PN-6

TERRITORY OF ALASKA

DEPARTMENT OF MINES

B. D. STEWART,
Commissioner of Mines

Pamphlet No. 6

SOME HIGH CALCIUM LIMESTONE DEPOSITS IN SOUTHEASTERN ALASKA

By

J. C. ROEHM

JUNEAU, ALASKA

March, 1946

TERRITORY OF ALASKA

DEPARTMENT OF MINES

B. D. STEWART,
Commissioner of Mines

Pamphlet No. 6

SOME HIGH CALCIUM LIMESTONE DEPOSITS IN SOUTHEASTERN ALASKA

By

J. C. ROEHM

JUNEAU, ALASKA

March, 1946

CONTENTS

ILLUSTRATIONS

SOME HIGH CALCIUM LIMESTONE DEPOSITS

IN SOUTHEASTERN ALASKA

ABSTRACT

Southeastern Alaska contains great tonnages of limestone of which a small percentage has been determined to be of the high-calcium type. The marble industry has been established in Alaska for nearly 40 years, and marble of great purity was produced. The purity of the marble reflects the purity of the associated limestones. The limestone industry began in southeastern Alaska in 1928. The stone produced has all been of the high-calcium type and has been exported to the continental United States, partly processed by crushing, for use in the manufacture of cement.

The high-calcium limestone deposits described in this report are amenable to cheap mining and cheap transportation, being situated on salt water and adjacent to deep water and protected harbors. Ocean transportation from southeastern Alaska to coastal United States ports can compete with railroad transportation inland, particularly the Pacific Coast, at a ratio of 10 miles by ocean to 1 mile by rail. This ratio only applies to actual cost of operation of transportation for large tonnages of raw rock products. Only the accessible portions of the deposits are herein described, but these represent many million tons. Each deposit has physical characteristics and chemical analysis which differ from the others, but all are within the "high-calcium" classification. The descriptions of the following individual deposits are for the sole purpose of assisting in further development.

Further development and tests are recommended for those deposits which appear to meet the requirements and qualifications set up by each consuming industry.

INTRODUCTION

The vast areas of limestone in southeastern Alaska have heretofore been considered of very little importance in spite of the fact that limerock has been produced since 1929 and substantial amounts of marble have been quarried since 1902. The first investigation in which the limestone areas became known was made by the U. S. Geological Survey.[*] The most complete publication with regard to marbles, which also contains classification and analyses of numerous limestones, was the work of Ernest F. Buchard.[†] During his mineral investigations in southeastern Alaska, A. F. Buddington[‡] outlined the main limestone areas, classified them according to geological ages, and furnished analyses of 20 limestones and marbles. The Pacific Coast Cement Company of Seattle, Washington carried on limestone investigations in southeastern Alaska prior to the location of its quarry site at View Cove, Dall Island. Recently, other Pacific Coast industrial firms have made investigations in the southern part of southeastern Alaska, seeking a particular grade and type of limestone.

The purpose of this paper is to direct the attention of Pacific Coast industry to the higher grade deposits. The physical conditions, analyses of preliminary samples, and petrographic features of each deposit examined are included. It is not within the scope of this paper to recommend definite deposits for each industrial use, since these are many and varied, each requiring a particular type and quality of limestone. The deposits herein described must be considered limestone prospects. The development of a limestone deposit suitable for a single industrial use or combination of uses requires the same careful attention to the nature of the stone, ore reserve and economic factors as would be given to a deposit of metallic ore. No burning tests of the limestones described have been made and the results of such tests are therefore not available for inclusion in this paper. It is hoped that the data that are herein presented will be useful and will contribute to the progress of industry on the Pacific Coast.

*—Note Bibliography of U. S. Geol. Sur. reports Nos. 1-11, inclusive.
†—Note Bib. No. 9.
‡—Note Bib. No. 10.

GENERAL TREND OF INDUSTRY AND THE UTILIZATION OF LIMESTONE ON THE PACIFIC COAST

The hydroelectric power developments in the Pacific Coast states prior to World War II, and the general war trend for the dispersion of industry, are very favorable indicators of increased industrial development in and along Pacific Coast ports of the United States. Newly established metallurgical, chemical, fertilizer and structural products plants along the Pacific Coast have created demands for raw materials. The future even promises to increase these demands with greater development of Alaska and the entire Pacific Coast area. Limestone of high quality is one of the many raw materials in demand and will probably constitute the greater bulk of such products. The source of supply for some of these raw products will fall within the borders of Alaska. This is indicated by the numerous inquiries received by the Department of Mines office at Juneau for information on deposits of raw materials. The most persistent demand is for high grade limestone deposits of the high calcium type.

The Bonneville Administration in its study has stated that if suitable limerock is obtained, it is probable that more than 750,000 tons would be consumed annually in the Columbia River area of Oregon and Washington. Indications based on inquiries point toward a much greater demand than heretofore for high grade limerock in the Seattle and Tacoma area. These demands are from chemical, metallurgical, building trade, glass, fertilizer and cement plants, with probable requirements totaling an additional 500,000 tons annually. The increasing use of limerock as a fertilizer and its increased application to the vegetable-producing area bordering the Pacific Coast of the United States offers another large-volume market. Recent inquiries and requests for information regarding coal to serve Pacific Coast industries for use in conjunction with limestone indicates possible large production of both. The present ocean transportation trend for Alaska is higher costs. It is believed that in the near future all U. S. shipping costs must be lowered if this country is to retain its place among the leading world powers. This will apply to Alaskan waters as well as to others of the world.

DEFINITION OF TERMS

High-calcium limerock is a special type classified by Grout[*] as of a mineralogic variety, distinguished by its high calcium carbonate content, from magnesium, dolomite, ferrugenous and phosphate limestones. Oliver Bowles & D. M. Banks[†] designate high-calcium limerocks as those containing 93 to 99 percent calcium carbonate. Since raw agricultural limerock is a product of growing importance on the Pacific Coast, and since the composition best suited to most soils is a rock containing 90 percent $CaCo^3$ and 10 percent MgO, limerock with a calcium carbonate range from 90 to 99 percent is considered as "high-calcium" in this paper.

Limerock is a term used here to designate rock containing a high percentage of calcium carbonate ($CaCo^3$), and from which lime (CaO) can be extracted by the process of calcining to drive off the CO^2 gas. Limestone is a general name for sedimentary rocks composed mainly of calcium carbonate but differing very widely in hardness, purity, texture and color. Limerock differs from limestone in that it includes limestones and also marbles and masses of calcium carbonate or calcite formed from metamorphism and igneous segregations or associated hot solutions, chalks, marls, and shell deposits of sufficient consolidation to form a rock. Lime, like the metal calcium which it contains, is unstable in nature; it is an alkali and its importance lies in the fact that it is the cheapest and most abundant alkali. Two lime products are formed by calcination—quick lime (CaO) and hydrated lime $Ca(OH^2)$, the latter formed by the addition of water to lime. Another term that is used in the lime industry is "air slacked lime", consisting of either quicklime or hydrated lime, which upon exposure to air reverts to calcium carbonate or limerock. This process of nature is utilized in concrete and building trade materials.

*—Bib. No. 18.
†—Bib. No 12.

MINING FACTORS AND COSTS APPLICABLE TO LIMEROCK IN ALASKA

Initial mining costs as applied to Alaskan conditions may be expected to be higher than the same capacity operation in the continental United States. Most labor and supplies must of necessity be imported. However, some Alaskan labor can be obtained. Wages would be practically the same since mainly skilled labor is used. Housing and boarding facilities are required; but almost the same costs would apply to similar operations in the United States. For large-capacity operation, the initial expenses are not considered to be much above those applicable in remote areas of the United States.

The initial investment in Alaska would include capital for the development of power for mining and crushing. One large limerock deposit is situated near two favorable undeveloped hydroelectric sites. (Note Sketch No. 6). All others will require imported power facilities and supplies. For mining only very little auxiliary power is required since most machinery used will contain individual power units. Considerably more power is necessary for crushing.

The same methods of mining limerock are applicable in Alaska as in the United States and all-year operation can be maintained in southeastern Alaska. The advantages of the Alaskan deposits described herein are: ready access to salt water transportation, and the location of the deposits for the adaptation of gravity in mining, transportation and crushing. These factors are of considerable importance in low-cost operation.

The deposits have only slight vegetal cover. This is another factor to be considered in mining a high-grade product. Alaskan limerock deposits may be mined at very low expense, and taxation on property at the present time is nil. Tax on net income from production is low in the Territory:

> "The license tax on mining, with the exception of the mining of gold, platinum, palladium, osmium, iridium and any other metal or mineral belonging to the platinum or palladium group, shall be as follows:
>
> "Upon all net income:
>
> Not over $10,000 .... ¾%
> Over 10,000 and not over $20,000 ....1¼%
> Over $20,000 and not over $100,000 ....2¾%
> Over $100,000 and not over $150,000 .. 3%
> Over $150,000 and not over $250,000 .. 4%
> Over $250,000 and not over $500,000 .. 5%

Over $500,000 and not over $750,000 ..	6%
Over $750,000 and not over $1,000,000	7%
Over $1,000,000	8%

"By "net income" is meant the cash value of the output of the mine, or mining operation, less the following deductions, viz: (a) actual operating expenses; (b) repairs actually made; (c) royalties actually paid; and (d) by way of depreciation, 10% of the actual cost of permanent improvements actually made during the calendar year in, on, or about and to the benefit of the mine during the calendar year; provided, however, that said 10% depreciation on said cost may be taken not only during the calendar year in which the improvement is actually made but also during each of the nine calendar years immediately following the calendar year in which the improvement is actually made, until a total of, but not in excess of, 100% depreciation, at the rate of 10% per calendar year, is taken for said improvement; provided further, however, that no deduction shall be made or taken, as depreciation, or otherwise, on, of or for any betterment or improvement, or the cost thereof, which betterment or improvement was made prior to January 1, 1937; no deductions shall be made on account of depreciation of any mine, mining operation, ore reserve, equipment, machinery, or otherwise, except the aforesaid 10% depreciation on cost of improvements, actually made, as hereinbefore provided, nor shall any deduction be made for interest on bonds or on money borrowed, or other taxes paid. Provided, further, that the lessee of any mine or mining operation, in order to receive credit for royalties paid, must give, in his return of his own taxes hereunder, the name and address of the person or persons, association or associations, company or companies, to whom such royalties were paid and the amount of money or the percentage of the gross output paid to each such person, association or company."

The mining method used at View Cove, operation of the Superior Portland Cement Company, is open quarry, and a level quarry floor is maintained, which allows movement of track and loading equipment from any part of the quarry pit. Six-inch churn-drill holes are placed 20 feet apart and 40 feet back from the face and drilled to the floor level. Small powder drifts are driven at the level of the quarry floor. These, together with the drill holes, are loaded across the entire face of the quarry and blasted together. This breakage, with the aid of some bulldozing, is sufficient to allow the operation of a one and three-quarter yard shovel for loading into cars. Cars are moved by locomotive to bins where the limerock is automatically dumped into crusher bins. From the bins the limerock is fed by gravity to a 40"x42" Traylor jaw crusher which reduces it to 6-inch minus size. The crushed material is then fed to a hammer mill which reduces the size to from 1½ to ¾ inch. Thence the crushed material is conveyed by elevator belt to a 9,000-ton glory hole, which serves as a storage bin, and which is connected to the loading conveyor by a raise from a short cross-cut at the bottom. The material is dropped from the chute onto a conveyor belt and thence over a series of conveyor belts to the loading dock, where it is dumped in a chute direct into the hold of the ship. A 6400-ton capacity ship is loaded in this manner in six hours and twenty minutes. Power at this operation consists of two Fairbanks-Morse 360-H. P. diesels direct-connected to 2400-kilowatt generators. Hence all the machinery, with the exception of the shovel, drills and locomotives, is operated by electricity. Any favorable limestone deposit located near a hydroelectric power development could be operated cheaply with resultant lower mining and crushing costs. The methods of mining and loading used by the company are applicable to many of the deposits herein described. Some deposits are so situated that underground methods may have to be applied to obtain the higher grade rock.

The storage of broken or crushed limerock would depend on the method of water transportation used. The use of large LST ships or steamers would require large storage capacity to facilitate quick loading. The use of barge or power-scow would allow a more direct quarry-to-load operation, due to smaller unit capacity and reduced storage capacity. All the limestone deposits described are outcrops above sea level, and gravity can be utilized to some degree in all cases.

There are many factors to be considered in loading, more or less dependent upon the type of transportation. Variations of the tides in the waters of southeastern Alaska range from a few feet to 20 feet and loading facilities must be built accordingly.

The only applicable costs for mining and crushing limerock in Alaska are those of the Superior Portland Cement Company at View Cove on Dall Island. These costs, together with the general price increase of supplies and labor, should form a basis for comparable operation costs in the near future. These cost figures are available in a report by Hodge.* The figures are based on a daily capacity of 1000 tons of limerock and for only part-season operation. The reported costs are $0.35 per ton to mine, with crushing and loading costs from 5 to 15 cents per ton additional. The total cost per ton, crushed to 1½ inch or less, amounts to $0.40 to $0.60 per ton aboard ship. These are pre-war costs and probably are only direct costs such as drilling and blasting, bulldozing, hauling, crushing and ship loading. Post-war costs on this basis, providing the above are correct, should be increased at least 30 per cent, making an applicable post-war cost ranging from $0.60 to $0.70 per ton with the addition of overhead and a yearly capacity on the basis of 1000 tons daily. Larger capacity plants should fall within the lower limits of this cost range. However, much depends upon natural physical advantages.

