factors may be assigned at that time.

6.0 SITE RANKING

The resulting ranking of the sites we considered is summarized on Table 6. In this table we have ranked sites using geologic criteria, non-geologic criteria, and the two sets of criteria combined. Dome Quarry ranked well above all other sites, primarily due to its

superior quality rock and favorable location. Although the current estimated volume may not be sufficient for future Sand Point development projects, it is based only on interpretation of the surficial geology and results of three borings described below. Because massive basalt structures of this type often originate from directly below, it is possible that Dome Quarry contains considerably more good rock than is currently estimated.

Dome Quarry has already provided a substantial volume of Type 1 and 2 rock for the armoring of the airport runway and boat harbor breakwater. This rock appears to have performed well in its present use without noticeable chemical or physical degradation.

7.0 PHASE II INVESTIGATION AT DOME QUARRY

The Phase I investigation indicated that Dome Quarry was the best site for a rock resource considering both geologic and non-geologic criteria. We determined that our volume and rock quality estimates of the reserves in this structure would be significantly improved by a limited program of core drilling.

7.1 Geology of Dome Quarry

Dome Quarry is located about a mile from Sand Point on the west side of the road between Sand Point and the airport. It occurs as an elliptical outcrop of mafic intrusive rock and originally projected 60 to 100 ft above the surrounding terrain prior to its development as a quarry. In Figure 2 we have presented a map of our interpretation of the geology at Dome Quarry, and a cross-sectional interpretation of the geology is presented in Figure 3.

The rock is a fresh gray to black porphyritic basalt, with about 10 percent pyroxene occuring as phenocrysts to 0.2 in. The rock is randomly and discontinuously jointed in several directions. Most joints have rough surfaces, are closed, and are usually cemented with calcite. The dome is bordered to the east by highly-altered volcanic

rocks (andesite flows and tuff-breccias) of low strength. The west side of the dome is bordered by a heavily-vegetated slope, the composition of which is unknown but which is likely to be similar to the altered rocks to the east.

Small outcrops 200 to 300 yds east of the dome exposed at sea level are likely satellite units of the dome occurring as dikes or sills.

Dome Quarry has been quarried for several years, having produced armorstone, riprap and crushed aggregate for the breakwaters of the Sand Point Harbor airport runway and other local uses. About 5,000 yd^3 of loose armorstone and riprap remain at the site.

7.2 Results of Core Drilling

The locations of our borings are shown on Figure 2. Results of the core drilling are detailed in field boring logs, Figures 4 through 6. Cores were logged with particular attention to jointing characteristics, weathering, alteration, and percent of core recovery. Core recovery is an indication of the quality of the drilling and of the soundness of the rock. Rock Quality Designation (RQD) values were determined for each core run. RQD is the ratio of the accumulated length of intact rock in the core sections longer than 4 in. to the total distance drilled. A ratio of 90 percent or more indicates excellent rock; 75 to 90 percent, good rock; 50 to 75 percent fair rock; and 25 to 50 percent poor rock. Boring 1 encountered competent fresh basalt from 0 to 100 ft depth. The first 6 ft was slightly fractured, possibly due to previous quarrying operations, but below 6 ft maintained an RQD greater than 90 percent. Most joints were cemented with calcite and were not significantly weathered. Joints were usually tight and surfaces were planar but rough. Breaks in the core were generally associated with or occurred along these cemented joints. Joints discolored by weathering occurred about every 10 ft and these represented the principal weakness in the rock mass. Weathering was usually limited to the joint surface, not penetrating the rock more than 0.2 in. to each side of the joint.

The coring proceeded very quickly with the bit advancing at a rate of about 30 ft/hour at an average 2800 rpm using water at 10 gallons/min with 75 percent return. Water return would likely have been greater had the upper 6 ft not been fractured. This indicates that joints in the formation are tight and well cemented.

Boring 2, 225 ft east of Boring 1, was located at what appeared to be the eastern limit of the competent basalt. Slightly altered basalt was encountered to about 20 ft. Joints were moderately spaced, RQD in this zone was variable between 67 and 96 percent, weathered joints occurred about every foot. Below 20 ft, the rock became very altered and friable with colors from dark purple to brown. RQD values also dropped, generally below 50 percent, indicating poor quality. Cores were broken up and weathered materials in many joints were washed out during drilling; there was no fluid return below 8 ft indicating open joints.

Boring 2 was terminated at 66.6 ft due to the poor quality of this rock so that the remaining drilling budget could be applied to another location likely to encounter competent rock near the east margin of the dome.

Boring 3, located 67 ft west of Boring 2 (160 ft east of Boring 1), was started on a boulder of competent basalt. Highly-fractured fresh to slightly-weathered basalt was then encountered to a depth of 23 ft. Drilling was very difficult due to frequent binding and blocking of the bit by rock fragments. This zone of fractured rock may be associated with previous quarrying operations.

Below 23 ft, joint spacing increased dramatically. RQD values were generally over 90 percent and rock in this zone resembled that encountered in Boring 1 with respect to weathering, rock type and joint spacing. Boring 3 was terminated at 34.5 ft depth as further drilling had not been authorized.

Dome Quarry is depicted in a geologic map on Figure 2. This figure was developed by enlarging a black and white 1980 airphoto to 1 in. = 100 ft and delineating the surficial features on an acetate overlay of the photo. The boring locations shown are approximate. Distances between boreholes were measured with a surveyors tape in the field. The 240 ft contour line was traced from an existing 1 in. = 100 ft contour map. Figure 3 is a cross-section of line A-A' on Figure 2 depicting our interpretation of the subsurface geology above the 140 ft elevation.

7.3 Core Drilling Conclusions

Results of the drilling indicated suitable rock capable of producing armor-stone-size blocks (3 ft plus stones) to a depth of at least 100 ft below existing ground level at the center of the quarry. The north and west boundaries of the basalt are observable as they form exposed cliffs. Rock quality at these margins appears somewhat lower than that found at the quarry center but is probably still adequate. The structure containing the fresh competent basalt is assumed to have a vertical orientation. The east margin of competent basalt is inferred to lie between Borings 2 and 3. The contact between the fresh and altered material is likely to be very steep as indicated by the steep cliffs on the north and west sides and the radical difference between material below 20 ft in Borings 2 and 3.

Based on our geologic interpretations of the surficial geology and the limited drilling data, it appears that Dome Quarry is capable of producing about 300,000 yds^3 of competent basalt between its present surface elevation and 140 ft above mean sea level. We have assumed the average surface elevation of the existing quarry to be 240 ft.

8.0 CONCLUSIONS

Based on our evaluation of Popof Island, several sources of rock were identified as suitable for future development for the City of Sand Point. Based on geologic criteria alone, the best sites likely to

produce Type 1 rock are Popof Head, Dome Quarry, Danger Point and Buffalo Bay. Considering that Popof Head and Buffalo Bay would be more costly to develop since they are only accessible by sea, it appears that Danger Point is the most practical site to develop once Dome Quarry is exhausted.

Sites with marginal geologic properties such as East Quarry and Gold Creek ranked high in the combined geologic-non-geologic criteria because their accessibility makes them cost effective to develop for certain but limited uses such as fill.

9.0 RECOMMENDATIONS

In the preceding sections we have presented the data we have obtained, and, using a decision-analysis approach, we have attempted to reduce the subjectivity often found in this type of siting study. From this it appears that the Dome Quarry site is the best location for obtaining armor stone and riprap for the immediate future. There is a possibility that this source will not provide all the material necessary for the tentatively-planned capital improvements. It should, however, provide a very good start for at least the airport expansion, and there is a good chance that it will provide all the armor necessary for all presently-anticipated projects. All other sites had either poorer-quality rock, less-predictable rock, or high access and development costs. Table 3 can be used to identify the next most promising quarry site when it becomes obvious that the rock supply at Dome Quarry will be exhausted. For a project where smaller rock can be used, the Gold Creek site may be better. Where large rock is important the Danger Point site may be best.

To extend the life of the Dome Quarry, contractors using this quarry should be required to provide detailed quarrying plans that demonstrate an ability and willingness to make the best use of the available material. The plan should show that fill and small rock will be obtained from other sources such as East Quarry rather than blasting heavily and breaking up the larger rocks at the Dome Quarry.

(Note: It may be necessary to crush a small quantity of the smaller high quality rock at Dome Quarry to provide surfacing for the runway and roads.) The plan should show how the contractor plans to blast the rock to maximize the size of rock that will remain after the blast. The plan should address access to the site and how the quarry will be left for future contractors so that the overall best use of the quarry can be accomplished.

Prior to the next construction contract, to more accurately define the quantity and quality of material in the Dome Quarry, it is recommended that a detailed boring program be carried out at the quarry in which at least six more continuous core borings are made. All these borings should penetrate to at least 100 ft depth and two should extend to 150 ft depth. A geologist or geotechnical engineer familiar with volcanic formations should log the borings and participate in developing the refined volume estimates. Such a coring program is expected to provide a good estimate of the volume of usable material available in the quarry.

This report has not addressed the specific percentage recovery of the various stone sizes from each site. This will, to a large degree, depend on the mining technique used. Prior to making the final selection of any site for a future quarry, detailed geologic maps, core borings, and possibly seismic refraction surveys should be made and mining plans should be prepared. Once specific sites begin to be developed, periodic evaluations of the rock being mined may be desirable to assure that the material being mined is fresh and of acceptable quality.

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AERIAL PHOTOGRAPHY (STEREO)

Black & White, August 1980, scale: 1 in = 500 ft, North Pacific Aerial Surveys.