Present Production Costs — 1000 tons daily capacity:

Quarrying and haulage to crusher	$0.40	
Crushing to 1½" size	.15	
Loading on ship	.10	
Total	.65	F.O.B. quarry

*—Bib. No. 19.

TRANSPORTATION METHODS AND COSTS

The limerock deposits described in this paper are situated on islands off the mainland of southeastern Alaska. They are convenient to ocean transportation. It is necessary to locate limerock deposits favorable for cheap mining and readily accessible to good harbors in order to keep transportation and handling costs at a minimum. The markets for raw limerock and lime products, as far as Alaska is concerned, will be the Pacific Coast of the United States. Many of the large cities along the coast have harbors and they are already industrial sites and would act as distributing centers for limerock and lime products. The distances from the deposits in Alaska range from 700 miles to 3000 miles, the latter being the distance to the southern part of California. Only the higher grades of limerock, and possibly those of dolomite, can be expected to compete with coast deposits. High grade limerock and dolomite deposits of large size in the Pacific Coast states are located from 200 to 300 miles inland from the coast, requiring a haul over one, and in some instances, two mountain ranges. The limerock and lime industry shows promise of developing into a large business, and will require the transportation of vast tonnages. The volume probably will amount to more than any other one raw material, with the possible exception of coal. For Alaska this would mean a return haul for the present transportation companies, providing they reduce their rates to those comparable to the cost of private operation. It is an all-water haul. For the railroads to haul limerock or lime products to the Pacific Coast from inland deposits means an additional burden on the heavy end of traffic. The coastal distribution centers may be reached only by means of a land haul.

An adverse factor to a water haul, especially from Alaska, is to be considered in the hauling of lime. This factor involves the nature of quicklime itself and the method of figuring water transportation by volume rather than by weight. The calcination of lime in Alaska is impractical for two reasons—first, lack of fuel other than wood;* and second, the undesirability of shipping quicklime over the distance necessary to markets because of air-slack. Theoretically, one ton of pure limerock (calcium carbonate) should yield 0.54 ton of pure lime. This reduces the weight of a ton of limerock by 920 pounds when limerock is reduced to lime by calcination. However, the volume of the lime remains nearly equal to that of limerock. Water transportation is based mainly on volume, while rail or land transportation is based mainly on weight. This factor gives the railroad an advantage in hauling lime rather than limerock. However, high grade limerock deposits are very rarely located adjacent to a source of cheap natural fuel. Usually two hauls are necessary—either fuel to the limerock source or vice versa, thence haulage of lime to distribution points. This additional haul, plus handling charges via rail, will, however, equalize the cost of hauling limerock from Alaska direct to centers of distribution and fuel supply. Further, the importation of limerock direct to the large port cities of the Pacific Coast will greatly add to their industrial importance. Waste gases from other industries

*—Note section on available fuel supply for calcining.

can be used in the burning of the limerock. The waste gas (CO^2) from the burning of limerock may be used in the manufacture of dry ice, and the waste limerock in the process of calcination can be turned to use. These waste products, where kilns are established away from industrial centers, are direct losses. They mean additional profits in industrial areas.

Either one of four methods of conveyance may be used in water-transportation of limerock from Alaska to Pacific Coast ports. In making a choice of method much depends on the location and physical conditions surrounding the deposit. The most economical means of conveyance is suggested in the description of each deposit. Two means are available under the present operating transportation facilities: Deep-bottom ships, and tug and barge. Both types are now returning practically empty from Alaska to northwest ports. Factors to be considered are: Deposits must lie close to regular steamship routes, good harbor facilities must be available, and large storage bins and expensive loading and docking facilities are necessary. Advantages of this means of transportation to the limerock operator are cheap rates of a return haul, and capital investment and risk in ships and their operation not required. Disadvantages are expensive dock and loading facilities, dependability upon transportation companies which are subject to labor strikes of two labor organizations, seamen and longshoremen. Operation of privately-owned deep-bottomed ships would also require large investment and risk. However, success of the latter means of transportation has been established by the one operating limerock company in Alaska.

Cheap transportation rates may be obtained from the tug and barge companies that operate between Pacific Coast ports and Alaska. These companies transport oil products chiefly and return empty. This method offers better and cheaper transportation for the mine operator due to less expense for docking and loading facilities and less investment for large storage bins. The disadvantages of private ownership of tugs and barges are: Expensive operation due to slowness, high risk in navigation losses, and one-way haul. The capital investment for private ownership and operation of tug and barge is considerably less than that required for deep-bottom ships.

Two new means of water conveyance are possible which may apply to this industry with reduced costs. They are the use of LST-type boats and the new-type power scow. LST boats offer many advantages for the transportation of limerock, particularly cheap loading and unloading facilities and would allow for mining at several locations without expensive docking installations. However, the disadvantages would be similar to the operation of deep-bottom ships, since large crews are necessary, cost of ships requires a large investment, and a one-way haul.

Power scow, as used by the U. S. Army in Alaskan waters, appears to offer the cheapest means for the transportation of limerock. Advantages are low-cost individual units, small crews, cheap loading and unloading facilities, and speed of transportation. Risks are much less and a greater degree of flexibility is possible. Expensive dockage and storage facilities are unnecessary.

The steamship and barge rates which are in effect at the present time cannot be applied to the moving of limerock. These rates are high due to government operation during the war, a period of excessive costs and a one-way haul. Definite cost figures of pre-war operation of the one operating limerock company are not available. This company owned and operated its own ship of six to seven thousand ton capacity which, under normal operation, made one trip a week from Dall Island to Seattle. Hodge[*] states that the limerock was said to have been mined, crushed to 1½ inch and less, and loaded on the boat for 40 to 50 cents per ton. Transportation was reported to have amounted to about 90 cents per ton. Since these are pre-war costs, they cannot be applied under post-war conditions.

Post-war ocean transportation costs are figured at one mill per nautical-mile ton by west coast industry where full capacity tonnages are carried. These rates can be applied to limerock, providing large amounts are mined and transported. The transportation of limerock on this basis from southeastern Alaska to Seattle, a distance of 700 miles, means a transportation cost of $0.70 per ton; to Portland, a distance of 900 miles, means a transportation cost of $0.90 per ton, and corresponding costs down the coast according to distances.

*—Bib. No. 19.

Post-war railroad transportation costs are figured on a basis of one cent per ton-mile for large continuous tonnages. Large deposits of high grade limestone occur inland from the Pacific Coast, eastern Washington, eastern Oregon and eastern California, but at distances from 200 to 300 miles from the coast.

The ratio of costs on the above basis is one mile via railroad to ten miles via water. Applying this ratio on distances, with comparative costs, the transportation of limerock from Alaska has a decided advantage.

CALCINING FACTORS AND AVAILABLE FUEL

High calcium limerock produces a high calcium lime when calcined, and this product is used by many industries. The addition of water to lime (CaCO) forms the hydroxide ($Ca(OH)_2$), commonly known as hydrated lime. Some industries require lime in this form. The transportation of lime and hydrated lime was discussed under the section on transportation factors and costs. The transportation of lime and hydrated lime requires facilities which would increase the cost as compared to the transportation of limerock. Lime is subject to air-slake caused by dampness and exposure. There are many conditions in the calcination of limerock applicable to Alaska which may cause economical advantages to overcome the additional transportation costs.

One hundred pounds of limerock produces approximately fifty-six pounds of lime. The reduction in weight is the result of heat driving off the CO_2 gas. Future processes may provide for the collection of this waste gas and it may be considered a by-product; however, at the present time under conditions in Alaska it is not so considered. Lump lime retains the same form and occupies the same amount of space as limerock, but the porosity of the lime is greatly increased. The impurities in a limerock that are not affected by heat remain in the lime without a corresponding reduction of weight. Hence a two-percent silica content in limerock increases to nearly four percent by weight in the lime after burning.

Limerock in the process of calcination requires a temperature of 898° C. Common cheap fuels are utilized such as coal, gas, oil, and wood. The close association of suitable limerock to an available supply of cheap fuel is usually the determining factor in lime kiln location. Wood was used in 79 kilns by 28 operating companies in the United States during the year 1939, according to Bureau of Mines figures.* The total lime production for the same year amounted to 3,300,500 short tons, not including refractory dolomite. The total tonnage produced by wood amounted to 170,505 short tons. Wood is considered generally as the best form of heat for producing lime. Lack of an abundant supply and the high cost of labor accounts for the small lime tonnage produced by this fuel.

Wood is used in two types of lime kilns—the pot-type and the shaft-type. One cord of dried wood yielded sufficient heat to produce, in the pot-type kiln, 4,104.58 pounds or 2.05 short tons of lime, according to the calculated average.† A higher efficiency is obtained in the shaft kiln with one cord of dried wood producing heat sufficient to produce 4,931.94 pounds of lime or nearly 2.5 short tons. The thermal efficiency of wood in pot kilns is 55 percent and is below that of coal and coke. In shaft kilns the thermal efficiency is 66 percent and is above that of coal and oil. Coke and gas have higher efficiency ratings.

The total theoretical heat needed per short ton of high calcium lime is 4,428,000 B.t.u. Bituminous coal has an average heat content of 12,000 B.t.u. per pound or 24,000,000 B.t.u. per short ton. Crude oil contains on an average 6,000,000 B.t.u. per barrel. Dried wood contains 16,500,000 B.t.u. per cord. All wood substances have about the same calorific value of 8,600 B.t.u. per pound of oven-dried wood.*

The only abundant fuel in southeastern Alaska is wood. Coal, oil and gas are practically non-existent. Operation of lime kilns in southeastern Alaska is therefore limited to the use of wood as a local source of fuel. Other means would be the importation of fuels other than wood or the transportation of the limerock to an abundant cheap fuel supply.

All the limestone deposits described in this paper are covered by or are near to abundant timber of average stand. The timber

*—Bib. No. 18.
†—Bib. No. 18.
*—According to Forest Products Laboratory. U. S. Department of Agriculture. Madison. Wis. Direct correspondence.

consists mainly of hemlock and spruce and the average stand, according to the Forest Service, U. S. Department of Agriculture, Juneau, Alaska, amounts to 20,000 board feet or approximately 40 cords per acre. The size ranges from 18 to 40 inches at the butt. Large amounts of wood are readily available on slopes above salt water. Permits are required from the U. S. Department of Agriculture for cutting on other than mining claims, payments for stumpage being approximately $0.50 per cord.* The entire cost of cutting, splitting and transporting wood to kiln in southeastern Alaska on a large scale, utilizing machinery for cutting and transporting, is roughly estimated at $5.00 per cord. The general ratio of bituminous coal to wood on B.t.u. content would be one and a half cords of wood to one ton of coal. The f.o.b. price of coal at the mines of interior Alaska is $7.82. Coal delivered from the mines of interior Alaska to kiln locations in southeastern Alaska would under present rates be prohibitive. Transportation of coal to southeastern Alaska on returning empty lime and limerock ships, barges or scows would only increase the Seattle price by handling charges. Fuel oil handled the same way may, upon investigation, prove to be the cheapest fuel. Combination of fuel oil and wood may be a suitable method.

Since kiln or burning tests have not been made on the limerock investigated in southeastern Alaska, recommendations of certain limerock deposits for ths purpose cannot be made. As there are no operating kilns in Alaska, actual cost figures are not available.

Suitable kiln-burning limerocks are indicated by petrographic analysis in the descriptions of the limerock of each individual deposit. Large crystal or very dense, extremely fine, limerocks are usually unsuitable for burning into lime.

*—According to U. S. Forest Service, Juneau, Alaska.

GENERAL ECONOMIC FEATURES

The high-calcium limerock areas of southeastern Alaska are situated very favorably for salt-water transportation, but are confined to areas where there are no associated industries, power developments or settlements. The exportation of all the limerock is necessary since Alaskan markets are practically nil. The labor supply in the Territory is most uncertain and for that reason most of the employees would have to be imported. Supplies, equipment and materials, other than lumber, will also have to be imported from the States. The locations of deposits described in this paper are near water supplies sufficient for camp and general use. Two hydroelectric power sites are available at the Waterfall Bay limerock deposits on Dall Island. Weather conditions permit all-year operations, and being accessible to salt water, transportation is possible at all times. Winter storms may temporarily halt small craft but would have little effect on larger hulls. Property tax at the present is nil and net income Territorial tax is exceedingly low.

These conditions are favorable to exceedingly low-cost operation providing production is on a large scale. Small-scale operations are not recommended.

GEOLOGIC CLASSIFICATION OF THE LIMEROCK DEPOSITS

The deposits described in this paper range from Pre-Silurian to and including Devonian; however, limerock deposits ranging from pre-Silurian to Tertiary were examined. The investigation disclosed that the high calcium limerock is confined to the Pre-Silurian, the Silurian and Devonian. These formations are not to be confused with the high grade magnesium limerock and dolomite deposits located along the mainland of southeastern Alaska and representing other geological ages.