Color, August 1980, scale: 1 in = 1000 ft, Resource Associates of Alaska

False Color Infra-red (IR), September 1983, scale: 1 in = 1 mi, BLM

TABLE 1
MODIFIED UNIFORM ROCK CLASSIFICATION SYSTEM

URCS Rating	Weathering	Strength	Joint Spacing	Density
5	Fresh: there is no discoloration or alteration of mineral elements. Evaluation is made with a 10-power hand lens	Very High Strength: rebound quality; shows no reaction under point of impact. UCS >15000 psi.	Massive: rock mass has homogeneous structure without stratification, fractures, cleavage, foliation, or other obvious directional weakness. Likely to produce exceptionally large blocks greater than 8 yd^3. (16 tons)	Very high density: >160 lb/ft^3
4	Slightly weathered: the rock material appears to be fresh or only faintly weathered to the naked eye. Very slight discoloration of mineral alteration may be present. This evaluation describes the general standard of rock quality for the site.	High Strength: pit quality; produces explosive departure of mineral grains under point of impact resulting in a shallow, rough pit. UCS = 8000 to 15000 psi.	Widely Spaced: planes of weakness spaced greater than 2 yds. Likely to produce large blocks from 2 to 8 yd^3 (4 to 16 tons).	High density: 150-160 lb/ft^3
3	Moderately weathered: where the rock is partly or completely discolored due to oxidation. It is not remoldable.	Moderate Strength: dent quality; produces dent under point of impact indicating pore spaces. It is equivalent in strength to concrete. UCS = 3000 to 8000 psi.	Medium Spaced: 2 to 3 intersecting planes of weakness 1-2 yd apart. Capable of producing medium sized blocks from 1 to 2 yd^3. (2 to 4 tons).	Medium density: 140-150 lb/ft^3
2	Highly weathered: refers to rock remoldable by finger pressure to gravel sized fragments.	Low Strength: crater quality; produces crater under point of impact. UCS = 1000-3000 psi.	Closely Spaced: 2 or more closely spaced intersecting planes of weakness less than 1 yd apart. Capable ot producing small blocks less than 1 yd^3. (2 tons)	Low density: 130-140 lb/ft^3
1	Completely weathered: is remoldable to sand, silt, or clay size particles.	Very Low Strength: is remoldable. UCS is less than 1000 psi.	Crushed: highly foliated, closely spaced fractures or other well developed planes of weakness unsuitable for riprap.	Very low density: less than 130 lb/ft^3

TABLE 2

RESULTS OF

LABORATORY DENSITY TESTS

	Site	Weight Dry (grams)	Weight in Water (grams)	Specific Gravity	Density lb./ft^3
1.	Dome Quarry #1A (fresh)	945	600	2.74	171
2.	Dome Quarry #1B (fresh)	1072	685	2.77	173
3.	Dome Quarry #2A (altered)	1025	625	2.56	160
4.	Dome Quarry #2B (altered)	635	380	2.49	156
5.	Danger Point	402	257	2.77	173
6.	Popof Head	585	355	2.54	159
7.	Pirate Cove	465	272	2.41	150
8.	Creek Point	350	215	2.59	162
9.	Airport Bluffs	162	87	2.16	135
10.	East Quarry	122	72	2.44	152
11.	Gold Creek East	307	185	2.52	157

TABLE 3

VOLUME ESTIMATES

Site	Confidence Level[1]	Estimated Dimensions (ft)	Estimated Mineable Depth (ft)	Estimated[2] Total Site Volume 1000's of Cu Yds	Type 1[2],[3] Estimated Volume 1000's of Cu Yds
Dome Quarry	1	320 ft diameter	100	300	60
Pyrite Knob	1	200 x 100	50	40	---
Red Cove Dome	2	1000 x 200	100	750	---
Humboldt Point	3	200 x 100	20	16	7
Black Pt.	3	60 x 45	30	3	1
Danger Pt.	2	750 x 200	200	1000+	300
Pirate Cove	2	1000 x 200	200	1000+	500
Dark Cliffs	2	1000 x 500	200	4000+	500
Buffalo Rocks	2	1000 x 400	200	4000+	1000+
Popof Head	3	3000 x 1000	500	50,000+	50,000+
East Simeon	2	700 x 500	50	600	60
Rap Rock	2	300 x 100	100	100	---
West Simeon	2	800 x 100	100	300	50
Red Cove West	2	500 x 250	200	1000	300
Creek Point	1	700 x 200	100	500	150
Gold Creek	1	1000 x 500	100	2000+	100
Airport Bluffs	1	1000 x 250	100	1000+	---
East Quarry	1	1000 x 500	50	1000+	10+

Notes

(1) Confidence Level 1 <25% of estimated volume exposed
Confidence Level 2 25-75% of estimated volume exposed
Confidence Level 3 75-100% of estimated volume exposed

(2) Within about 10% for Confidence Level 3
Within 10 to 20% for Confidence Level 2
Within 20 to 40% for Confidence Level 1

(3) Type 1 = 3 ft or larger stones

TABLE 4

SUMMARY OF RESULTS OF PETROGRAPHIC ANALYSES

AND EXPANSION BREAKDOWN TESTS

Site	Rock Type	Petrographic Weathering Susceptibility Index	Expansion Breakdown	WCC Alteration Potential Rating
Airport Bluffs	Tuff	3-4	Negligible	2
Creek Point	Andesite/Basalt	4-5	Negligible	1
Danger Point	Diabase	2-3	Negligible	3
Dome Quarry	Basalt	2-3	Negligible	3
East Quarry	Andesite	3-4	Negligible	2
Gold Creek East	Andesite	3	Negligible	3
Pirate Cove	Basalt	3-4	Negligible	2
Popof Head	Rhyodacite	3-4	Moderate	2
Red Cove Dome	Andesite	3	Negligible	3

TABLE 5

SITE RATING TABLE

Geologic Criteria	Importance Factor	Dome Quarry	Pyrite Knob	Red Cove Dome	Humboldt Point	Black Point	Danger Point	Pirate Cove	Dark Cliffs	Buffalo Bay	Popof Head	East Simeon	Rap Rock	West Simeon	Red Cove West	Creek Point	Gold Creek East	Airport Bluffs	East Quarry
1) Weathering	1	5	3	4	4	4	4	4	3	4	4	4	4	4	3	3	3	2	3
2) Strength	1	5	3	4	4	4	4	3	4	4	4	4	4	4	4	4	3	2	3
3) Joint Spacing	1	3	2	2	3	2	3	4	2	3	5	2	2	2	3	3	2	1	2
4) Density	1	5	4	5	5	5	5	3	5	5	4	5	5	5	5	5	4	2	4
5) Volume	1	2	N	N	N	N	4	5	5	5	5	2	N	4	4	3	3	N	3
6) Alteration	1	3	A	A	A	A	3	2	A	A	2	A	A	A	A	1	3	2	2
Geologic Rating		23	N	N	N	N	23	21	21	23	24	19	N	21	21	19	18	N	17
Non-Geologic Criteria																			
7) Proximity	1	5	5	3	5	5	3	1	1	1	1	1	1	1	3	4	5	5	5
8) Land Access	1	5	4	3	4	5	3	1	1	1	1	1	1	1	2	3	4	5	5
9) Sea Protection	1	2	4	4	2	2	3	3	1	2	1	2	2	2	2	1	1	4	4
10) Water Depth	1	3	0	0	3	3	1	2	3	3	3	3	2	3	3	3	2	0	0
11) Environmental	1	3	3	3	3	3	2	1	1	1	1	2	3	2	2	2	3	3	3
12) Ownership	1	5	2	2	2	5	2	2	2	1	2	2	2	2	2	2	2	5	5
Non-Geologic Rating		23	18	15	19	23	14	10	9	9	9	11	11	11	14	15	17	22	22
Combined Ratings		46	N	N	N	N	37	31	30	32	33	30	N	32	35	34	35	N	39

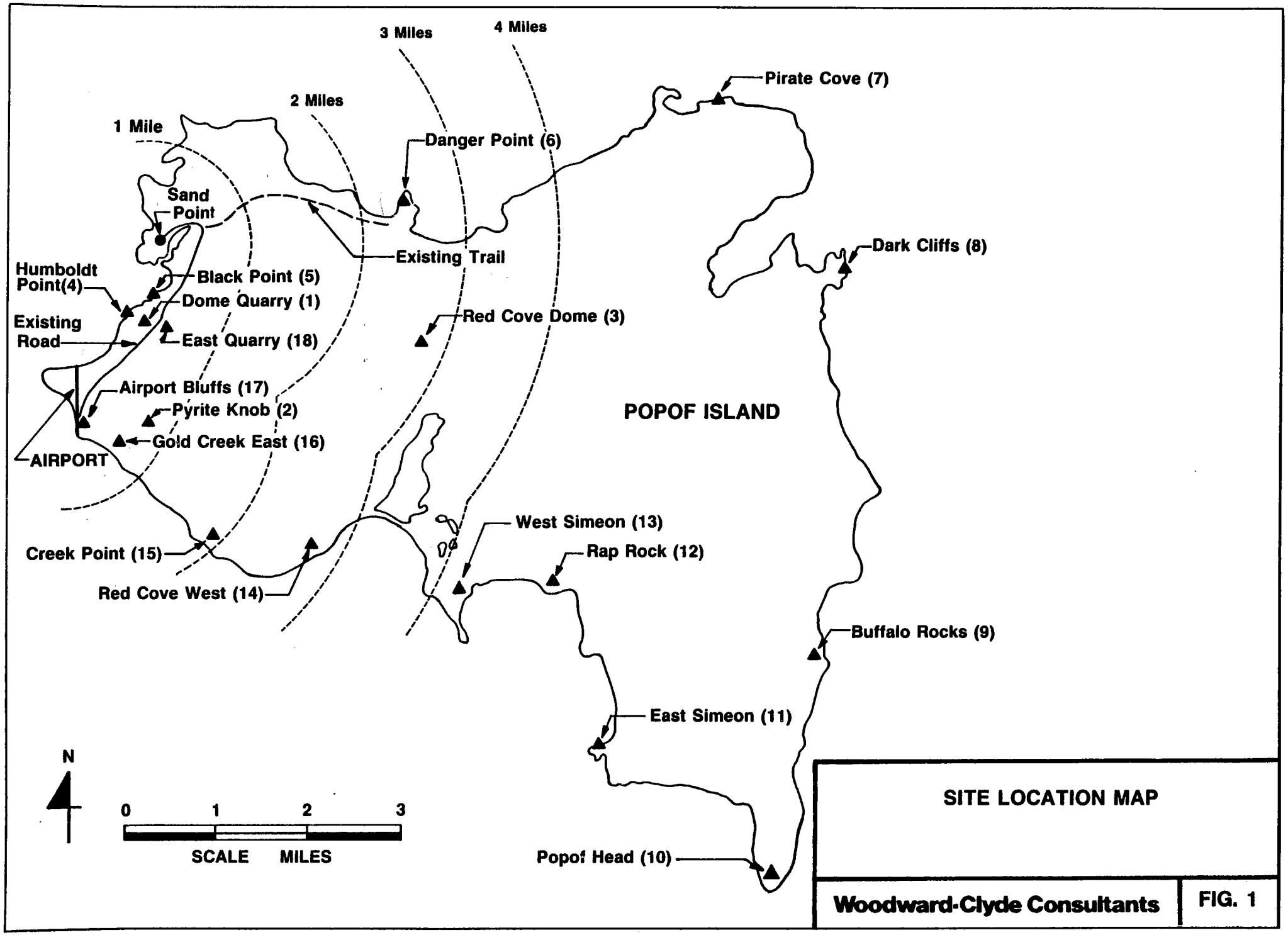
N = Volume less than 20,000 yds. These sites were not ranked.