The Pre-Silurian limerock deposits are situated on Dall, Long and the southern portion of Prince of Wales islands and are contained in the Wales group of schists, volcanics and sediments, according to Buddington.[*] Definite correlation of this group with similar rocks to the north has not been completed. As a result some of the limestones on Long and Dall islands classified as Silurian may be Pre-Silurian and vice versa. The main limerock masses of the Wales group are found in Port Bazan, Gooseneck and Gold Harbors along the west coast of Dall Island, in Coning Inlet and inland from the head of Cleva Bay on Long Island, and the heads of Cholmondeley Sound and Hetta Inlet, Prince of Wales

*—Bib. No. 11.

Island. The limerock of this group was found intruded by underlying diorite and volcanics. On Dall and Prince of Wales islands the limerock was found to be highly altered, in part schistose, and to contain numerous contact minerals and alterations. The deposits of Long Island are of a higher purity but have been invaded with dioritic intrusives near the central portion of the island.

The limerock deposits of the Silurian are the most extensive of any in southeastern Alaska. They have the highest calcium carbonate content, the beds are the thickest—up to 2,000 feet—and they are the most uniform. Seventeen of the limerock analyses (note table) are of Silurian limerock. The Silurian is abundantly distributed among the islands of the west coast, extending from Dall Island to Glacier Bay. Three wide belts of Silurian formations, with enclosed thick beds of high calcium limerock, are found on Dall Island. The south belt extends from Howkan, on the east shore, northwesterly to Waterfall Bay. The middle area extends from View Cove on the east coast to Sea Otter Harbor on the west coast. The north belt extends from Breezy Bay across to Diver Bay on the west coast. Kosciusko, Heceta, Marble, Orr and Tuxekan islands consist mainly of Silurian sediments with extensive beds of limerock, portions of which are marbleized. The northern half of Prince of Wales Island contains wide belts of Silurian sediments. The larger islands of the Kashevarof group in Clarence Straits are made up mainly of Silurian limerock. A wide belt follows the west shore of Saginaw Bay on the north end of Kuiu Island. Other occurrences are known along the west coast of Admiralty Island, the east coast of Chichagof Island and Glacier Bay. Lack of suitable harbors and unfavorable mining conditions have disqualified these three occurrences.

The Silurian limerocks were found to be highly crystallized along some of the contacts, particularly the diorites and greenstones or lavas. Some areas contain lava dikes and sills. Marble is found near the contacts of the main masses of lavas which readily give way to semi-crystalline limerock 100 or 200 feet from the contact. From the semi-crystalline rock the gradation is into limerock with variable degrees of crystallization. Heat with some pressure appears to have been the cause of the marbleization rather than direct introductive solutions. As a result the recrystallization near the contacts has to a certain degree caused the limerock to lose some of the impurities and in many instances the color. Near the contacts in the marbleized zones impurities such as ferrous iron, iron oxides and others have given colored shades to the marbles.

The Silurian limerock ranges from very finely crystalline to semi-crystalline and marble. The deposits are generally found massive and dense. However, some are distinctly layered, resembling shale, while others resemble argillites in appearance. The prevailing color is bluish gray and gray to white on fresh surfaces. The weathered surfaces range from bluish gray through buff to light brown. The light colored varieties were found in many instances to be the most fractured, with the bluish gray to gray the most massive. Other than some of the white strata in the mableized zones, the bluish gray limerock was found to have the highest calcium carbonate content.

Few fossils were found in the Silurian limerock. According to Buddington[1], the limerock of the Silurian is classified as Middle Silurian and identified from graptolites in the lower slates.

The important features of the Silurian limerock are the prevailing high calcium content, and the great thickness and uniformity of the beds. Limerock of this age offers the greatest amount of high calcium rock in southeastern Alaska.

The next in order, according to geological sequence, are Devonian formations which contain limerock. Extensive Devonian sediments are found in the central portion of Prince of Wales Island, north end of Dall Island, Sukkwan Island, the islands of San Alberto Bay in the vicinity of Klawak, islands of Kasaan Bay, and in the vicinity of Duncan Canal on Kupreanof Island. Limerock of this age was found to be of the high-calcium type and apparently ranges next in line to the Silurian as a source of high grade limerock. While good average grades of high-calcium limerock were determined to exist in Duncan Canal along the bluffs on the west shore, the unfavorable transportation features disqualify these deposits. The limerock of the islands in San Alberto Bay is more favorable for transportation. The larger island of the group furnished a very favorable analysis (Sample No. 13).

[1]—Bib. No. 11.

The Devonian limerock is extremely fine grained and occurs massive. The color ranges from light grayish brown to gray and weathers to a grayish brown. The beds were found to be variable in thickness, ranging from narrow up to 600 feet. The area of maximum thickness was noted on the islands in San Alberto Bay.

The Carboniferous formations contain many occurrences of limerock in southeastern Alaska. The greater number are situated on the mainland and in close contact to the coast batholith, extending from the Ketchikan district to the head of Lynn Canal. These mainland deposits have been subjected to the metamorphic influences of the batholith, with the limerock mainly recrystallized to marbles and containing high percentages of magnesium. High purity magnesium limerock and dolomites are found both in the Carboniferous and the Triassic sediments along the marginal belt of the coast batholith.

Carboniferous limerock occurs along the west coast of Prince of Wales Island in the vicinity of Klawak, on Kuiu Island on the northeast shore of Saginaw Bay, and on some of the Keku islands in Keku Strait.

Generally, the Carboniferous limerock is fossiliferous, cherty zones are common, and silica as veinlets and fractures frequently occurs. The color ranges from nearly white, shades of gray and buff to dark gray and black. Samples from the Saginaw Bay area on Kuiu Island indicate a high percentage of impurities.

Limerock deposits of the Triassic were investigated on Point Cornwallis, Kuiu Island, Hamilton Bay on Kupreanof Island, Gravina Island, and at Thomas Bay on the mainland. The beds were found to be narrow and interbedded with slate and shale. Visual inspection shows impurities which, together with unfavorable mining conditions, disqualified these deposits as a class. Former analyses generally show high magnesium content.

Limy shales and sandstones occur in the small Tertiary areas in southeastern Alaska. Such areas are found on Zarembo, Kupreanof, Kuiu and Admiralty islands. Visual inspection shows these formations to be exceedingly low in calcium carbonate content.

METHOD OF SAMPLING

Samples of limerock, as indicated by analyses shown in this paper, were taken across massive beds of limestone varying in thickness from 150 feet to over 2,000 feet. Small pieces were chipped from outcroppings at irregular intervals across the thicknesses indicated. The size of these samples varied according to widths of deposits and ranged from 15 to 30 pounds in weight. A portion of each sample contained weathered surfaces. Weathered surfaces usually contain greater percentages of insolubles than the unweathered portion of the parent rock, with a decreasing ratio according to the purity of the limerock. Therefore, these analyses may indicate an insoluble content slightly higher than the true content of the body in general.

Samples taken from outcrops also are not indicative of the loose soil which covers to some extent all the deposits. In open quarry mining using mechanical loading, unless very special preparations are made, the soil covering works into the limerock as an impurity. Selective underground mining eliminates both the subsoil and surface weathering sources of impurities.

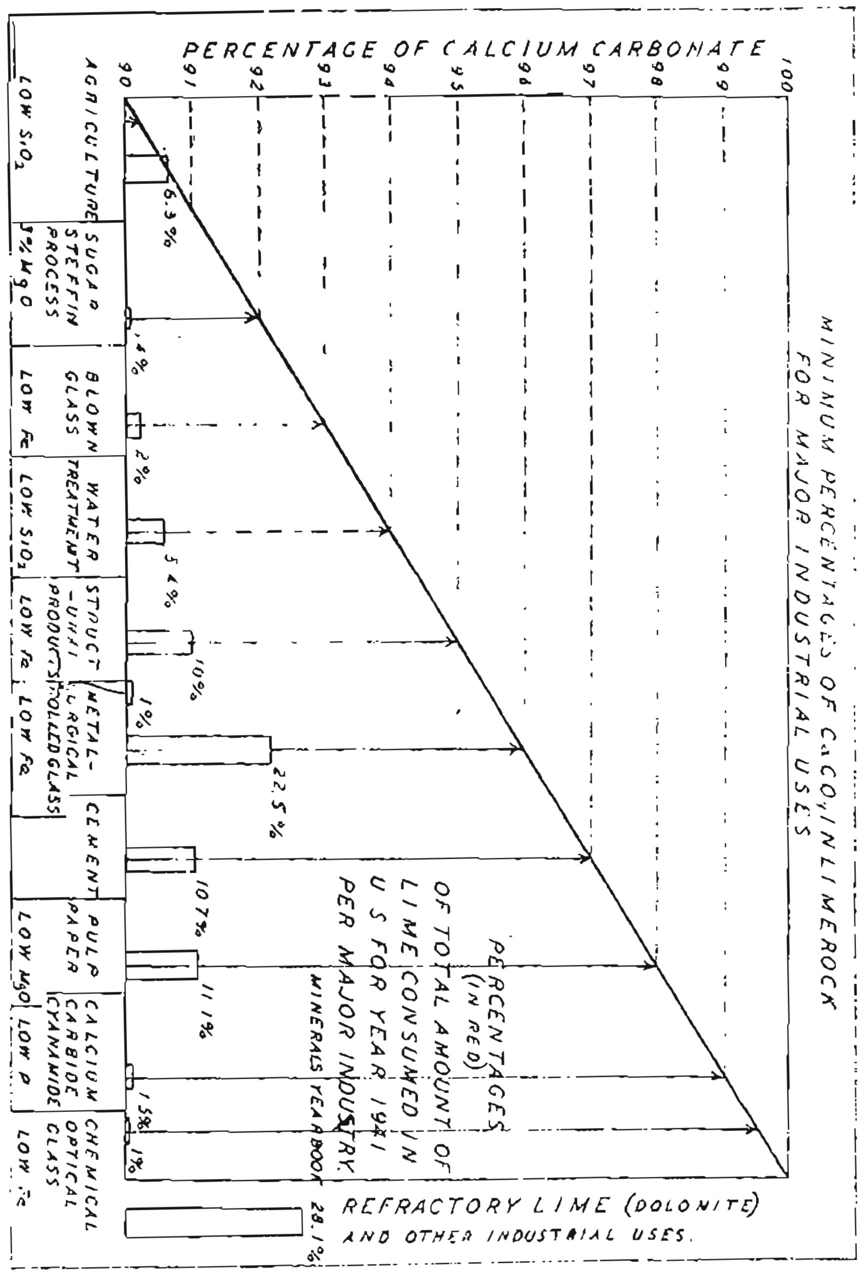
Since the purpose of this paper is to indicate minable bodies of limerock of the high calcium type, the amount of sampling is not sufficient to be representative of the minable tonnage estimates given. Considerably more surface sampling, followed by diamond drilling, is recommended to definitely determine average analyses of these deposits.

All samples were analyzed at the Territorial Assay Office, Ketchikan, Alaska, by Nils Johansson, Assayer.*

*—Formerly employed as chemist for Superior Portland Cement Co., Concrete, Washington.

MAJOR INDUSTRIAL USES OF LIMEROCK

The accompanying graph indicates in percentages the amount of calcium carbonate required in a limerock for the major industrial uses, and also the percentage of lime used by each industry in the United States for the year 1941 as shown by Bureau of Mines Minerals Yearbook, 1942, as distributed among the major industries.


PERCENTAGE OF CALCIUM CARBONATE
90
91
92
93
94
95
96
97
98
99
100
MINIMUM PERCENTAGES OF $CaCO_3$ IN LIMEROCK FOR MAJOR INDUSTRIAL USES
PERCENTAGES (IN RED) OF TOTAL AMOUNT OF LIME CONSUMED IN U S FOR YEAR 1941 PER MAJOR INDUSTRY. MINERALS YEAR BOOK
AGRICULTURE
LOW SiO_2
6.3%
SUGAR STEFFIN PROCESS
3% MgO
.4%
BLOWN GLASS
LOW Fe
2%
WATER TREATMENT
LOW SiO_2
5.4%
STRUCT-URAL PRODUCTS
LOW Fe
10%
METAL-LURGICAL
1%
ROLLED GLASS
LOW Fe
22.5%
CEMENT
10.7%
PULP PAPER
LOW MgO
11.1%
CALCIUM CARBIDE CYANAMIDE
LOW P
1.5%
CHEMICAL OPTICAL GLASS
LOW Fe
1%
REFRACTORY LIME (DOLOMITE) AND OTHER INDUSTRIAL USES.
28.1%

The ideal limerock deposit would be one that meets all industrial demands in regard to calcium carbonate content. However, a limerock must also meet with physical and economic, as well as chemical, requirements in order to be an ideal rock for industrial use. Specifications for a limerock for each industrial use vary. Further, limestone deposits vary within their own masses both in chemical and physical properties. High chemical grade limerocks (99% + $CaCO_3$) are usually highly crystalline marbles, where the natural process of recrystallization of limerock to marble has eliminated the greater portion of impurities. Highly crystalline marbles are usually unfit for lime burning due to decrepitation and degradation. Such limerock is in demand by many chemical industries. However, the percentage of total amount used (Note graph) is low in comparison with other industrial uses.

Alaskan production will necessarily be on a large scale—300,000 to 500,000 tons annually—in order to maintain low production and transportation costs. The limerock deposits of southeastern Alaska, to be put on an economic competitive basis with those of the Pacific Coast, will require extensive reserves of a consistently uniform grade and must be of sufficient purity to meet all the large industrial uses.