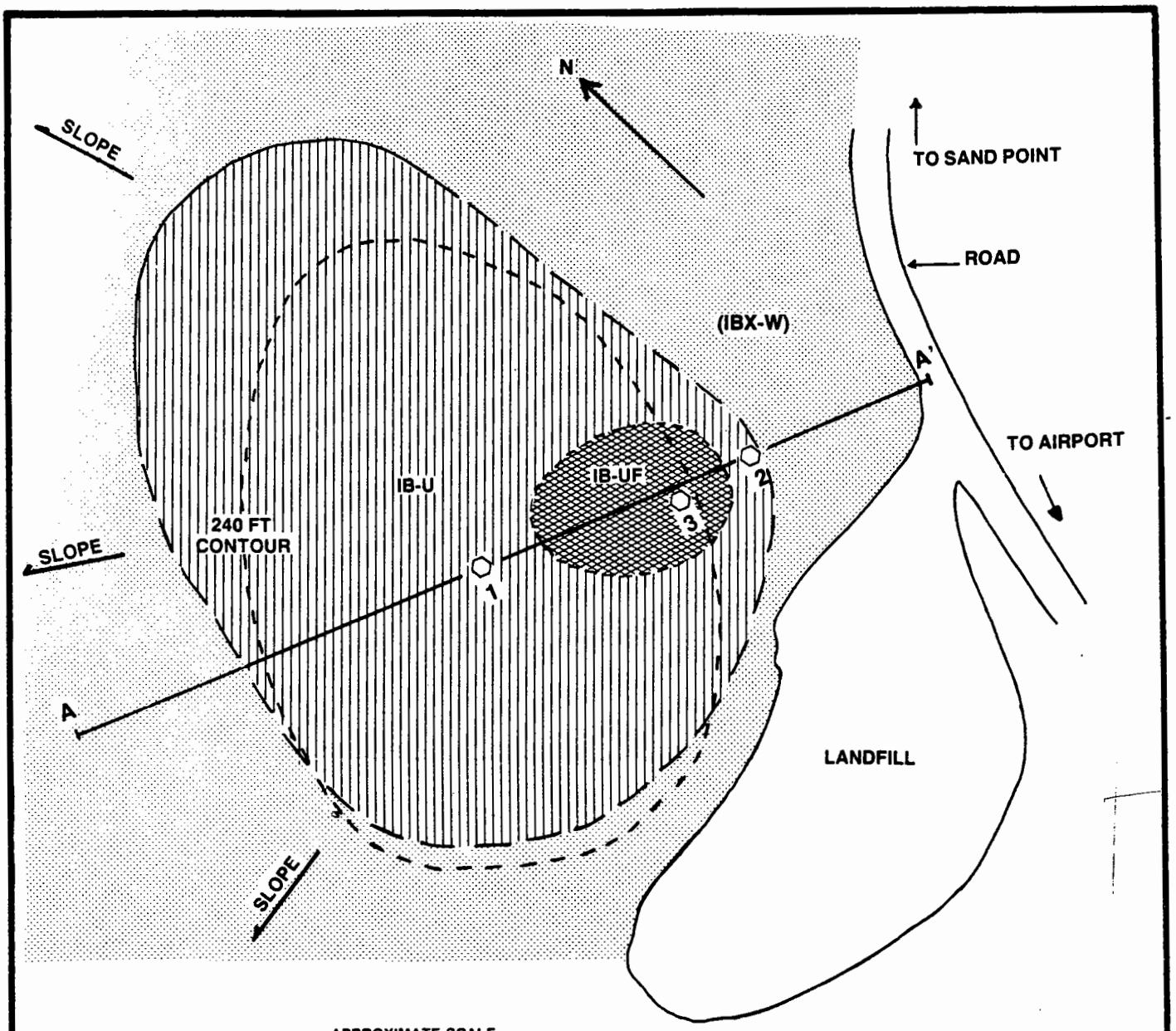
A = No petrography. These sites were given an arbitrary 2 rating for alteration.

TABLE 6

SITE RANKINGS

Rank	Geologic Criteria		Non-Geologic Criteria		Combined Criteria	
	Site(s)	Rating	Site(s)	Rating	Site(s)	Rating
1	Popof Head	24	Black Point, Dome Quarry	23	Dome Quarry	46
2	Buffalo B., Danger P., Dome Q	23	Airport Bluffs	22	East Quarry	39
3	Pirate C., D. Cliffs W. Simeon, Red Cove W.	21	East Quarry	22	Danger P.	37
4	E. Simeon, Creek P.	19	Humboldt, Gold Creek	19	Gold Creek, Red Cove W.	35
5	Gold Creek	18	Airport Bluffs, Pyrite Knob	18	Creek P.	34
6	East Quarry	17	Red Cove W., Creek P., Red Cove Dome	15	Popof Head	33
7			Danger P.	14	Buffalo B., W. Simeon	32
8			Rap R.,E. Simeon, W. Simeon	11	Pirate Cove	31
9			Pirate Cove	10	D. Cliffs, E. Simeon	30
10			Popof, D. Cliffs Buffalo B.	9		


3 Miles
4 Miles
2 Miles
1 Mile
Pirate Cove (7)
Danger Point (6)
Sand Point
Existing Trail
Dark Cliffs (8)
Humboldt Point(4)
Black Point (5)
Dome Quarry (1)
Red Cove Dome (3)
Existing Road
East Quarry (18)
Airport Bluffs (17)
Pyrite Knob (2)
POPOF ISLAND
Gold Creek East (16)
AIRPORT
West Simeon (13)
Creek Point (15)
Rap Rock (12)
Red Cove West (14)
Buffalo Rocks (9)
East Simeon (11)
N
0
1
2
3
SCALE
MILES
Popof Head (10)
SITE LOCATION MAP
Woodward-Clyde Consultants
FIG. 1



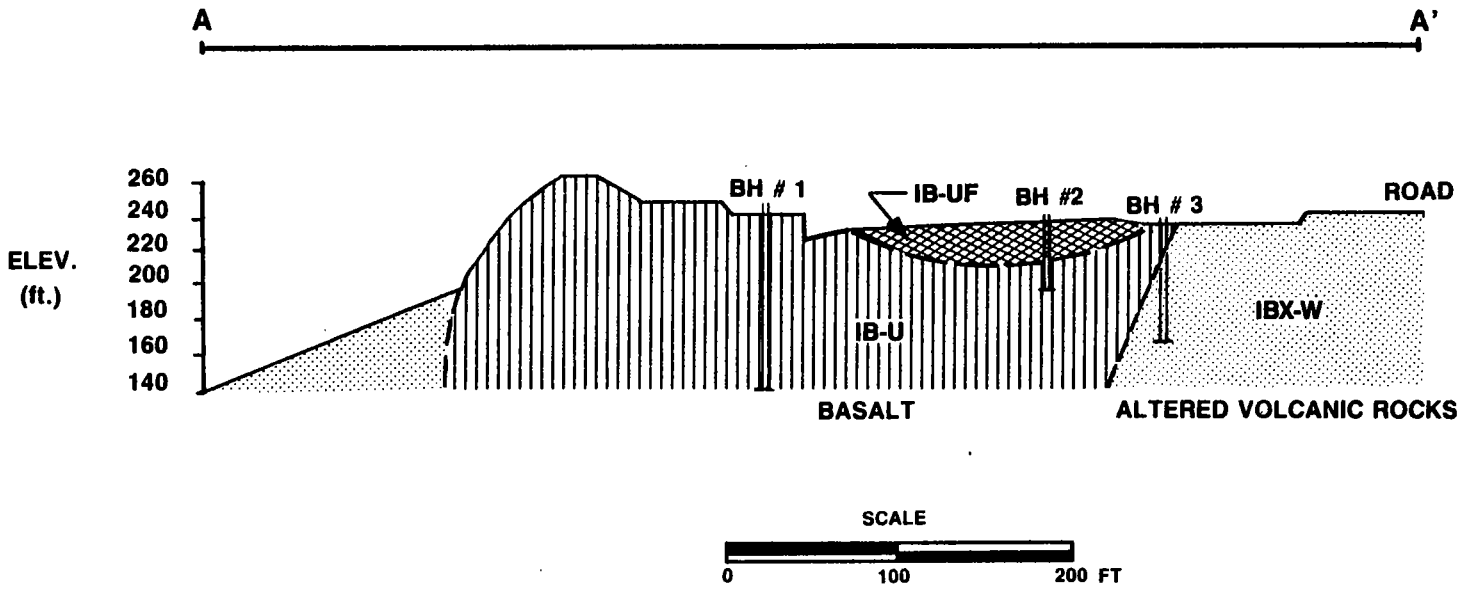
LEGEND

- WCC BORING
- FRESH TO SLIGHTLY WEATHERED BASALT (IB-U)
- FRACTURED OR RUBBLE-LIKE BASALT (IB-UF)
- MODERATELY TO HIGHLY WEATHERED VOLCANIC ROCKS AND/OR SEDIMENTS (IBX-W)
- GEOLOGIC CONTACT, DASHED WHERE INFERRED

INTERPRETED GEOLOGIC MAP OF DOME QUARRY

Woodward-Clyde Consultants | FIG. 2

CROSS-SECTION A-A' ON FIGURE 2



LEGEND

FRESH TO SLIGHTLY WEATHERED BASALT (IB-U)