The chemical and physical requirements of the six largest consuming industries; i.e., metallurgy, agriculture, water treatment, pulp and paper, building structure and cement, and glass, are: Calcium carbonate content of 96 to 98 percent, one percent or less of magnesium carbonate, one percent or less of silica, less than one-half percent iron oxide and less than one percent of all others. Some industries require calcination of limerock before it is used. The writer is of the opinion that great tonnages of limerock suitable for burning, and of consistent chemical qualifications as outlined above, are readily accessible to ocean-going vessels in southeastern Alaska.

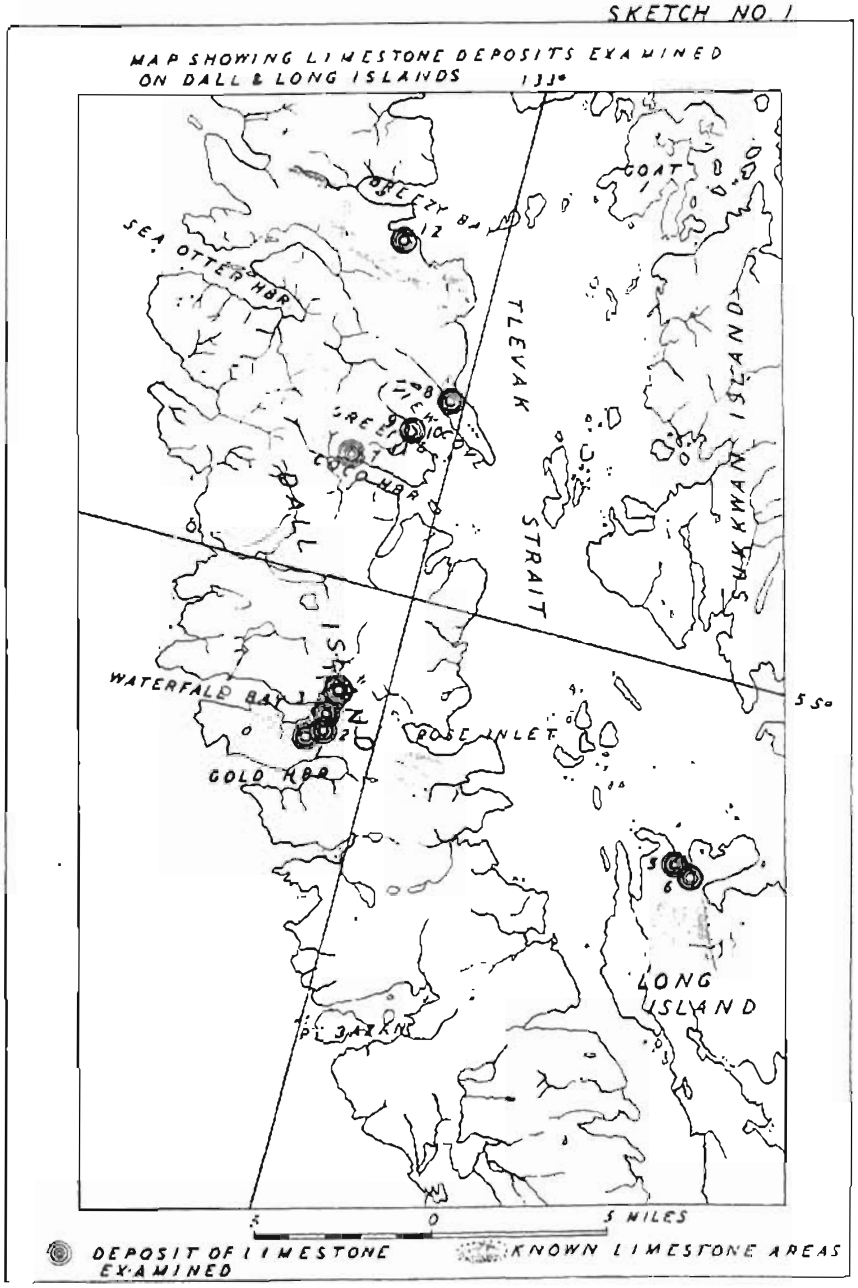
ANALYSES OF SAMPLES FROM LIMESTONE DEPOSITS INVESTIGATED IN SOUTHEASTERN ALASKA DURING 1945

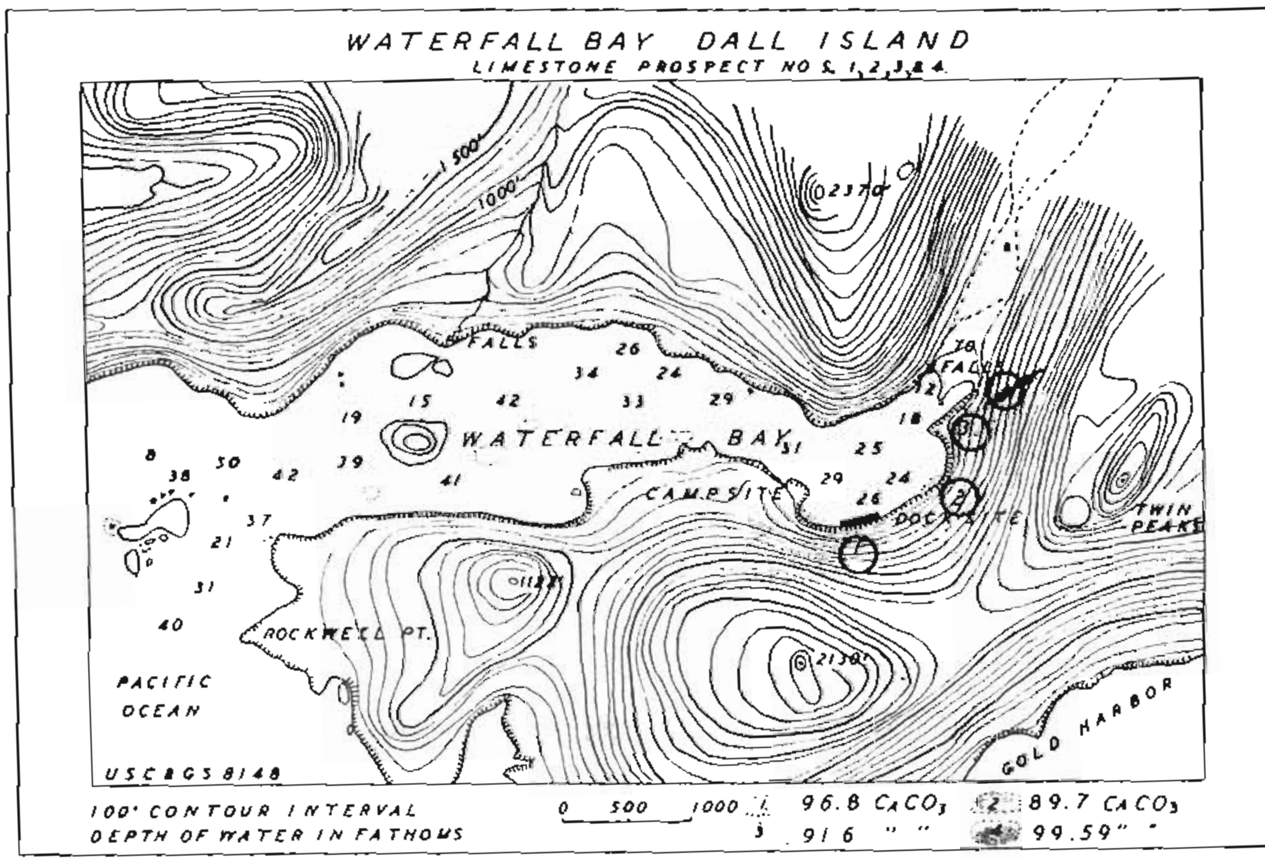
Deposit No.	Sketch No.	Locality	$CaCO_3$	$MgCO_3$	Insol.	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	S
1	1 & 6	SE. shore—head of Waterfall Bay, Dall Island	96.8	2.6	0.27	54.4	1.24	0.05	0.08	.004	.017
2	1 & 6	E. shore—head of Waterfall Bay, Dall Island	89.7	9.7	0.44	50.2	4.6	0.12	0.13	.002	.024
3	1 & 6	E. shore, point—head of Waterfall Bay, Dall Island	91.6	6.2	0.41	51.3	2.95	0.15	0.33	.010	.37
4*	1 & 6	Inland—E. shore Waterfall Bay at head	99.59	1.03	0.32						
5	1 & 7	W. shore Cleva B., Long I.—top stratum	96.0	2.46	0.94	53.8	1.17	0.11	0.23	.001	.031
6	1 & 7	Do.—under stratum	97.8	1.00	0.20	54.8	0.48	0.06	0.08	.002	.011
7	1 & 8	N. shore Coco Harbor, Dall I.	96.1	1.9	1.90	53.8	0.9	0.12	0.26	.033	.037
8	1 & 8	View Cove, N. shore, Dall I. Quarry of Superior Portland Cement Co.	96.6	1.13	0.62	54.1	0.54	0.12	0.38	.005	.033
9	1 & 8	Mouth of Green Cove, S. shore, View Cove, Dall I., 150′ width	97.6	1.4	0.99	54.7	0.68	0.13	0.08	.020	.028
10	1 & 8	Do.—additional 150′ S.	95.84	1.76	2.20	53.7	0.84	0.09	0.05	.019	.014
11	1 & 8	Do.—300′ S. of No. 10 across 150′ belt	96.37	1.38	1.23	54.0	0.66	0.13	0.19	.028	.010
12	1 & 9	Breezy B., S. bay, S. side Dall I.	96.0	2.26	0.83	53.8	1.08	0.09	0.07	.005	.009

*- Bib. No. 9 -U. S. G. S. marble sample.

13	2 & 10	Wadleigh I., San Alberto group, San Alberto B.	97.44	1.21	0.44	54.6	0.58	0.06	0.14	.001	.052
14	2 & 11	Port Alice, W. side, N.W. end of Heceta I.	92.0	5.4	0.66	51.5	2.57	0.09	0.11	.013	.011
15	2 & 12	N. side Heceta I. opposite largest island, N. end	93.34	1.9	3.45	52.3	0.91	0.16	0.35	.012	.094
16	3 & 13	Calder marble quarry, Shakan B., P. W. I.	97.6	1.27	0.06	54.7	0.61	0.04	0.02	.008	.017
17	3 & 13	Calder B., E. shore, Prince of Wales I.	88.17	9.17	0.33	49.4	4.39	0.09	0.11	.013	.008
18	3 & 14	Exchange Cove, P. W. I.	95.5	1.7	0.47	53.5	0.81	0.14	0.12	.011	.013
19	3 & 15	Mud B., NW. end of Shrubby I., Clarence Strait	95.48	1.05	1.48	53.5	0.50	0.44	0.18	.016	.040
20	3 & 15	Piledriver B., E. side Shrubby I.	94.6	3.57	0.54	53.0	1.70	0.40	0.10	.015	.028
21	4 & 16	Saginaw B., W. side, Kuiu I.	96.7	0.63	1.03	54.2	0.30	0.21	0.12	.011	.010
22	4	Saginaw B., E. side	23.40	5.90	67.0	13.1	2.82	(2.7) (combined)			
23	5	Little Duncan, Duncan Canal, Kupreanof I.	93.23	4.7	0.32	52.2	2.24	(1.07)		.287	.050

SKETCH NO. 1


MAP SHOWING LIMESTONE DEPOSITS EXAMINED
ON DALL & LONG ISLANDS
133°
BREEZY BAY
SEA OTTER HBR
TLEVAK
STRAIT
GOAT I
SUKKWAN ISLAND
DALL
ISLAND
WATERFALL BAY
GOLD HBR
ROSE INLET
LONG
ISLAND
55°
5 0 5 MILES
DEPOSIT OF LIMESTONE
EXAMINED
KNOWN LIMESTONE AREAS


WATERFALL BAY DALL ISLAND
LIMESTONE PROSPECT NOS. 1, 2, 3, & 4.
WATERFALL BAY
FALLS
CAMPSITE
DOCK SITE
TWIN PEAKS
ROCKWELL PT.
PACIFIC OCEAN
GOLD HARBOR
1500'
1000'
2370'
1127'
2130'
USC&GS 8148
100' CONTOUR INTERVAL
DEPTH OF WATER IN FATHOMS
0 500 1000
1. 96.8 CaCO3
2. 89.7 CaCO3
3. 91.6 " "
4. 99.59" "

SKETCH NO 6.

THE DEPOSITS

Nos. 1, 2, 3 and 4 — Sketches Nos. 1 and 6:

Waterfall Bay, Dall Island.

East and South portions at head of Bay.

4000-yd. beach outcrop.

2000' — estimated thickness.

200,000,000 tons estimated within 1-mile radius.

Chemical Analyses

Sample No.	Width & Wt. of Sample	Location and Color	$CaCO_3$	$MgCO_3$	Insol.	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	S
1	25 lbs. across 500'	SE. shore head of bay — Dark blue gray	93.8	2.6	0.27	54.4	1.24	0.05	0.08	.004	.017
2	30 lbs. across 800'	E. shore at head—Light gray to mottled	89.7	9.7	0.44	50.2	4.6	0.12	0.13	.002	.024
3	20 lbs. across 500'	NE. shore of bay at head next to marble—Bluish white mottled semi-crystalline	91.6	6.2	0.41	51.3	2.96	0.16	0.33	.010	.37
4[a]		NE. section of bay. Marble section—White crystalline marble	99.59	1.03	0.32						

[a]—Bib. No. 9—U. S. G. S. marble sample.

Sample No. 1:

Description and classification—

Dark bluish gray, massive, dense and fine crystalline rock.

Contains a few narrow lava dikes as filled fractures 200' - 300' apart.

Fractures easily and is hard; slightly friable.

Contains a few white calcite spots.

Weathers to dull bluish gray; weathers even and smooth faced.

Specific gravity—2.70.

Petrographic analysis—The groundmass of this limerock consists of fine anhedral grains of calcite of an average size of 0.01 mm. and making up 60 percent of the volume. In this matrix are contained larger twinned calcite subhedral grains of an average size of 0.033 mm. These larger grains comprise 15 to 20 percent of the volume. The remaining 15 to 20 percent of volume is made up of dark carbon matter, 2 percent dolomite and traces of iron oxides, traces of silica, and extremely fine calcium carbonate is indicated along flow lines.

The larger calcite grains show twinning and wavy extinction. The dolomite shows zoned crystalline structure and apparently a secondary recrystallization. Flow lines were noted along minute veinlets.

Economic uses recommended—Chemical and physical analyses of the limerock indicate qualifications for metallurgical, cement, structural products, water treatment and agricultural uses. The magnesium and phosphorous content disqualifies it for the pulp and paper and calcium carbide industries.

Sample No. 2:

Description and classification—

Light gray to nearly white—slightly mottled in color.
Thinly laminated and shows stress.
Weathers unevenly in bands, to smooth surfaces, to light buff colors.
Bedding indicated.
Easily fractured and very friable.
Extremely fine grained and easily crushed.
Uniform for over 2000′ exposure along shore.
Specific gravity—2.68.

Petrographic analysis—The groundmass of this limerock is made up of 90 percent of extremely fine anhedral calcite grains of even size ranging from 60 to 160 microns. Scattered larger sized dolomite grains and crystals were noted. A small amount of wavy extinction was noted indicating pressure together with scattered streaks of carbonaceous matter.

Economic uses recommended—Chemical and physical analyses of this limerock indicate a combination of calcium and magnesium correctly balanced and nearly free from impurities for use as agricultural limerock and lime.

Sample No. 3:

Description and classification—

Bluish white mottled and semi-crystalline.
Grades into marble.
Shows rough uneven weathering as veinlets and to dull bluish gray color.
Banded nature.
Specific gravity—2.60.

Petrographic analysis—This rock shows a degree of marmarosis with the recrystallization of extreme fineness. The recrystallized grains range in size from 30 to 100 microns, averaging 60 microns. Dolomite amounting to over 5 percent contains some of the carbonaceous material which together produce the mottled coloring effect. Magnetite and iron stains as accessories occur less than 1% of volume.

Economic uses recommended—Chemical and physical analyses indicated a suitable limerock for both raw limerock and lime for agricultural purposes. Crystalline nature indicates low crushing and grinding costs.

Sample No. 4:

Description and classification—

Finely crystalline white marble—banded and narrow width associated with colored marbles. Chemical grade and suitable for those chemical industries using raw limerock.
Probable high friability when calcined.

Petrographic analysis—None made.

Economic uses recommended—Industrial chemical use including pulp and paper, lime-burning qualities uncertain.

Geological and Topographical Relations:

Age—Silurian and Pre-Silurian (?).

Position—Formation rises immediately from beach line, 40% slope, to 1000′ to 1500′. Main mass rises to elevation 2100′.

Structure—Strike NW. to SE.—Dip variable to NE. and North.

Relations—Deposit overlain by greenstone lava. Base rests with conglomerate 70′ to 100′ thick on diorite. Marbleized zone underlies lava cap 200′ to 400′ thickness. Lava dikes, as filled openings in fractures in limestone, most abundant in upper portion.

Overburden—Heavy timber growth with slight amount of subsoil.

Mining Methods Applicable:

Underground cave method utilizing gravity.
Quarry method with high backs.
Uniform width of variable grades 500′ to 1000′.

Accessibility to Dock and Harbor Facilities:

Adjacent to shore line on 10 to 20 fathoms of water.
Harbors for large and small ships—protected.
Load direct with elevator belts from underground storage.
Concrete dock recommended. Bedrock bottom.
Average water depth over 20 fathoms in bay.

Water Power and Supply:

Natural waterfall at head of bay—70′ fall ¼ mile of limestone deposits.
Large drainage area to excellent dam site—possible capacity 100-300 HP.
Natural fall—unmeasured—2½ miles from deposit, possible 100-200 HP. development.
Camp water supply adequate.

Camp Site:

Two available at head of bay—northeast corner at power site; southeast corner at head.

Available Fuel:

Heavy growth of spruce and hemlock—adequate lumber and kiln fuel.

Estimated costs on 1000-ton daily production delivered 1½″ size to Pacific Coast ports 30% over pre-war cost figures.

Mining	.40
Crushing	.15
Loading	.10
	.65
Unloading	.10
	.76

Miles at 0.001 per ton-mile		Total
780 to Seattle	.78	1.53
900 to Portland	.90	1.65
1350 to Eureka, Cal.	1.35	2.10
1600 to San Francisco	1.60	2.35
1990 to San Pedro	1.99	2.74

Nos. 5 and 6—Sketches Nos. 1 and 7

Cleva Bay—Long Island.

North end of Long Island—west side of bay.

2000-yd. outcroppings 300′ from beach.

432,000,000 tons—1-mile radius of dock site, above sea level.

28,000,000 tons of 97 + $CaCO^3$ content.

Chemical Analyses

Sample No.	Width & Wt. of Sample	Location and Color	$CaCO_3$	$MgCO_3$	Insol.	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	S
5	30 lbs. across 1000′	Hill due West of Cleva Bay—Bluish gray	95.3	2.46	0.94	53.8	1.17	0.11	0.23	.001	.031
6	10 lbs. across 300′	W. shore Cleva B.—Light bluish white	97.8	1.00	0.20	54.8	0.48	0.06	0.08	.002	.011

Sample No. 5:

Description and classification—

Streaked dark bluish gray, massive, fine crystalline and dense.

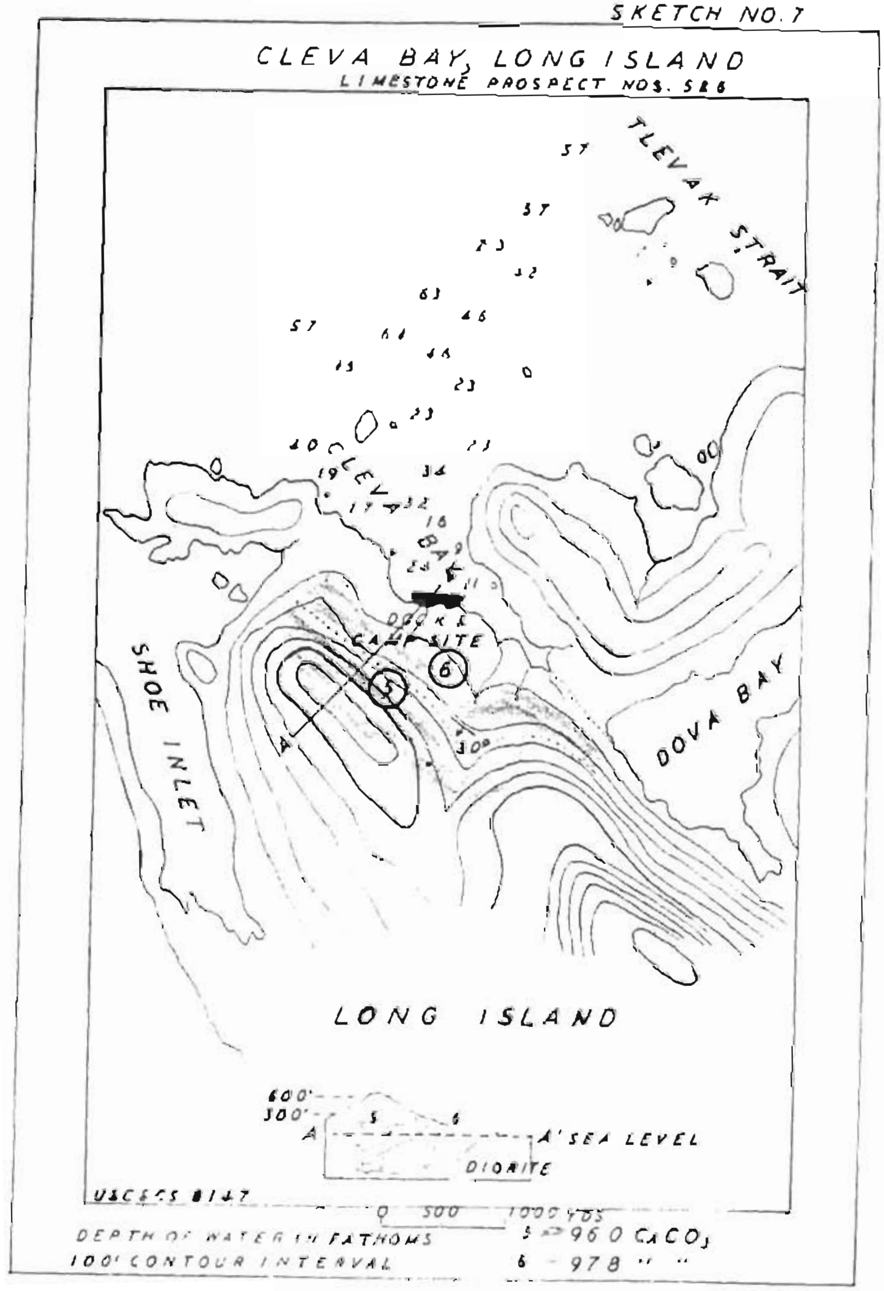
Slightly friable—fractures easily.

Grades from dark at top to lighter at bottom.

Weathers to light bluish dull gray—even smooth surfaces.

Specific gravity—2.70.

SKETCH NO. 7


CLEVA BAY, LONG ISLAND
LIMESTONE PROSPECT NOS. 5 & 6
TLEVAK STRAIT
CLEVA BAY
DOCK & CAMP SITE
SHOE INLET
DOVA BAY
LONG ISLAND
A'SEA LEVEL
DIORITE
USC&GS 8147
0 500 1000 YDS
DEPTH OF WATER IN FATHOMS
100' CONTOUR INTERVAL
5 = 96.0 CaCO3
6 - 97.8 " "

Petrographic analysis—The groundmass of this rock is extremely fine grained with 90 percent of the volume ranging from 3 to 6 microns in size and consisting of calcite grains. A larger grain size of calcite averaging 15 microns and showing considerable strain and wavy extinction makes up over 5 percent of the volume. Dolomite grains make up 2-3 percent. Impurities noted were carbonaceous matter, traces of iron oxide, occasional gypsum crystals, and quartz grains .1 to .2 mm. in size.

Economic uses recommended—Chemical and physical analyses indicate metallurgical and agricultural uses for this rock. The extremely fine nature of the grains and comparative denseness indicate doubtful burning qualities for lime.

Sample No. 6:

Description and classification—

Light bluish gray to nearly white—mottled crystalline luster.
Easily fractured and slightly friable.
Bedding evident.
Uniform massive band.
Specific gravity—2.70.

Petrographic analysis—Sixty percent of this rock has been recrystallized and consists of calcite grains .15 to .3 mm. in size. These are enclosed in a matrix of fine cloudy calcite with grain size ranging from 60 to 100 microns. The large crystals are twinned and show wavy extinction indicating considerable strain. Bent or curved calcite crystals are common. Dolomite was the only impurity noted.

Economic uses recommended—Chemical and physical analyses indicate nearly a chemical grade rock. Suitable for pulp and paper and agricultural purposes. Physical characteristics make suitability for lime burning doubtful.

Geological and Topographical Relations:

Age—Silurian or Pre-Silurian (?).

Position—Sample No. 5—Above 250′ contour overlying stratum. Sample No. 6—Beach to 25′ elevation—Note Sketch No. 7. Upper band rises to 600′ elevation near beach—1250′ toward interior of island. Lower band sea level to 250′ elevation.

Structure—Strike NW.-SE.—Dips 30 SW.

Relations—Base of limestone rests on a schist of dioritic composition—unconformable—covered to west by Silurian sediments. Semi-crystalline but massive at base. No intrusive evidence noted in vicinity—probable in interior of island.

Overburden—Heavy timber—benches contain a few feet of subsoil—not extensive.

Mining Method Applicable:

Open-cut quarry method with 100′ to 600′ face.

Accessibility to Dock and Harbor Facilities:

Floor of quarry at 50-foot elevation, 300 feet back from beach.

Requires trestle on rock grade.

Harbor for large and small ships—protected.

Pile dock possible—concrete dock recommended.

Dock would require bunker facilities for quick loading of large vessels.

Average depth of water from dock to mouth of bay 20 fathoms.

Water Power and Supply:

Water power—none.

Camp water supply adequate at camp site.

Camp Site:

Level strip along beach 300′ wide, 5′-10′ above high tide level—central western side of Bay.

Available Fuel:

Adequate timber for lumber and fuel—heavy growth of spruce and hemlock.