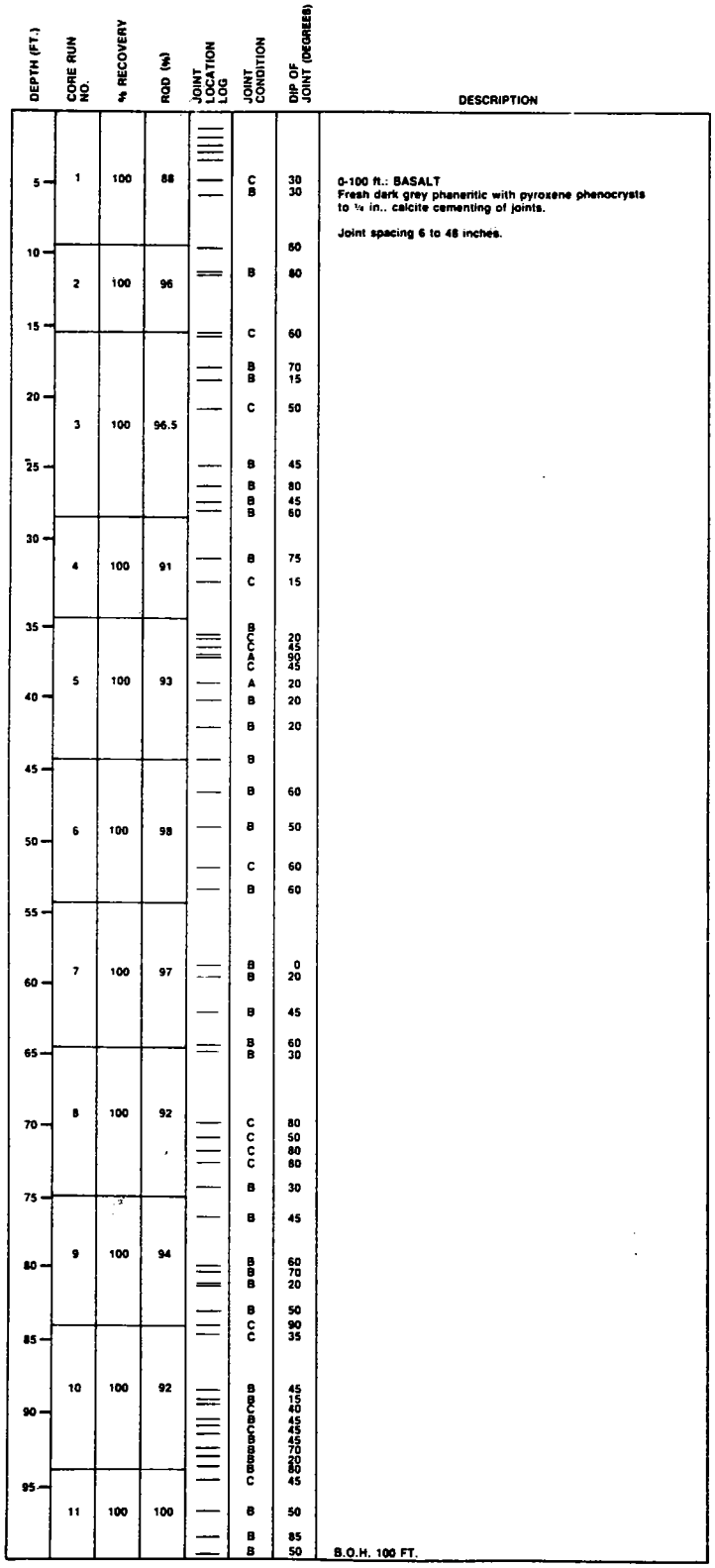
FRACTURED OR RUBBLE-LIKE BASALT (IB-UF)

MODERATELY TO HIGHLY WEATHERED VOLCANIC ROCKS OR SEDIMENTS (IBX-W)

GEOLOGIC CONTACT, DASHED WHERE INFERRED

INTERPRETED GEOLOGIC CROSS SECTION OF DOME QUARRY

Woodward-Clyde Consultants | **FIG. 3**



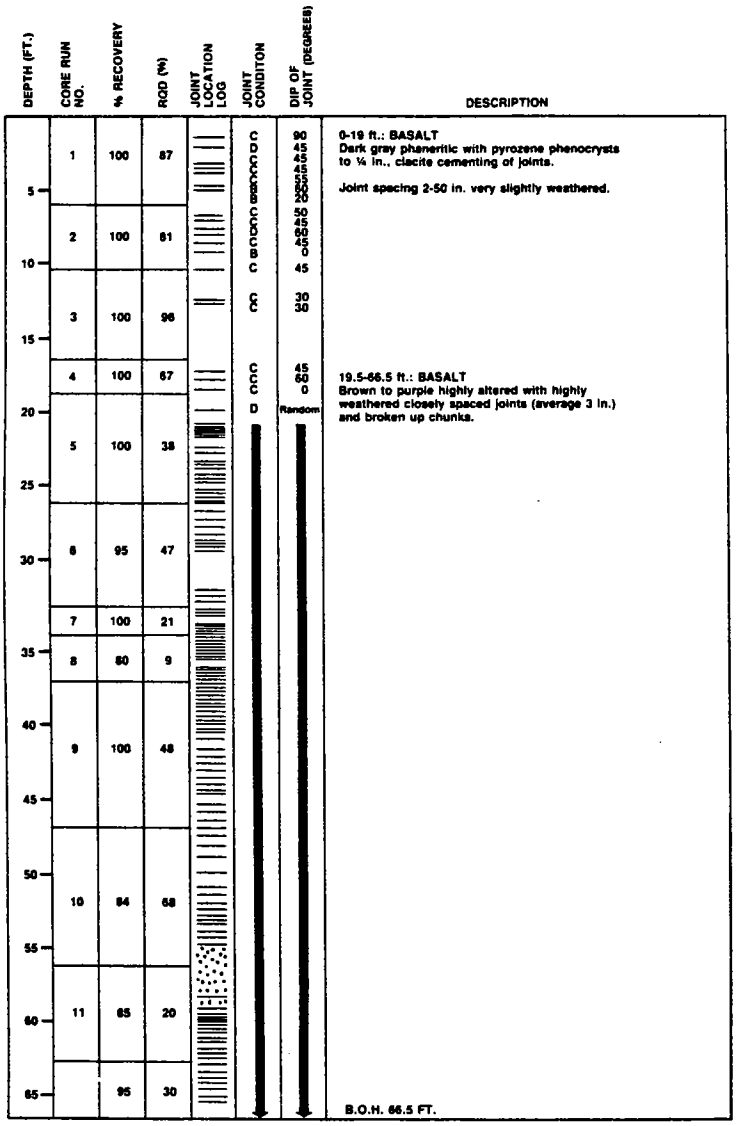
JOINT CONDITION LEGEND

- HIGHLY FRACTURED ROCK
- A FRESH
- B SLIGHTLY WEATHERED
- C MODERATELY WEATHERED
- D HIGHLY WEATHERED
- E COMPLETELY WEATHERED

LOG OF BORING NO. 1

Woodward-Clyde Consultants

FIG. 4



JOINT CONDITION LEGEND

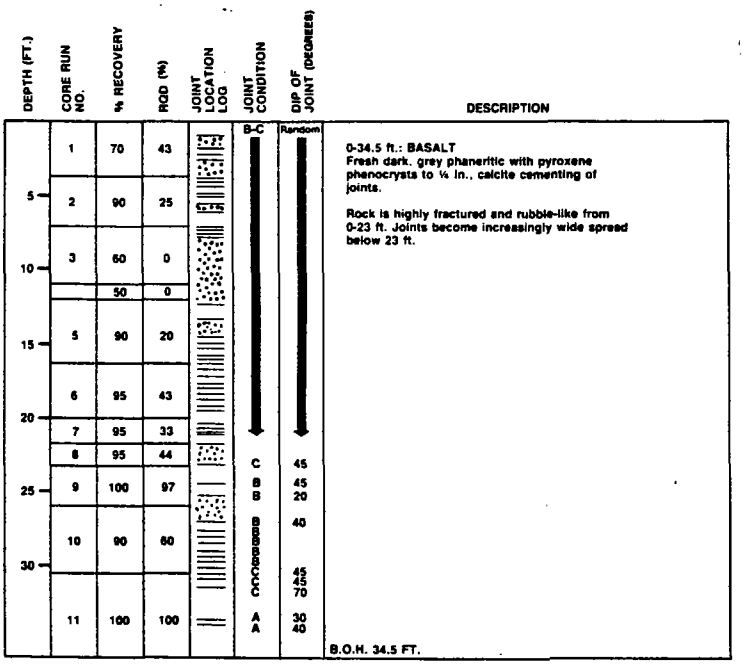
HIGHLY FRACTURED ROCK

- A FRESH
- B SLIGHTLY WEATHERED
- C MODERATELY WEATHERED
- D HIGHLY WEATHERED
- E COMPLETELY WEATHERED

LOG OF BORING NO. 2

Woodward-Clyde Consultants

FIG. 5



JOINT CONDITION LEGEND

HIGHLY FRACTURED ROCK

- A FRESH
- B SLIGHTLY WEATHERED
- C MODERATELY WEATHERED
- D HIGHLY WEATHERED
- E COMPLETELY WEATHERED

LOG OF BORING NO. 3

Woodward-Clyde Consultants

FIG. 6

APPENDIX A

FIELD SITE DESCRIPTION SUMMARIES

FIELD SITE DESCRIPTION SUMMARY

SITE: Dome Quarry

PERSONNEL: Tart and Dugan

METHOD OF RECONNAISSANCE:

DATE: 21 May 1984

Ground traverse.

PROBABLE OWNERSHIP: City of Sand Point and Shumagin Native Corporation

WEATHER: Overcast, 50°F

LOCATION (Map, section, township, range): Port Moller (B-2), NE 1/4, Sec 17, T56S, R73W.

GENERAL DESCRIPTION: Massive basalt dome, originally projecting 60 ft above road prior to quarrying.

GEOLOGIC TYPE: Phaneritic black basalt with scattered pyroxene phenocrysts and 1/4 in. calcite-cemented joints.

JOINT SPACING: Medium spaced, variable. URCS: 3

BEDDING AND PLANES OF STRATIFICATION: None.

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Irregular blocks, some approaching 5 ft cubes.

OBSERVED SHAPE OF FRAGMENTS: Irregular blocks, some planar surfaces

ESTIMATED STRENGTH: Very high. URCS: 5

EXPECTED DENSITY: Very high. URCS: 5

DEGREE OF WEATHERING: Fresh. URCS: 5

ANY PROPERTIES NOT COVERED ABOVE: This material is already functioning well as armor rock on existing harbor breakwaters and airport runway.

VOLUME ESTIMATE: 300,000 yd^3; 320 ft diameter, 100 ft height.

OVERBURDEN: None.

ACCESSIBILITY: Excellent. On the road between airport and Sand Point village.

ENVIRONMENTAL SENSITIVITY: None except possible noise disturbance to Sand Point residents.

COMMENTS: Landfill for city is active on the south face of the quarry.

FIELD SITE DESCRIPTION SUMMARY

SITE: Pyrite Knob

PERSONNEL: Tart and Dugan

METHOD OF RECONNAISSANCE: Ground Traverse

DATE: 24 May 1984

WEATHER: Partly cloudy, 55°F, Wind NE @ 10 mph.

PROBABLE OWNERSHIP: Aleut Native Corporation

LOCATION (Map, section, township, range): Port Moller (B-2), S 1/2, Sec 20, T565, R73W.

GENERAL DESCRIPTION: Small andesite knob in rolling hills.

GEOLOGIC TYPE: Dark gray andesite with some brecciated and altered zones.

JOINT SPACING: Closely spaced, variable. URCS: 2.

BEDDING AND PLANES OF STRATIFICATION: None observed.

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Small irregular blocks mostly less than 1 ft cubes.

OBSERVED SHAPE OF FRAGMENTS: Irregular.

ESTIMATED STRENGTH: Moderate. URCS: 3.

EXPECTED DENSITY: High. URCS: 4.

DEGREE OF WEATHERING: Moderate. URCS: 3.