Estimated costs on 1000-ton daily production delivered

1½" size to Pacific Coast ports 30% over pre-war cost figures.

Mining	.40
Crushing	.15
Loading	.10
	.65
Unloading	.10
	.75

Miles at 0.001 per ton-mile		Total
770 to Seattle	.77	1.52
890 to Portland	.89	1.64
1340 to Eureka, Cal.	1.34	2.09
1590 to San Francisco	1.59	2.34
1980 to San Pedro	1.98	2.73

No. 7—Sketches Nos. 1 and 8

Coco Harbor, Dall Island.
Outcrops along shore line—north shore at head.
1000-ft. beach outcrop.
200′ thickness—sample 150′
3,000,000 tons estimated within 1-mile radius.

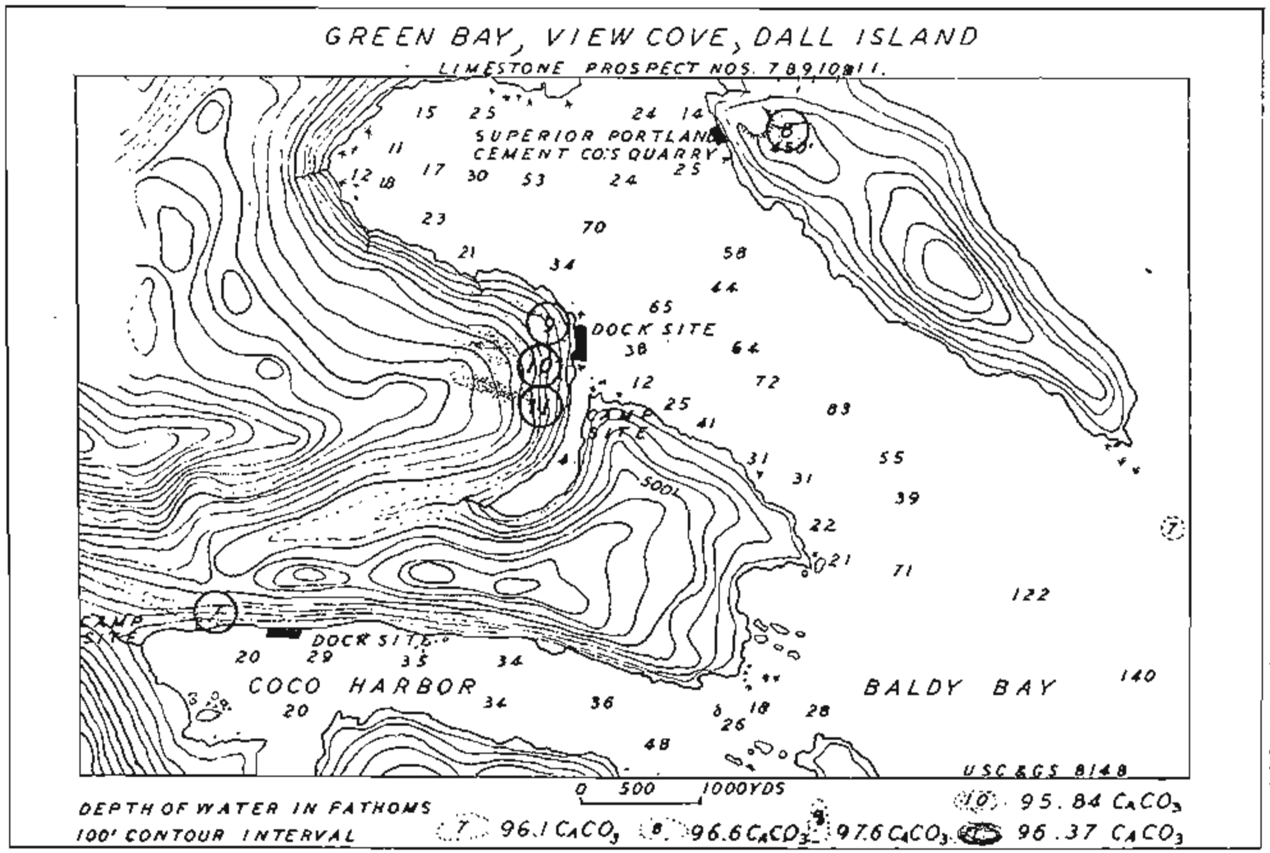
Chemical Analysis

Sample No.	Width & Wt. of Sample	Location and Color	$CaCO_3$	$MgCO_3$	Insol.	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	S
7	150′ 15 lbs.	North shore head of bay—Buff	98.1	1.9	1.9	53.6	0.9	0.12	0.26	.033	.037

Description and classification—

Chalky white to light gray—occasional fine brownish streaks.
Dense and chalky nature—extremely fine grained.
Soft and friable—slightly iron stained in small spots only.
Marbleized along footwall.
Weathers to buff color.
Specific gravity—2.68.

Petrographic analysis—The matrix of this rock consists of interlocking anhedral grains of calcite ranging in size from 130 microns up to 0.6 mm. Sixty percent range from 130 microns up to 300 microns, 20 percent range from .13 mm. to .3 mm., and 10 percent range from .3 mm. to .6 mm. Three percent of the volume consists of very fine calcium carbonate, dolomite, pyrite, and silica grains.


GREEN BAY, VIEW COVE, DALL ISLAND
LIMESTONE PROSPECT NOS. 7 8 9 10 & 11.
SUPERIOR PORTLAND CEMENT CO.'S QUARRY
DOCK SITE
CAMP SITE
DOCK SITE
CAMP SITE
COCO HARBOR
BALDY BAY
500'
USC&GS 8148
0 500 1000 YDS
DEPTH OF WATER IN FATHOMS
100' CONTOUR INTERVAL
7 96.1 CaCO3
8 96.6 CaCO3
9 97.6 CaCO3
10 95.84 CaCO3
11 96.37 CaCO3

SKETCH NO. 8

Economic uses recommended—Chemical and physical analyses recommend this limerock for cement, agricultural and metallurgical uses. Burning qualities are doubtful for manufacture of lime due to grain sizes and crystalline nature.

Geological and Topographical Relations:

Age—Silurian or Pre-Silurian (?).

Position—50'-500' bluffs on beach to 500' elevation.

Structure—Strike slightly north of west—dips steeply to south.

Relations—Limestone stratum 200' thick.
Hanging-wall rather impure—few feet in width.
Foot-wall marbleized—few feet in width.
150' center good quality.
Schist hanging-wall and foot-wall.
Small lava filled fractures along foot-wall.

Overburden—Timber growth—subsoil and light talus.

Mining Methods Applicable:

Open quarry—face 50' to 400'.
Selective method center of stratum 150' wide.
Underground method for selective mining recommended.

Accessibility to Dock and Harbor Facilities:

50' bluff—50' back from high tide line.
20 fathoms water 300' from beach.
Pile or concrete dock.
Excellent harbor for large or small boats.
Excellent site for barge or power scow loading.
Average depth of water in bay over 20 fathoms.

Water Power and Supply:

Water power—none.
Good supply of water at camp site head of bay.

Camp Site:

Good location head of bay adjacent to deposit.

Available Fuel:

Heavy growth of spruce and hemlock.

Estimated costs on 1000-ton daily production delivered 1½″ size to Pacific Coast ports 30% over pre-war cost figures.

Mining	.40
Crushing	.15
Loading	.10
	.65
Unloading	.10
	.75

Miles at 0.001 per ton-mile		Total
790 to Seattle	.79	1.54
910 to Portland	.91	1.66
1360 to Eureka, Cal.	1.36	2.11
1610 to San Francisco	1.61	2.36
2000 to San Pedro	2.00	2.75

No. 8—Sketches Nos. 1 and 8

View Cove, Dall Island—Superior Portland Cement Co. quarry.

North shore of View Cove—2 miles from mouth.

Beach outcrop.

2000′ thickness.

25,000,000 tons above sea level radius 1 mile of plant.

Chemical Analysis

Sample No.	Width & Wt. of Sample	Location and Color	$CaCO_3$	$MgCO_3$	Insol.	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_6	S
8	40 lbs. across face of quarry	Quarry—Dark and shades of light bluish gray	96.6	1.13	0.62	54.1	0.54	0.12	0.38	.005	.033

Description and classification—

Four grades of limerock—designated by color:

1. Dark bluish gray—150′ width quarry face.

   Highest grade in $CaCO^3$—shaly appearance—softest of 4 grades. Fine grained.

   Contains minor seams of white calcite.

   Thinly laminated and bedded.

   Shows evidence of folding.

   Weathers to gray—smooth surface.

2. Light bluish gray.
   Hard—breaks with semi-conchoidal fracture.
   Extremely fine grained.
   Fractures easily—slightly friable.
   Weathers to dull light gray.

3. Light bluish gray—mottled—buff colored seams.
   Schistose fracture system.
   Hard and friable.
   Semi-crystalline.
   Fractures easily.
   Weathers to buff gray—light.

4. Pale bluish gray to white.
   Resembles white marble.
   Hard—contains visible calcite crystals.
   Friable—fractures semi-conchoidal.

Average specific gravity—2.68.

Petrographic analysis—The groundmass of this limerock is extremely fine and uniform in size ranging from 5 to 15 microns. A few larger calcite crystals of variable size and subhedral form make up 5 percent of the groundmass. Large crystals of dolomite occur sparsely, making up 1 to 3 percent of the volume and confined to fractures and veinlets. Carbonaceous matter makes up the greater portion of the dark material and gives the limerock its bluish gray color. One percent disseminated pyrite was noted, indicating low iron and sulphur.

Economic uses recommended—This rock has been utilized in the manufacture of Portland cement. Other industrial uses are agricultural, water treatment, structural and metallurgical, depending upon its burning qualities.

Geological and Topographical Relations:

Age—Silurian.

Position—Occupies point north side of View Cove. In contact with Devonian lavas and breccias to the west. Deposit extends from sea level to 700′ elevation.

Structure—Formation strikes northwest and steeply inclined or nearly vertical in dip.

Relations—Geological relation is not known due to both contacts in water. Devonian lavas to west apparently covered formations. Lava dike with low dip to south exposed in quarry face.

Overburden—Heavy stand of timber and small amount loose rock and soil.

Mining Methods:

Open quarry method used.
75′ to 135′ face across width of 400′.
40′ section blasted across face of quarry utilizing 6″ churn drill holes at 20′ intervals and powder drift at base of face.
50-B shovel using 1¾-yard bucket which dumps into steel cars on track to crusher.
Four grades of limerock mined.
Very favorable for selective mining.

Accessibility to Dock and Harbor Facilities:

Quarry to crusher 1200′; crushing plant into 9000-ton underground storage bin.
Underground storage to pile dock by series of elevator belts.
Average water depth over 20 fathoms.

Water Power and Supply:

No water power—salt water used in mining operations—camp supply of water very limited.

Camp Site:

Favorable.

Available Fuel:

Heavy growth of spruce and hemlock.

Operating and Transportation Costs:

See Bib. No. 19.

Nos. 9, 10 and 11—Sketches Nos. 1 and 8

Mouth Green Bay, View Cove, Dall Island.

Steep walled—favorable mining sites.

Central portion of wide massive limestone structure 1500 + ft. thickness.

100,000,000 tons within 1-mile radius.

Chemical Analyses

Sample No.	Width & Wt. of Sample	Location and Color	$CaCO_3$	$MgCO_3$	Insol.	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	S
9	15 lbs. across 150′ band	Mouth of bay, W. side — Dark gray to nearly black	97.6	1.4	0.99	54.7	0.68	0.13	0.08	.020	.028
10	15 lbs. across 150′ band	200′ S. sample 9—Dark gray	95.84	1.76	2.20	53.7	0.84	0.09	0.05	.019	.014
11	15 lbs. across 150′ band	300′ S. Sample 10—Dark gray	96.37	1.38	1.23	54.0	0.66	0.13	0.19	.028	.010

Sample No. 9:

Description and classification—

- Nearly black color—thinly laminated and fissile.
- Fractures and breaks easily.
- Hard—breaks with uneven fractures across laminations, making rough angular pieces.
- Weathers to uneven highly pitted surface with little change of color.
- Specific gravity—2.66.

Petrographic analysis—The groundmass of this limerock is extremely fine anhedral grains of calcite of uniform size from 2 to 3 microns. Slightly veined sections appear but large crystals are lacking. Fine pyrite crystals and bluish carbonaceous matter were found as impurities.

Another feature noted in all the Silurian limestones is the presence of brownish red parallel lines—their significance is unknown but their existence was noted only in the Silurian.

Economic uses recommended—Cement manufacture, agricultural limerock, water treatment and probably metallurgical uses

are recommended, depending upon burning qualities. The rock is dense, with extremely fine interlocking grains.
Sample No. 10:

Description and classification—

Dark gray to bluish gray—banded mottled and streaked with white calcite.

Slightly friable and slightly fissile.

Weathers to lighter gray and rough.

Specific gravity—2.70.

Petrographic analysis—Ninety-five percent of the groundmass of this limerock consists of fine anhedral calcite grains ranging in size from 1 to 5 microns. Larger size calcite crystals measuring .04 mm. make up one percent of the volume. Dolomite crystals of varying size make up from 1 to 2 percent of the volume. Carbon matter is in evidence giving the rock its dark gray color. Occasional scattered small crystals of wollastonite were noted.

Economic uses recommended—This limerock appears to be suitable for cement manufacture, use as agricultural limerock, and possibly structural lime and use in metallurgical plants, depending on burning qualities.
Sample No. 11:

Description and classification—
Dark bluish gray—shaly character and schistose.
Uniform color—slightly friable and fissile.
Thinly laminated—cross fractured.
Weathers to light gray.
Lava dikes in a few large fractures.
Specific gravity—2.70.

Petrographic analysis—The groundmass of this limerock consists of 95 percent fine anhedral interlocking grains of calcite. One to two percent of larger calcite crystals are contained in veinlets. Dolomite crystals comprise from 1 to 2 percent of the volume. Carbonaceous material is abundant. Veining is more in evidence than in samples Nos. 9 and 10, indicating an increase of metamorphism to the south.

Economic uses recommended—This limerock is similar to samples Nos. 9 and 10, and all could be mined as one deposit for cement manufacture, agricultural limerock, and should burning tests prove satisfactory, the uses would include structural and metallurgical lime.

Geological and Topographical Relations:

Age—Silurian.

Position—Green Bay crosscuts strike of limestone formation, making two natural quarry faces 100′ to 1200′ on the west to 100′ to 500′ on the east.
Favorable site for selective mining.

Structure—Strike of strata slightly north of west—steep dip to the south.

Relations—Deposit borders salt water on north. In contact with diorite to south at head of Green Bay—south contact not observed. Lava dikes present as filled fractures. Limestone banded and cross fractured.

Overburden—Heavy timber with slight amount of unconsolidated material, mainly soil and fractured limerock.

Mining Methods Applicable:
Open quarry method with high backs.
Uniform width and quality—easily crushed rock.
Two quarry sites close to dock site.

Accessibility to Dock and Harbor Facilities:
Adjacent to 20 fathoms of water. Small boat harbor.
Quarry site immediately adjacent to shore line.
Concrete dock—bedrock bottom.
Possible underground storage and elevator belt loading.

Water Supply:
Camp supply only.

Camp Site:
Ideal camp site at mouth of Green Bay.

Available Fuel:

Heavy growth of hemlock and spruce. Adequate lumber and kiln fuel.

Estimated costs on 1000-ton daily production delivered 1½" size to Pacific Coast ports 30% over pre-war cost figures.

Mining	.40
Crushing	.15
Loading	.10
	.65
Unloading	.10
	.75

Miles at 0.001 per ton-mile		Total
790 to Seattle	.79	1.54
910 to Portland	.91	1.66
1360 to Eureka, Cal.	1.36	2.11
1610 to San Francisco	1.61	2.36
2000 to San Pedro	2.00	2.75

No. 12 — Sketches Nos. 1 and 9

Breezy Bay, Dall Island—South bay—south side.
50' bluff at beach.
4,000-yd. beach outcrop.
900' thickness.
125,000,000 tons 1-mile radius—above sea level.

Chemical Analysis

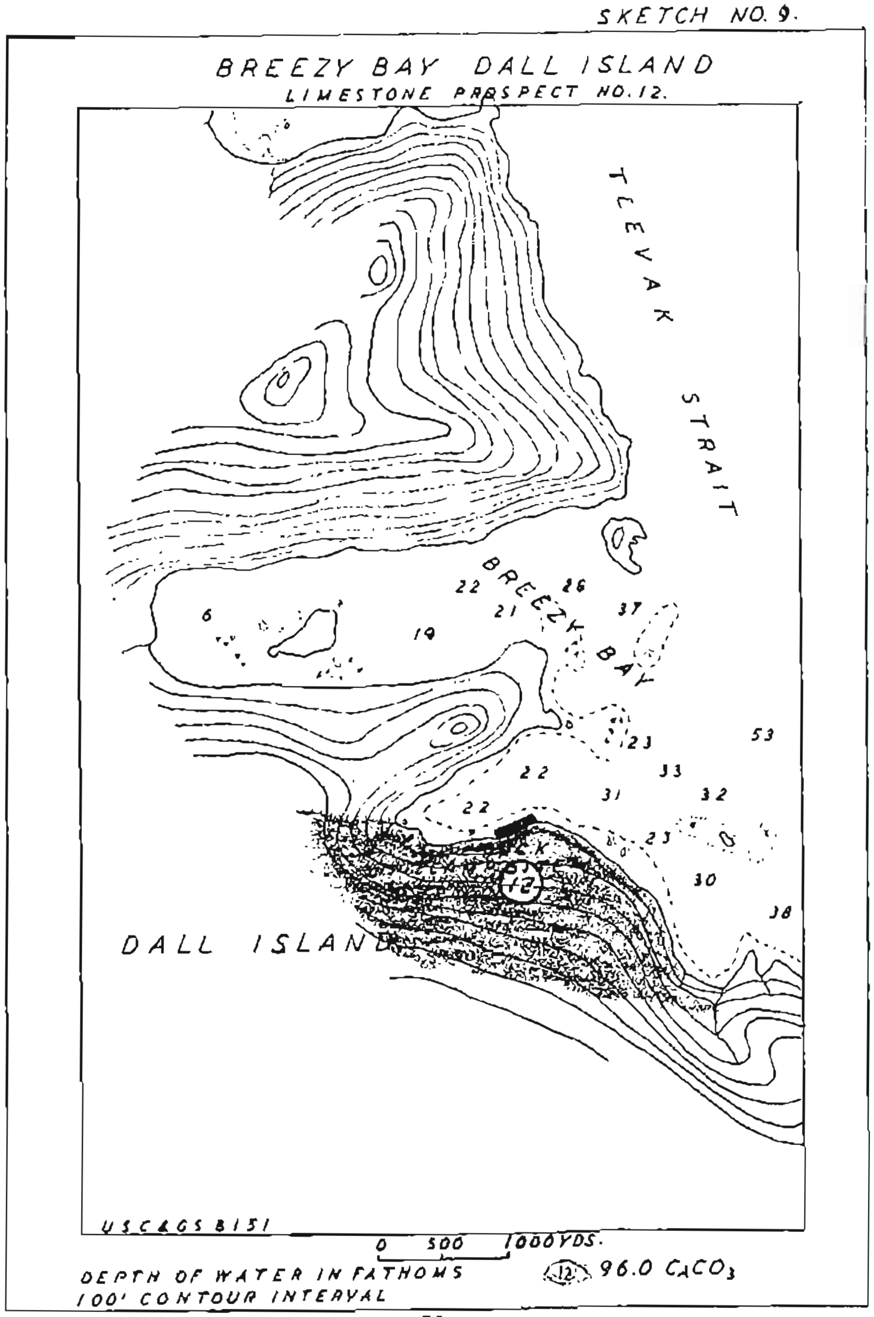
Sample No.	Width & Wt. of Sample	Location and Color	$CaCO_3$	$MgCO_3$	In-sol.	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	S
12	20 lbs. across 1000'	South shore due S. up grade—Light buff	96.0	2.26	0.83	53.8	1.08	0.09	0.07	.005	.009

Description and classification—

Light bluish buff gray.
Very fine—few scattered crystals visible and white calcite seams.
Irregular fracture—slightly friable.
Weathers to light buff color.
Specific gravity—2.66.

Petrographic analysis—The composition of this limerock consists of 25 to 30 percent recrystallized calcite of subhedral crystals in a 70-percent fine anhedral calcite-grained matrix. The larger crystals are uniformly distributed throughout the groundmass and

SKETCH NO. 9.


BREEZY BAY DALL ISLAND
LIMESTONE PROSPECT NO. 12.
TLEVAK STRAIT
BREEZY BAY
DALL ISLAND
22
26
21
37
6
19
23
53
22
33
31
32
22
23
30
38
12
USC&GS 8151
0 500 1000 YDS.
DEPTH OF WATER IN FATHOMS
100' CONTOUR INTERVAL
12 96.0 CaCO3

average .33 mm. in size. The calcite making up the matrix is exceedingly fine, measuring from 1 to 2 microns. Some of the larger calcite crystals are found in the fractured veinlets which also contain the greater portion of the dolomite which comprises from 2 to 3 percent of the volume. Pyrite and carbonaceous matter were noted in minor amounts as the only impurities.

Economic uses recommended—The burning qualities of this limerock are doubtful due to distribution of larger calcite crystals. Chemical and physical analyses indicate a suitable rock for agricultural, water treatment, cement industry, and possibly metallurgical uses.

Geological and Topographical Relations:

Age—Silurian.

Position—Rises from 50′ bluff on shore line to 900′ 1 mile inland.

Structure—Strike N.W.—dips low to north.

Relations—Overlain by Devonian lava to north side of bay.
Contains cross dikes of lava.
Semi-marbleized upper portion under lava contact.

Overburden—Timber growth, soil and some fractured limestone.

Mining Method Applicable:

Quarry method with 200′ - 300′ backs.
Uniform grade, with exception of lava dikes.

Accessibility to Dock and Harbor Facilities:

400′ haulage to obtain 200′ back.
250′ dock to reach 20 fathoms water—concrete dock only —bottom limestone.
Storage and dock necessary for quick loading.
Fair harbor.

Water Power and Supply:

Power—none.
Camp supply adequate at camp site, head of bay.

Camp Site:

Head of bay 1500′ from dock site.

Available Fuel:

Moderate growth spruce and hemlock.

Adequate lumber and kiln fuel.

Estimated costs on 1000-ton daily production delivered 1½″ size to Pacific Coast ports 30% over pre-war cost figures.

Mining	.40
Crushing	.15
Loading	.10
	.65
Unloading	.10
	.75

Miles at 0.001 per ton-mile		Total
800 to Seattle	.80	1.65
920 to Portland	.92	1.67
1370 to Eureka, Cal.	1.37	2.12
1620 to San Francisco	1.62	2.37
2010 to San Pedro	2.01	2.76

No. 13—Sketches Nos. 2 and 10

Wadleigh Island, San Alberto Island group.

San Alberto Bay, opposite Klawak, west coast of Prince of Wales Island, upper portion of island.

600′ thickness.

2 miles of continuous outcrop above 100′ elevation.

40,000,000 tons estimated on island.

Chemical Analysis

Sample No.	Width & Wt. of Sample	Location and Color	$CaCO_3$	$MgCO_3$	In-sol.	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	S
13	20 lbs. over 600′ thickness	Central E. side of I.—Brownish gray	97.44	1.21	0.44	54.6	0.58	0.06	0.14	-.001	.052

Description and classification—

Brownish gray—massive and dense.

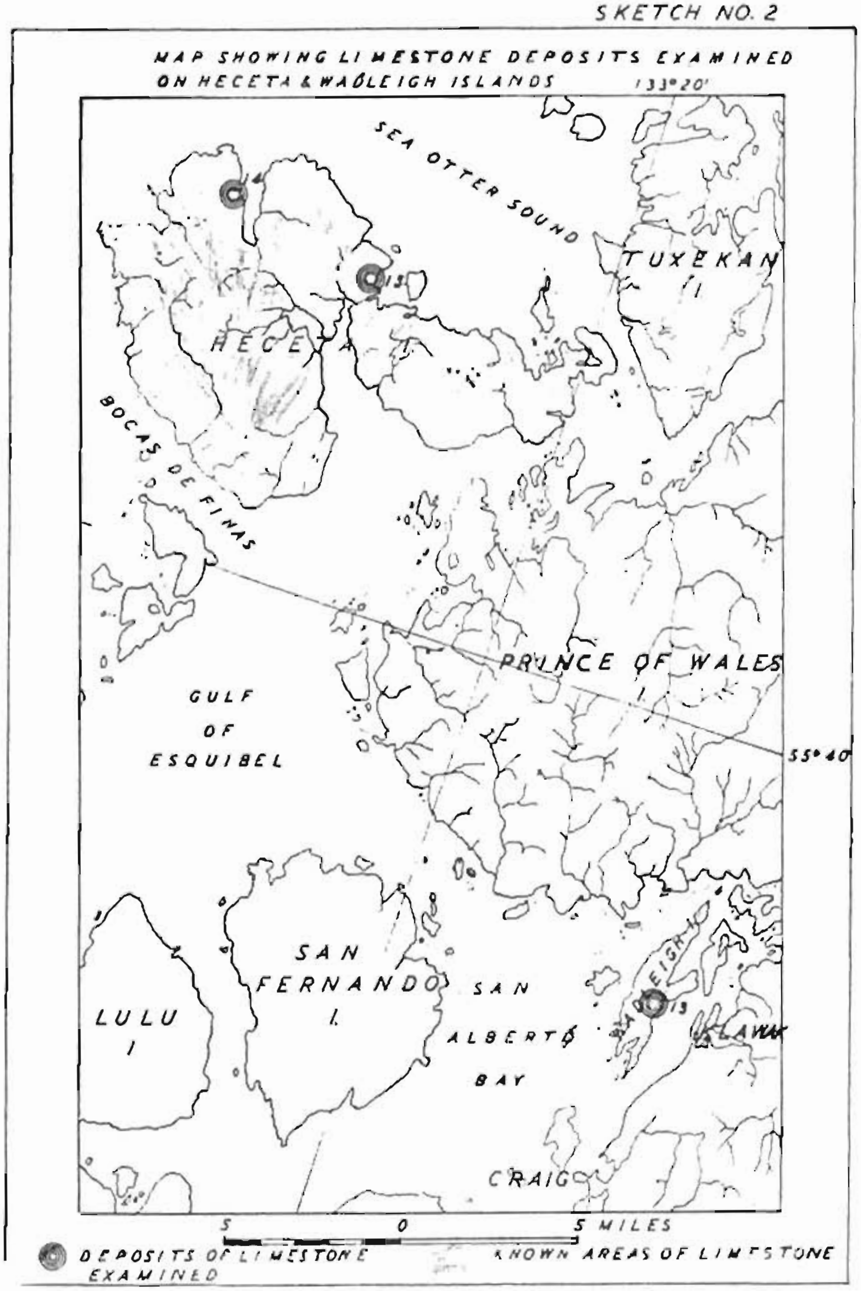
Finely crystalline—contains a few dark streaks.