ANY PROPERTIES NOT COVERED ABOVE: Mineralized, pyrite crystals to 1/16 inch.

VOLUME ESTIMATE: 40,000 yds^3; 200 ft length, 100 ft width, 50 ft height.

OVERBURDEN: None.

ACCESSIBILITY: Good. 1/2 mi. east of existing gravel road.

ENVIRONMENTAL SENSITIVITY: None.

COMMENTS: Surface exposures of the outcrop were limited to less than 10 percent of the rock.

FIELD SITE DESCRIPTION SUMMARY

SITE: Red Cove Dome

PERSONNEL: Tart and Dugan

METHOD OF RECONNAISSANCE: Ground traverse.

DATE: 22 May 1984

PROBABLE OWNERSHIP: Aleut Native Corporation

WEATHER: 50°F, Overcast, Wind - N @ 5 mph

LOCATION (Map, section, township, range): Port Moller (B-2), NE 1/4, Sec 23, T56S, R73W

GENERAL DESCRIPTION: Andesite dome.

GEOLOGIC TYPE: Dark gray andesite with scattered pyroxene phenocrysts.

JOINT SPACING: Closely spaced, variable. URCS: 2

BEDDING AND PLANES OF STRATIFICATION: Mostly vertical and horizontal with many variations.

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Small irregular blocks, mostly less than 2 ft cubes.

OBSERVED SHAPE OF FRAGMENTS: Blocky cubes.

ESTIMATED STRENGTH: High. URCS: 4

EXPECTED DENSITY: = Very high. URCS: 5

DEGREE OF WEATHERING: Moderate. URCS: 3

ANY PROPERTIES NOT COVERED ABOVE:

VOLUME ESTIMATE: = 750,000 yd^3; 1000 ft length, 200 ft width, 100 ft height.

OVERBURDEN: Minimal.

ACCESSIBILITY: Fair. Red Cove plus 1000 ft road or road 2 mi + from Sand Point.

ENVIRONMENTAL SENSITIVITY: None.

COMMENTS: 4 Chip Samples

FIELD SITE DESCRIPTION SUMMARY

SITE: Humboldt Point

PERSONNEL: Dugan

METHOD OF RECONNAISSANCE: Ground traverse.

DATE: 26 May 1984

PROBABLE OWNERSHIP: Shumagin Native Corp.

WEATHER: Partly cloudy, 50°F, wind calm.

LOCATION (Map, section, township, range): Port Moller (B-2), SE 1/4 of Sec 17, T56S, R74W.

GENERAL DESCRIPTION: Slightly dipping basalt flow outcropping at small headland underlain by brecciated andesite.

GEOLOGIC TYPE: Dark gray olivine basalt with pyroxene phenocrysts to 1/16 in.

JOINT SPACING: Medium spaced, variable. URCS: 3

BEDDING AND PLANES OF STRATIFICATION: Basalt layer approximately 10 ft thick dipping southeast.

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Large blocks, up to 4 ft cubes.

OBSERVED SHAPE OF FRAGMENTS: Irregular

ESTIMATED STRENGTH: High. URCS: 4

EXPECTED DENSITY: Very high. URCS: 5

DEGREE OF WEATHERING: Slight. URCS: 4

ANY PROPERTIES NOT COVERED ABOVE: Some brownish weathering on micro joints; difficult to break with hammer.

VOLUME ESTIMATE: 16,000 yd^3; 200 ft length, 100 ft width, 20 ft height.

OVERBURDEN: Variable: 0 to 15+ ft.

ACCESSIBILITY: Good. Could pick about 1000 yd^3 of 4 ft armor stone cubes from the beach or build 1/4 mile road along beach.

ENVIRONMENTAL SENSITIVITY: None?

COMMENTS: Excellent for picking from a barge for 1000 yds of 3-5 ft armor stones.

FIELD SITE DESCRIPTION SUMMARY

SITE: Black Point

PERSONNEL: Dugan and Tart

METHOD OF RECONNAISSANCE: Ground traverse.

DATE: 23 May 1984

PROBABLE OWNERSHIP: City and/or Shumagin Corporation.

WEATHER: Partly cloudy, 50°, wind NW @ 5 mph.

LOCATION (Map, section, township, range): Port Moller (B-2). Sec 17, T56S, R73W.

GENERAL DESCRIPTION: Basalt dike outcropped at tidewater.

GEOLOGIC TYPE: Black fine-grained basalt with occasional pyroxene phenocrysts to 1/16 in.

JOINT SPACING: Closely spaced. URCS: 2

BEDDING AND PLANES OF STRATIFICATION: Approximate thickness = 25 ft.

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Angular, irregular small blocks, mostly less than 1 ft cubes.

OBSERVED SHAPE OF FRAGMENTS: Blocky.

ESTIMATED STRENGTH: High. URCS: 4

EXPECTED DENSITY: Very high. URCS: 5

DEGREE OF WEATHERING: Slight. URCS: 4

ANY PROPERTIES NOT COVERED ABOVE:

VOLUME ESTIMATE: 3000 yd^3; 60 ft length, 45 ft width, 30 ft height

OVERBURDEN: None.

ACCESSIBILITY: Excellent. Borders existing workpad adjacent to harbor.

ENVIRONMENTAL SENSITIVITY: None obvious.

COMMENTS: 1000 yd^3 proven. Dike may extend back into slope to the east but overburden covers it.

FIELD SITE DESCRIPTION SUMMARY

SITE: Danger Point

PERSONNEL: Tart and Dugan

METHOD OF RECONNAISSANCE: Ground traverse plus trail bike.

DATE: 22 May 1984

PROBABLE OWNERSHIP: Aleut Native Corporation

WEATHER: 50°F, overcast with intermittent mist, wind N @ 5 mph.

LOCATION (Map, section, township, range): Port Moller (B-2), SW 1/4, Sec 11 T56S, R73W

GENERAL DESCRIPTION: Basalt dome forming headland on North side of Popof Island.

GEOLOGIC TYPE: Dark-gray basalt with scattered pyroxene phenocrysts to 1/8 in.

JOINT SPACING: Medium spaced, variable. URCS: 4

BEDDING AND PLANES OF STRATIFICATION: None.

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Large blocks, some up to 5 ft cubes.

OBSERVED SHAPE OF FRAGMENTS: Blocky-cubic.

ESTIMATED STRENGTH: High. URCS: 4

EXPECTED DENSITY: Very high. URCS: 5

DEGREE OF WEATHERING: Slight. URCS: 4

ANY PROPERTIES NOT COVERED ABOVE: Surface weathering usually less than 1/2 in. on exposed surfaces and joints. Fresh below 1/2 in. URCS: 4.

VOLUME ESTIMATE: 1,000,000 yds^3; 750 ft length, 200 ft width, 200 ft height.

OVERBURDEN: Insignificant.

ACCESSIBILITY: Fair. Would require 2 mi. road or possible access by barge.

ENVIRONMENTAL SENSITIVITY: Aesthetic value of prominent headland. Some birds; no nests evident.

COMMENTS: Blasts probably could be designed to shoot rock such that it would fall to waterline for loading and transport. 3-chip samples, 1 large block sample.

FIELD SITE DESCRIPTION SUMMARY

SITE: Pirate Cove

PERSONNEL: Tart and Dugan

METHOD OF RECONNAISSANCE: Boat with landing

DATE: 25 May 1984

PROBABLE OWNERSHIP: Aleut Native Corporation.

WEATHER: Partly cloudy, 50°F, wind NW @ 5 mph.

LOCATION (Map, section, township, range): Port Moller (B-2), N 1/2, Sec 5, T55S, R72W.

GENERAL DESCRIPTION: Massive, layered, welded tuff-breccia on 200 ft plus vertical sea cliff.

GEOLOGIC TYPE: Gray-brown welded basaltic tuff-breccia slightly vesicular and glassy.

JOINT SPACING: Widely spaced, variable. URCS: 4

BEDDING AND PLANES OF STRATIFICATION: Bedding plans of individual flow layers 20-40 ft.

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Large, irregular blocks, some up to 4 ft cubes.

OBSERVED SHAPE OF FRAGMENTS: Large, irregular blocks.

ESTIMATED STRENGTH: Moderate. URCS: 3

EXPECTED DENSITY: High. URCS: 3

DEGREE OF WEATHERING: Moderate. URCS: 3

ANY PROPERTIES NOT COVERED ABOVE: More intense staining around larger clasts. May be easily weathered.

VOLUME ESTIMATE: 1,500,000 yd^3 plus. 1000 ft length, 200 ft width, 200 ft height

OVERBURDEN: None significant

ACCESSIBILITY: Poor. Barge with deep water approach. Good beach nearby.

ENVIRONMENTAL SENSITIVITY: Seabirds and sea otters.

COMMENTS: Difficult site to develop due to precipitous topography. May not be desirable enough. Ignimbrite. worth red.

FIELD SITE DESCRIPTION SUMMARY

SITE: Dark Cliffs

PERSONNEL: Tart and Dugan

METHOD OF RECONNAISSANCE: Boat with landing.

DATE: 25 May 1984

PROBABLE OWNERSHIP:

WEATHER: Clear, 50°F, calm.

LOCATION (Map, section, township, range): Port Moller (B-1), NE 1/4, Sec 16, T56S, R72W.

GENERAL DESCRIPTION: Andesite dike with columnar jointing outcropped at tidewater.

GEOLOGIC TYPE: Gray andesite.

JOINT SPACING: Closely spaced. URCS: 2

BEDDING AND PLANES OF STRATIFICATION:

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Small blocks, some up to 2 ft cubes.

OBSERVED SHAPE OF FRAGMENTS: Hexagonal columns.

ESTIMATED STRENGTH: High. URCS: 4

EXPECTED DENSITY: Very high. URCS: 5

DEGREE OF WEATHERING: Slight, moderate along joints. URCS: 4

ANY PROPERTIES NOT COVERED ABOVE:

VOLUME ESTIMATE: 4,000,000 yd^3 plus 1000 ft length, 500 ft width, 200 ft height.

OVERBURDEN: None.

ACCESSIBILITY: Poor. Deep water at outcrop face.

ENVIRONMENTAL SENSITIVITY: Sea birds and sea mammals abound in vicinity.

COMMENTS: Difficult to develop due to high cliff face at tidewater.

FIELD SITE DESCRIPTION SUMMARY

SITE: Buffalo Rocks

PERSONNEL: Tart and Dugan

METHOD OF RECONNAISSANCE: Boat with landing

DATE: 25 May 1984

PROBABLE OWNERSHIP: Aleut Native Corporation and U.S. Fish and Wildlife Service.

WEATHER: Clear, 50°F, wind 0-5 from N.

LOCATION (Map, section, township, range): Port Moller (B-2), SE 1/4 Sec 2, T56S, R72W.

GENERAL DESCRIPTION: Andesite domes, some columnar structure.

GEOLOGIC TYPE: Gray zeolitic andesite.

JOINT SPACING: Medium spaced. URCS: 3

BEDDING AND PLANES OF STRATIFICATION: None.

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Moderate blocks, some up to 3 ft cubes.

OBSERVED SHAPE OF FRAGMENTS: Blocky.

ESTIMATED STRENGTH: High. URCS: 4

EXPECTED DENSITY: Very high. URCS: 5

DEGREE OF WEATHERING: Slight. URCS: 4

ANY PROPERTIES NOT COVERED ABOVE:

VOLUME ESTIMATE: 4,000,000 yd^3 plus; 1000 ft length, 400 ft width, 200 ft height.

OVERBURDEN: None significant.

ACCESSIBILITY: Poor. Barge only, good beach landing, deep water nearby, plenty of room with gentle slope for shore facilities.

ENVIRONMENTAL SENSITIVITY: Seabirds and sea otters in the vicinity. Buffalo grazing in the valley.

COMMENTS: Good site, would require blasting.

FIELD SITE DESCRIPTION SUMMARY

SITE: Popof Head

PERSONNEL: Tart and Dugan

METHOD OF RECONNAISSANCE: Boat with landing.

DATE: 25 May 1984

PROBABLE OWNERSHIP: Aleut Native Corporation

WEATHER: Clear, 50°F, wind 5 mph.

LOCATION (Map, section, township, range): Port Moller (A-1, A-2, B-1, and B-2), Sec 14, T575, R72W.

GENERAL DESCRIPTION: Hypabyssal dacite neck with large columnar joints

GEOLOGIC TYPE: Light gray dacite with numerous large weathered phenocrysts of horneblende to 1/3 inch. Trace quartz.

JOINT SPACING: Massive. URCS: 5.

BEDDING AND PLANES OF STRATIFICATION: None.

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Large blocks, many 8 ft + cubes.

OBSERVED SHAPE OF FRAGMENTS: Planar columns and blocks.

ESTIMATED STRENGTH: High. URCS: 4.

EXPECTED DENSITY: High. URCS: 4.

DEGREE OF WEATHERING: Slight. URCS: 4.

ANY PROPERTIES NOT COVERED ABOVE: Some blocks to 20 ft sq.

VOLUME ESTIMATE: 50,000,000 yd^3 plus; 3000 ft length, 1000 ft width, 500 ft height.

OVERBURDEN: None.

ACCESSIBILITY: Poor. Barge only, large armor stone might be picked up with crane. Deep water up to steep talus slope.

ENVIRONMENTAL SENSITIVITY: Sea lions, sea otter, cormorants, gulls, puffins

COMMENTS: The biggest armor rock observed. Large talus slope to waterline could be worked with a barge mounted crane. Some ground swell, located in the lee of the prevailing NW wind that is common to Popof Island. No blasting necessary on talus.

FIELD SITE DESCRIPTION SUMMARY

SITE: East Simeon Bight

PERSONNEL: Dugan and Tart

METHOD OF RECONNAISSANCE: Boat with landing.

DATE: 25 May 1984

PROBABLE OWNERSHIP: Aleut Native Corporation

WEATHER: Clear, 50°F, Wind S @ 5 mph.

LOCATION (Map, section, township, range): Port Moller (B-2), NW 1/4, Sec 4, T575, R73W.

GENERAL DESCRIPTION: Andesite flow.

GEOLOGIC TYPE: Medium-gray andesite.

JOINT SPACING: Closely spaced. URCS: 2.

BEDDING AND PLANES OF STRATIFICATION: None.

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Small blocks, up to 2 ft cubes.

OBSERVED SHAPE OF FRAGMENTS: Blocks.

ESTIMATED STRENGTH: High. URCS: 4.

EXPECTED DENSITY: High. URCS: 5.

DEGREE OF WEATHERING: Slight. URCS: 4.

ANY PROPERTIES NOT COVERED ABOVE: Moderately weathered to 1/8 in. along joints and seams.

VOLUME ESTIMATE: 600,000 yd^3 plus; 700 ft length, 500 ft width, 50 ft height.

OVERBURDEN: None.

ACCESSIBILITY: Poor. Barge only, deep water approach.

ENVIRONMENTAL SENSITIVITY: Sea otters in vicinity.

COMMENTS: This outcrop forms a small peninsula or headland providing a partially protected anchorage. Topography suitable for establishing onshore facilities.

FIELD SITE DESCRIPTION SUMMARY

SITE: Rap Rock

PERSONNEL: Tart and Dugan

METHOD OF RECONNAISSANCE: Boat with landing.

DATE: 25 May 1984

PROBABLE OWNERSHIP: Aleut Native Corporation

WEATHER: Clear, 50°F, Wind S @ 5 mph.

LOCATION (Map, section, township, range): Port Moller (B-2), NE 1/4, Sec 35, T565, R73W.

GENERAL DESCRIPTION: Andesite Flow.

GEOLOGIC TYPE: Gray-brown andesite.

JOINT SPACING: Closely spaced. URCS: 2.

BEDDING AND PLANES OF STRATIFICATION: None.

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Small blocks, mostly less than 1 ft cubes.

OBSERVED SHAPE OF FRAGMENTS: Blocky, angular.

ESTIMATED STRENGTH: High. URCS: 4

EXPECTED DENSITY: High. URCS: 5

DEGREE OF WEATHERING: Slight. URCS: 4

ANY PROPERTIES NOT COVERED ABOVE: Outcrop includes some moderately altered zones.

VOLUME ESTIMATE: 100,000 yd^3; 300 ft length, 100 ft width, 100 ft height.

OVERBURDEN: None.

ACCESSIBILITY: Poor. Barge with shallow approach shoals.

ENVIRONMENTAL SENSITIVITY: None obvious.

COMMENTS: Good adjacent beach for shore facilities; 100 yd causeway may be necessary.

FIELD SITE DESCRIPTION SUMMARY

SITE: West Simeon Bight

PERSONNEL: Dugan and Tart

METHOD OF RECONNAISSANCE: Observe from aircraft & boat.

DATE: 25 May 1984

PROBABLE OWNERSHIP: Aleut Native Corporation

WEATHER: Clear.

LOCATION (Map, section, township, range): Port Moller (B-2), SE 1/4, Sec 35, T56S, R73W.

GENERAL DESCRIPTION: Andesitic flows.

GEOLOGIC TYPE: Andesite.

JOINT SPACING: Medium spaced. URCS: 2.

BEDDING AND PLANES OF STRATIFICATION: Unit greater than 40 ft thick.

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Moderate blocks, up to 3 ft cubes.

OBSERVED SHAPE OF FRAGMENTS: Blocky.

ESTIMATED STRENGTH: High. URCS: 4

EXPECTED DENSITY: High. URCS: 5

DEGREE OF WEATHERING: Slight. URCS: 4

ANY PROPERTIES NOT COVERED ABOVE:

VOLUME ESTIMATE: 300,000+ yds^3; 800 ft length, 100 ft width, 100 ft height

OVERBURDEN: None significant.

ACCESSIBILITY: Poor. Barge access only.

ENVIRONMENTAL SENSITIVITY: Forms base of peninsula. Some sensitivity as wildlife habitat.

COMMENTS: Similar access as Rap Rock. Same beach available. Confidence. (low)

FIELD SITE DESCRIPTION SUMMARY

SITE: Red Cove West

PERSONNEL: Tart and Dugan

METHOD OF RECONNAISSANCE:
Air Recon, Boat Recon w/o landing.

DATE: 25 May 1984

PROBABLE OWNERSHIP: Aleut Native Corporation

WEATHER: Partly cloudy, 45°F, Wind S @ 5 mph.

LOCATION (Map, section, township, range): Port Moller (B-2), NE 1/4, Sec 34, T56S, R73W.

GENERAL DESCRIPTION: Massive andesite flows.

GEOLOGIC TYPE: Gray andesite (?).

JOINT SPACING: Medium spaced. URCS: 3.

BEDDING AND PLANES OF STRATIFICATION: Not determined.

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Moderate blocks, up to 3 ft cubes.

OBSERVED SHAPE OF FRAGMENTS: Blocky.

ESTIMATED STRENGTH: High. URCS: 4

EXPECTED DENSITY: High. URCS: 5

DEGREE OF WEATHERING: Slight. URCS: 4

ANY PROPERTIES NOT COVERED ABOVE:

VOLUME ESTIMATE: 1,000,000 yd^3 plus; 500 ft length, 250 ft width, 200 ft height.

OVERBURDEN: None significant.

ACCESSIBILITY: Fair. Barge or road from Red Cove (1/2 mi.)

ENVIRONMENTAL SENSITIVITY: Unknown.

COMMENTS: Difficult to develop. Material could be blasted from above and loaded below by barge picking of the beach.

FIELD SITE DESCRIPTION SUMMARY

SITE: Creek Point

PERSONNEL: Tart and Dugan

METHOD OF RECONNAISSANCE: Ground traverse.

DATE: 23 May 1984

PROBABLE OWNERSHIP: Aleut Native Corporation

WEATHER: Drizzle.

LOCATION (Map, section, township, range): Port Moller, (B-2), SE 1/8, Sec 29, T56S, R73W.

GENERAL DESCRIPTION: Coastal bluff andesite flow.

GEOLOGIC TYPE: Andesite or basalt - greenish gray with pyroxene phenocrysts and olivine, fine-grained.

JOINT SPACING: Medium spaced, variable. URCS: 3

BEDDING AND PLANES OF STRATIFICATION: Basalt units in folded beds to 30 ft thickness.

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Moderate blocks, up to 4 ft cubes.

OBSERVED SHAPE OF FRAGMENTS: Blocks and rounded boulders.

ESTIMATED STRENGTH: High. URCS: 4

EXPECTED DENSITY: Very high. URCS: 5

DEGREE OF WEATHERING: Moderate to slight, variable. URCS: 3

ANY PROPERTIES NOT COVERED ABOVE: Upper flow with 2 ft diam. boulders in conglomerate-like matrix, 30 ft thick. Underlying basalt flow is blocky.

VOLUME ESTIMATE: .5 million yd^3 plus; may require significant movement of inferior rock. 700 ft length, 200 ft width, 100 ft height.

OVERBURDEN: Variable, probably not significant; 0-5 ft.

ACCESSIBILITY: Good. Coastal road from airport, barge (possibly), overland road from Sand Point possible.

ENVIRONMENTAL SENSITIVITY: Otters and cormorant in area.

COMMENTS: Shoals in the area. Beach talus consists of 1 to 4 ft boulders which appear suitable for armor stone.

FIELD SITE DESCRIPTION SUMMARY

SITE: Gold Creek East

PERSONNEL: Tart and Dugan

METHOD OF RECONNAISSANCE:
Ground traverse.

DATE: 23 May 1984

PROBABLE OWNERSHIP:

WEATHER: Rain and Mist, 45°F, Wind NW @ 5 mph.

LOCATION (Map, section, township, range): Port Moller (B-2), SE 1/4, Sec 19, T50S, R73W.

GENERAL DESCRIPTION: Breciated andesite flows and tuff-brecias with occasional large andesite clasts and some altered areas.

GEOLOGIC TYPE: Gray andesite with pyroxene phenocrysts to 1/8 in.

JOINT SPACING: Closely spaced. URCS: 2

BEDDING AND PLANES OF STRATIFICATION: Individual flows 20-50 ft.

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Small blocks, mostly less than 1 ft cubes.

OBSERVED SHAPE OF FRAGMENTS: Irregular, angular.

ESTIMATED STRENGTH: Moderate. URCS: 3

EXPECTED DENSITY: High. URCS: 4

DEGREE OF WEATHERING: Moderate. URCS: 3

ANY PROPERTIES NOT COVERED ABOVE: Large clasts of massive andesite (not breciated) comprised about 10 percent of the mass.

VOLUME ESTIMATE: 2,000,000+ yds^3; 1000 ft length, 500 ft width, 100 ft height.

OVERBURDEN: 2-5 ft of till.

ACCESSIBILITY: Very good. Adjacent to south end of runway.

ENVIRONMENTAL SENSITIVITY: Need to cross stream at south end of airport.

COMMENTS: Rock appears suitable for fill but is not likely to produce more than 10 percent as rip rap. The more weathered zones may break down rapidly.

FIELD SITE DESCRIPTION SUMMARY

SITE: Airport Bluffs

PERSONNEL: Tart and Dugan

METHOD OF RECONNAISSANCE: Ground traverse.

DATE: 23-24 May 1984

PROBABLE OWNERSHIP: City of Sand Point on Shumagin Native Corporation

WEATHER: Cloudy, 45°F, Wind 0-5 mph.

LOCATION (Map, section, township, range): Port Moller (B-2), E 1/2, Sec 19, T56S, R73W.

GENERAL DESCRIPTION: Highly variable andesite tuff-breccia flows.

GEOLOGIC TYPE: Light gray andesite with pyroxene phenocrysts.

JOINT SPACING: Crushed. URCS: 1

BEDDING AND PLANES OF STRATIFICATION: None.

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Small pieces less than 0.5 ft cubes.

OBSERVED SHAPE OF FRAGMENTS: Irregular.

ESTIMATED STRENGTH: Low. URCS: 2

EXPECTED DENSITY: Low. URCS: 2

DEGREE OF WEATHERING: Highly weathered. URCS: 2.

ANY PROPERTIES NOT COVERED ABOVE: Material is variable. About 20 percent of the total is of higher quality.

VOLUME ESTIMATE: 1,000,000 yd^3; 1000 ft length, 250 ft wide, 100 ft height.

OVERBURDEN: 5-10 ft of till.

ACCESSIBILITY: Excellent. No new roads necessary.

ENVIRONMENTAL SENSITIVITY: None obvious although local air taxi operators will be inconvenienced by the development.

COMMENTS: Likely suitable as fill. Not suitable for rip rap or armor.

FIELD SITE DESCRIPTION SUMMARY

SITE: East Quarry

PERSONNEL: Dugan and Tart

METHOD OF RECONNAISSANCE: Foot traverse

DATE: 21 May & 26 May 1984

PROBABLE OWNERSHIP: City of Sand Point and Native Corporations

WEATHER: Cloudy, 45°F, Wind 0-5 mph.

LOCATION (Map, section, township, range): Port Moller (B-2), NE 1/4, Sec 17, T56S, R73W.

GENERAL DESCRIPTION: Variable volcanic units of andesitic tuff breccia flows.

GEOLOGIC TYPE: Gray to yellow andesite, moderately to highly altered.

JOINT SPACING: Closely spaced. URCS: 2

BEDDING AND PLANES OF STRATIFICATION: Variable and unpredictable.

LIKELY CHARACTER OF ROCK BREAK ON BLASTING: Small blocks, mostly less than 1 ft cubes.

OBSERVED SHAPE OF FRAGMENTS: Irregular, blocky.

ESTIMATED STRENGTH: Moderate. URCS: 4

EXPECTED DENSITY: Medium. URCS: 4

DEGREE OF WEATHERING: Moderate. URCS: 3

ANY PROPERTIES NOT COVERED ABOVE: Includes some higher quality material.

VOLUME ESTIMATE: 1,000,000 yd^3 plus; 1000 ft length, 500 ft width, 50 ft height.

OVERBURDEN: 5 ft of till.

ACCESSIBILITY: Excellent. On road between airport and town.

ENVIRONMENTAL SENSITIVITY: None.

COMMENTS: Good fill source. Not suitable as rip rap or crushed aggregate.

APPENDIX B

PETROGRAPHIC REPORT

STEVENS EXPLORATION MANAGEMENT CORP.

700 West International Airport Road
Anchorage, Alaska 99502
(907) 561-1991

Woodward-Clyde Consultants
701 Sesame
Anchorage, Alaska 99503

July 16, 1984

Dear Sir:

Enclosed herewith is a brief petrographic report on the Popof Island rock samples. This report includes a definition of the terms used, a discussion of weathering and the broader subject of rock alteration, a quantification of the subjective parameters used in the petrographic analyses, and petrographic reports on the nine thin sections examined.

If there are any questions or suggestions on this work, please contact Carolyn Stevens (561-8890). We sincerely hope to be able to provide petrographic services to your organization again in the future. Thank you for the business.

Sincerely,

Carolyn Stevens

Carolyn Stevens

Enclosure

INTRODUCTION

This petrographic study was conducted on a suite of nine rock specimens collected by Woodward-Clyde Consultants from Popof Island, Alaska.

PURPOSE

The purpose of this petrographic study was to:

(1) Identify the rocks;
(2) Determine the degree and nature of alteration;
(3) Describe the rock textures;
(4) Determine intensity of microfracturing; and
(5) Suggest susceptibility to weathering.

AUTHORIZATION

Authorization to proceed on this project was given by Bucky Tart of Tart Associates. The definitions of the terms used and the discussion of weathering and alteration were included in this report at the request of Bob Dugan of Woodward-Clyde Consultants.

METHODS OF OPERATION

Woodward-Clyde Consultants personnel brought the rocks to be examined to the offices of Stevens Exploration Management Corp. The rocks were forwarded to Western Petrographics for thin sectioning and returned after about 14 days later.

The petrographic analyses of the thin sections were done by Carolyn Stevens using a Zeiss petrographic research microscope equipped with fluorite lenses. Analyses were performed using standard optical tests to determine the identity of mineral species. Percentages of the minerals were estimated visually.

DEFINITION OF TERMS

(From American Geological Institute Glossary of Geology)

AMYGDULES - A gas cavity or vesicle in an igneous rock which is filled with such secondary minerals as calcite, quartz, chalcedony, or a zeolite.

ANDESITE - An intermediate volcanic rock with a color index of 10-40, quartz <10%, feldspathoids <10%, and plagioclase content 2/3 to 9/10 of total feldspar with An content of <50%.

ANHEDRAL - A mineral without crystal faces.

BASALT - A basic volcanic rock with a color index 40-70, plagioclase (An >50%) constitutes >9/10 of total feldspar, and quartz and feldspathoids each amount to <10% of the rock.

BASIC ROCK - Said of an igneous rock having a relatively low silica content that is relatively rich in iron, magnesium, and/or calcium.

CHLORITE - A group of platy, usually greenish minerals characterized by prominent ferrous iron and by the absence of calcium and the alkalies. Chlorites are associated with and resemble the micas. They may also be considered as clay minerals. The chlorites are widely distributed especially in low-grade metamorphic rocks or as alteration products of ferromagnesium minerals.

CLAY - A complex and loosely defined group of finely crystalline metacolloidal or amorphous hydrous silicates formed chiefly by alteration or weathering of primary silicate minerals such as feldspars, pyroxene and amphiboles. The most common clay minerals belong to the kaolin, montmorillonite, and illite groups.

CRYSTAL TUFF - A consolidated pyroclastic rock consisting of predominantly crystal particles or fragments.

EPIDOTE - A mineral or mineral group which commonly occurs associated with albite and chlorite as formless grains or masses or as monoclinic crystals in low grade metamorphic rocks, or as a rare constituent in igneous rocks where it represents alteration products of ferromagnesium minerals. Epidotization is a process characteristically associated with metamorphism whereby epidote is hydrothermally introduced or results from rock alteration in which plagioclase feldspar is albitized freeing the Anorthite molecule to form epidote, often accompanied by chloritization.

EUHEDRAL - The mineral is completely bounded by crystal faces.

FINE-GRAINED - The average grain size is <1 mm.

GLASS - An amorphous product of the rapid cooling of a magma which is metastable.

GRANOBLASTIC - A texture in which recrystallization has formed essentially equidimensional crystals with normally well-sutured boundaries.

INTERMEDIATE ROCK - Said of an igneous rock that is chemically transitional between basic and silicic (or between mafic and felsic), based on silica content.

LITHIC TUFF - A consolidated pyroclastic rock consisting predominantly fragments of other pyroclastic or volcanic rock fragments.

MAFICS - Ferromagnesium (dark-colored) minerals such as olivine, pyroxene, amphibole and biotite.

OPAQUES - Minerals that do not transmit visible light such as pyrite, magnetite, and masses of hydrous iron oxide.

PLAGIOCLASE FELDSPAR - A group of minerals with the general formula of $(Na,Ca)Al(Si,Al)Si_2O_8$. At high temperatures it forms a complete solid solution series from Albite ($NaAlSi_3O_8$) to Anorthite ($CaAl_2Si_2O_8$). The plagioclase series is arbitrarily subdivided and named according to increasing mole fraction of the An component: Albite (An 0 to 10), Oligoclase (An 10 to 30), Andesine (An 30 to 50), Labradorite (An 50 to 70), Bytownite (An 70 to 90), Anorthite (An 90 to 100).

PSEUDOMORPHIC - A mineral whose outward crystal form is that of another mineral species which, in the case of this report, has been replaced by alteration.

RHYODACITE - An intermediate volcanic rock with a color index of 15 - 30, Plagioclase (An 25 to 40) 2/3 to 9/10 of total feldspar, and quartz >10%.

SERIATE - An igneous texture, typically porphyritic, in which the grain sizes vary gradually or in a continuous series.

SUBHEDRAL - A mineral partially bounded by crystal faces.

DISCUSSION OF WEATHERING AND ALTERATION

Weathering may be very briefly defined as the natural destructive process (through chemical and/or mechanical means) whereby earth and rock materials are changed in character (color, texture, composition, firmness, or form), resulting in an in-situ mantle of loosened/altered material. Most weathering is surficial, but may occur at considerable depths, as in well-jointed rocks, for example. However, alteration due to weathering is by definition, confined to changes produced under atmospheric conditions of the earth's surface.

Alteration, however, is a broader term in that it includes the compositional changes in minerals and rocks brought about by physical or chemical means through weathering, the action of hydrothermal solutions, supergene processes, or even mild metamorphic processes. Therefore, alteration refers to changes produced under a wide range of pressure-temperature environments whereas weathering is restricted to atmospheric pressure-temperature conditions.

Hydrothermal alteration refers specifically to those mineralogical changes produced through the reaction of heated water with preexisting solid mineral phases. Hydrothermal water is subsurface water that is geologically or hydrologically significant because of its elevated temperature, whether or not it is hotter than the containing rock.

Deuteric alteration results from the reactions between primary magmatic minerals and the water-rich solutions produced from the same body of magma at a late stage in its cooling history. Deuteric alteration is therefore a specific type of hydrothermal alteration.

The nature of hydrothermal alteration products depends upon three factors:

(1) the character of the original rock;

(2) the character of the invading fluid;

(3) the temperature and pressure under which the reactions took place.

Minerals that are unstable in the presence of hydrothermal fluids will undergo physical and chemical changes to reach equilibrium under the prevailing conditions. The resultant alteration may be subtle, as in the incipient hydration of ferromagnesian minerals, or may be complete as in the silicification of limestone. Alteration may range from simple recrystallization to addition, removal, or rearrangement of chemical components. Color changes, permeability changes, and recrystallization are resulting physical changes due to alteration. Examples are reduction of permeability through argillization, or increase of permeability through recrystallization of carbonate rocks. The alteration process involves a complex process of ion exchange whereby some constituents are removed, others added, and still others redistributed. Physical processes that may take place during alteration are silicification, carbonatization, argillization, and hydration. These processes may all be operative simultaneously.

According to Schwartz (1959), sericite, quartz, chlorite, pyrite, epidote, zoisite, carbonate, and clay minerals are probably the most common hydrothermal alteration minerals. Chlorite is probably one of the most abundant minerals in near-surface (epithermal) altered rocks. Alteration products at shallow

depths are ordinarily fine-grained, and many are difficult to separate for identification. Probably the most diagnostic minerals are the clays and chlorite. The character of the alteration products depends greatly on the nature of the invaded material.

It is probably appropriate here to quickly review some generalizations concerning the stability of various rock-forming minerals at surface or near-surface conditions, since the rock samples from Popof Island are volcanics and hypabyssal intrusives. Generally speaking, the late phase minerals (quartz and alkali feldspar, etc.) crystallizing from a "typical" silicate melt are those that are more stable at earth's surface because they crystallized at lower temperatures and pressures as the magma cooled and therefore are closer to equilibrium conditions. Conversely, those silicates that crystallize early out of the melt at higher temperatures and pressures (i.e., olivine, pyroxene, amphibole, and very calcic plagioclase) are less stable in atmospheric conditions because they crystallized in a higher temperature environment. Therefore, the ferromagnesian minerals and more calcic plagioclase feldspars of an intermediate or basic igneous rocks weather or alter more readily than the minerals formed later in the crystallization history.

The comments in the above paragraph on susceptibility of minerals to weathering/alteration at surface/near surface conditions are to be applied generally. These generalizations do not apply universally, for exceptions are common. Rate of weathering is also very dependent on such factors as grain size and degree of fracturing; therefore universal generalizations are normally impossible. Grain size and fracturing contribute to decomposition susceptibility because the smaller the grain size of the constituent minerals of a given rock and the greater the surface

area of a rock exposed to weathering agents due to fracturing, the greater the susceptibility of the rock to the decomposition process.

ANALYTICAL PARAMETERS DEFINED

DEGREE OF ALTERATION OF INDIVIDUAL MINERAL GRAINS

1 = Unaltered: 0 - 4% alteration. Alteration nil; fresh clear primary minerals.

2 = Slightly altered: 5 - 24% of mineral altered.

3 = Moderately altered: 25 - 74% of mineral altered.

4 = Highly altered: 75 - 94% of mineral altered.

5 = Completely altered: 95 - 100% of mineral altered.

GRAIN SIZE PARAMETERS

<1 mm = fine

1 - 5 mm = medium

5 mm -3 cm = coarse

WEATHERING SUSCEPTIBILITY

These are very subjective estimates based on these petrographic analyses.

1 = Not susceptible; a very resistant rock type.

2 = Resistant rock; slightly susceptible.

3 = Moderately resistant rock; moderately susceptible.

4 = Slight resistance only; strong susceptibility to weathering

5 = Non-resistant; highly susceptible to weathering.

BRIEF PETROGRAPHIC DESCRIPTIONS

Airport Bluffs - Aphanitic porphyritic andesitic (?) lithic tuff with groundmass highly altered to mostly clays and chlorite with opaques. Smaller mafic phenocrysts (<1mm.) are completely altered to chlorite ± opaques. Plagioclase phenocrysts exhibit various states of alteration (some to zeolites). Intermediate to basic volcanic fragments are all moderately to highly altered. Small (<1mm.), devitrified, chloritized, glass-filled amygdules noted locally. Weathering susceptibility index = 3 or 2.

Creek Point - Highly altered porphyritic andesite (?) or basalt (?) with euhedral to subhedral progressively altered plagioclase (An <40) phenocrysts up to 3 mm. diameter and completely chloritized mafics in a highly altered, devitrified glass groundmass of sericite, clays, calcite and some incipient epidote plus opaques. A few anhedral quartz grains (<1 mm.) were noted, one possibly pseudomorphic after pyroxene. This rock is probably highly susceptible to weathering because the original metastable glassy groundmass is very fine-grained and highly altered (1-2).

Danger Point - diabase with chloritized olivine. This fine-to-medium grained moderately altered hypabyssal rock is characterized by intergranular seriate texture with approximately 7% olivine (?) totally altered to chlorite and green mica with opaques. Pyroxene is only slightly altered, but randomly oriented plagioclase is moderately altered to clays and cholorite (+ sericite?). Interstitial chlorite may have been glass before the deuteric alteration. Plagioclase grains are almost entirely fine-grained, while pyroxene and altered mafics range from ≤.1mm. diameter to 2 mm. diameter. If this is a diabase, this presence of glass indicates that the sample was selected from near the intrusive margin. Weathering susceptibility index = 3 - 4.

Dome Quarry - Porphyritic amygdaloidal basalt with large ($\leq$ 4 mm.) phenocrysts of slightly altered pyroxene (augite) and plagioclase with completely altered olivine (?) occasionally present. 90% of the rock is a fine-to-medium grained groundmass of euhedral to subhedral, seriate, randomly-oriented unaltered to slighltly altered plagioclase crystals with fine-grained granular pyroxene and brown, chloritized (palagonite) glass occurring interstitially. Calcite fills some amygdules, chlorite fills others; occasionally secondary quartz lines some. Calcite also occurs with chlorite as an alteration product of a mafic probably olivine. Weathering susceptibility - 3 to 4 because of coarser grain size and the slight alteration.

East Quarry - Porphyritic andesite with clumps of plagioclase and plagioclase/pyroxene phenocrysts (30%) up to 3 - 5 mm. diameter. Fine-grained groundmass (70%) consists of randomly-oriented plagioclase laths with altered interstitial glass (chlorite) and opaques. Groundmass also partially altered to granular epidote. Carbonate patches and zeolites are alteration products of the euhedral to subhedral plagioclase phenocrysts. Chlorite may be pseudomorphic after olivine. Pyroxenes are usually jacketed by alteration rims of carbonate and uralite (?). Weathering susceptibility index 2 - 3.

Gold Creek East - Porphyritic seriate amygdaloidal andesite with almost all seriate plagioclase phenocrysts ($\leq$ 2 mm. diameter) slightly to moderately altered to clays, chlorite and possible zeolites (?). Fine-grained altered mafic phenocrysts (pyroxene ? completely altered to chlorite plus opaques. The fine-grained groundmass consists of plagioclase (slightly-to moderately altered), glass (highly altered to chlorite), and opaques. The rock has a crowded, somewhat crushed appearance, though amygdules up to 3 mm. in diameter are present. These are mostly filled

with glass which is devitrifying and altering to chlorite plus opaques. One large amygdule (3 mm. diameter) is lined with chlorite (?) needles, then filled with a zeolite. Weathering susceptibility estimate - 3.

Pirate Cove - Porphyritic / seriate amygdaloidal basalt. Amygdules lined with chlorite then filled with optically continuous calcite constitute approximately 20% of the rock. Seriate fine-to-medium grained (<.1 mm. to 2 mm. diameter) euhedral to subhedral zoned plagioclase crystals are labradoritic in composition. Mafics (pyroxene ~ 10%) are almost entirely altered to gray chlorite. The groundmass consists of about 10% fine-grained plagioclase and 25 -28% opaques. The rock should be rather susceptible to weathering because of high calcite content and the fine-grained texture: 2 to 3.

Popof Head - Porphyritic hornblende rhyodacite with seriate phenocrysts of approximately 30% sodic (oligoclase) plagioclase ($\leq$ 7 mm. diameter) 10% medium - to-coarse grained altered (chlorite and opaques) hornblende phenocrysts, and one large, rounded quartz grain in a fine-grained, granoblastic, essentially quartz and sodic (?) feldspar (possibly some minor K-spar) ground-mass containing evenly distributed fine grained minor (<5%) opaques, and altered glass (chlorite and epidote). Rock may be slightly hornfelsed. This rock may be moderately resistant to weathering. Though it's somewhat altered and has a fine-grained groundmass, the higher quartz content of the groundmass may make it more resistant. Rated 3-4.

Red Cove Dome - Porphyritic seriate andesite with zoned euhedral to subhedral plagioclase phenocrysts (An 27-35 on rims, An 70 in cores), some in clumps, up to 2 mm. diameter, composing approximately 25% of the rock. Pyroxene (augite + orthopyroxene) phenocrysts, usually subhedral, often twinned, are approximately

5% of the rock. Phenocrysts are unaltered to slightly altered to clay and chlorite. The groundmass consists of fine-grained, randomly oriented, slighltly to moderately altered (to chlorite and sericite) plagioclase laths with interstitial chlorite and opaques. This rock is probably moderately susceptible to weathering because of its fine-grained groundmass and some micro-fracturing with calcite. Rating - 3.

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