Fractures rough—slightly semi-crystalline.

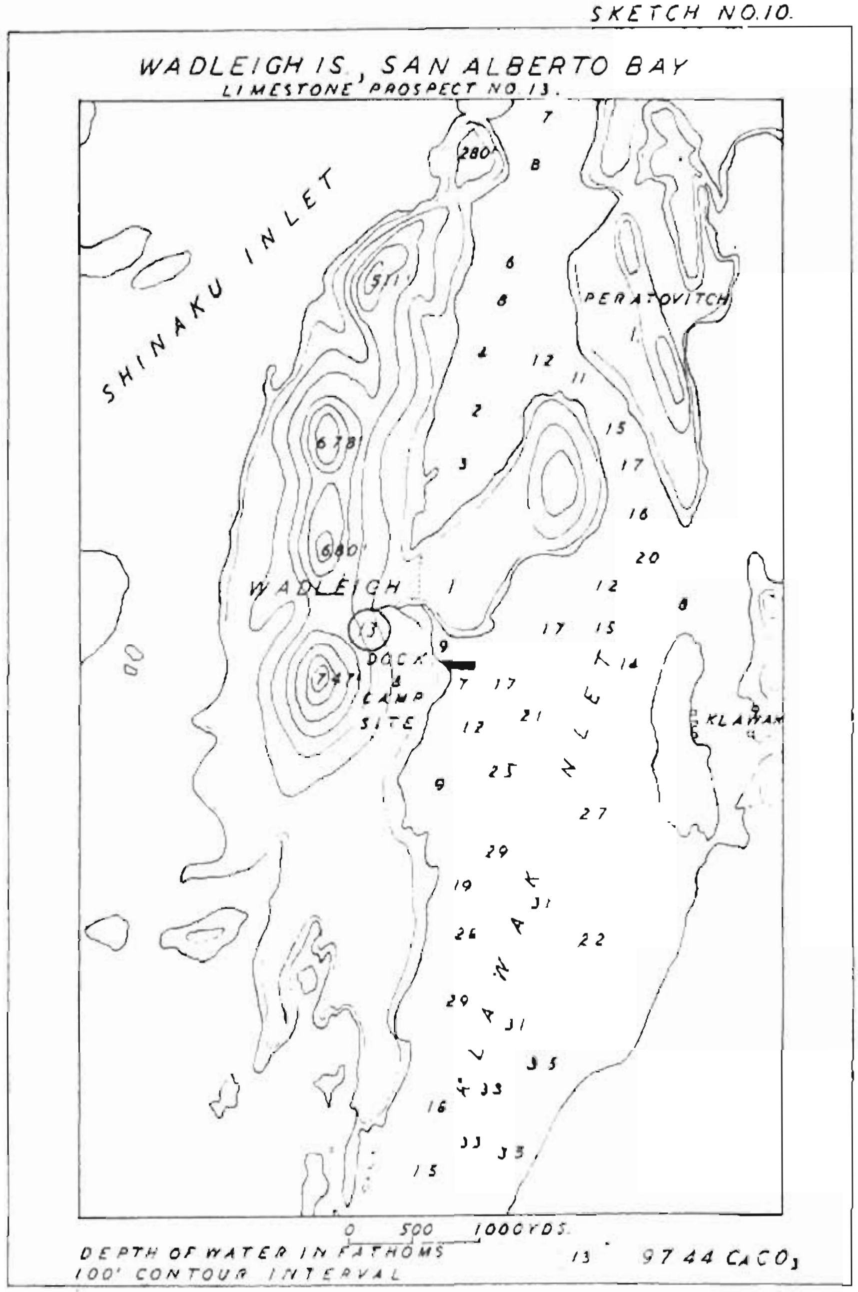
Weathers to light gray and smooth faces.

Specific gravity—2.69.

SKETCH NO. 2


MAP SHOWING LIMESTONE DEPOSITS EXAMINED
ON HECETA & WADLEIGH ISLANDS
133°20'
SEA OTTER SOUND
TUXEKAN I.
HECETA
BOCAS DE FINAS
PRINCE OF WALES I.
GULF OF ESQUIBEL
55°40'
SAN FERNANDO I.
LULU I.
SAN ALBERTO BAY
WADLEIGH I.
KLAWAK
CRAIG
5 0 5 MILES
DEPOSITS OF LIMESTONE EXAMINED
KNOWN AREAS OF LIMESTONE

SKETCH NO. 10.


WADLEIGH IS., SAN ALBERTO BAY
LIMESTONE PROSPECT NO. 13.
SHINAKU INLET
WADLEIGH
PERATOVITCH
DOCK
CAMP SITE
KLAWAK
KLAWAK INLET
280'
511'
678'
680'
747'
0 500 1000 YDS.
DEPTH OF WATER IN FATHOMS
100' CONTOUR INTERVAL
13 97.44 $CaCO_3$

Petrographic analysis—Thin sections reveal this limerock to be of oolitic type, consisting of a groundmass of 75 percent oolitic remains cemented in a partly recrystallized matrix. The oolites measure from 100 to 150 microns in size and consist of extremely fine calcium carbonate matter. Some of the oolites have recrystallized centers. The subhedral calcite grains of the matrix measure from 250 to 300 microns. The matrix consists of 25 percent of the volume of the rock. No impurities were identified, but chemical analyses indicate minor amounts, probably contained in the fine calcium carbonate material of the oolites.

Economic uses recommended—Chemical and physical analyses indicate nearly chemically pure limerock. Should lime burning tests prove satisfactory, the economic industrial uses of this limerock are many. This limerock nearly meets the carbide and cyanamide specifications. Selective mining may fulfill chemical demands. Further, this limerock meets all the other industrial demands of a high calcium limerock, providing burning tests are satisfactory, except agricultural where higher magnesium and phosphate content is preferred.

Geological and Topographical Relations:

Age—Divonian.

Position—Erosive remnants.
Forms elevated ridge of island, 0 - 700′ +.
Elevated beach 50′ to 75′ as bluffs.

Structure—Nearly horizontal—slightly inclined to east. North strike.

Relations—Overlies older Devonian sediment—graywacke and slate. Overlain to east by carboniferous limestone.

Overburden—Moderate timber growth—slight amount of subsoil.

Mining Methods Applicable:

Open quarry with high back.
Two faces along creek above dock site.
Uniform grade and texture.

Accessibility to Dock and Harbor Facilities:

300′ shore to bluff face.
200′ dock to 10 fathoms water.
Good pile dock bottom.
Storage on dock required for quick loading.
Excellent large and small boat harbor.

Water Power and Supply:

Water power—none.

Excellent camp supply of water.

Camp Site:

Excellent—adjacent to dock site.

Available Fuel:

Moderate growth of spruce and hemlock—adequate for lumber.

Labor Supply:

Native settlement of Klawak 1½ miles; Craig—cannery and fishing village. Commodity supply center—oil, etc.

Estimated costs on 1000-ton daily production delivered 1½″ size to Pacific Coast ports 30% over pre-war cost figures.

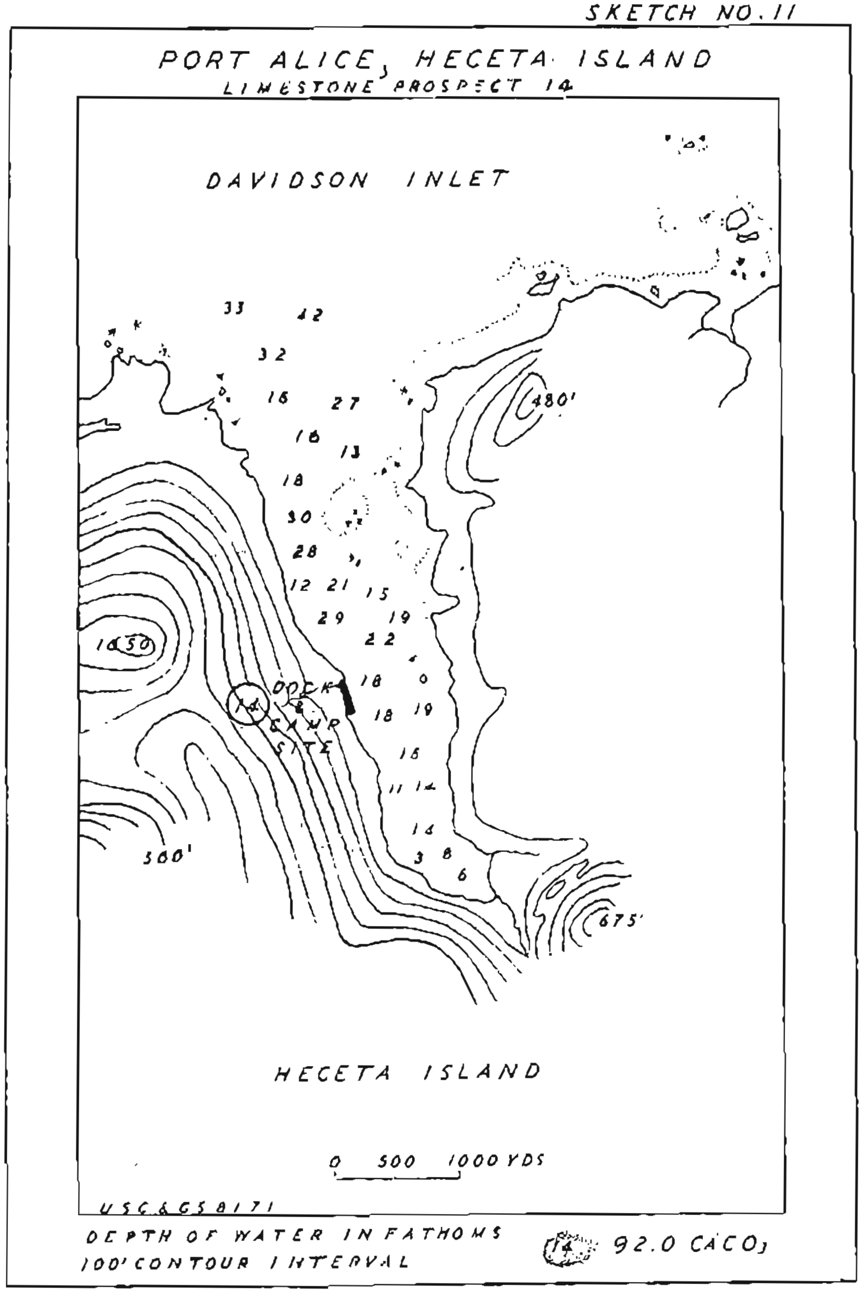
Mining	.40
Crushing	.15
Loading	.10
	.65
Unloading	.10
	.75

Miles at 0.001 per ton-mile		Total
830 to Seattle	.83	1.58
950 to Portland	.95	1.70
1400 to Eureka Cal.	1.40	2.15
1650 to San Francisco	1.65	2.40
2040 to San Pedro	2.04	2.79

No. 14—Sketches Nos. 2 and 11

Port Alice—Heceta Island.
North end of island.
West side—middle portion of island.
3000-yd. beach outcrop.
600′ thickness.
135,000,000 tons 1-mile radius.

SKETCH NO. 11


PORT ALICE, HECETA ISLAND
LIMESTONE PROSPECT 14
DAVIDSON INLET
480'
1650
DOCK & CAMP SITE
500'
675'
HECETA ISLAND
0 500 1000 YDS
USC&GS 8171
DEPTH OF WATER IN FATHOMS
100' CONTOUR INTERVAL
14 92.0 CACO3

Chemical Analysis

Sample No.	Width & Wt. of Sample	Location and Color	$CaCO_3$	$MgCO_3$	Insol.	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	S
14	20 lbs. across 400′	Bluff at creek W. side of bay—Light gray to buff	92.0	5.4	0.66	51.5	2.37	0.09	0.11	.013	.011

Description and classification—

Light gray to buff—contains dark streaks.
Dense—semi-crystalline.
Fractures uneven.
Weathers to buff to brown.
Specific gravity—2.70.

Petrographic analysis—The groundmass of the limerock consists of unevenly-grained calcite crystals; 30 percent shows recrystallization, consisting of subhedral crystals measuring 200 to 225 microns; another 30 percent consists of fine anhedral grains of calcite measuring 80 to 125 microns; another 30 percent of the groundmass consists of fossil remains of fine calcium carbonate material. Veinlets of calcite with uneven-sized calcite crystals, mainly fracture fillings, comprise 4 percent of the volume. Grain and crystal boundaries are irregular, interlocking and twinned. Fossil remains, mainly as partial remnants, are much in evidence. Dolomite and a small amount of iron oxide staining is present, mainly confined to the veinlets. Other impurities, such as small threads of mica and silica grains, were in evidence.

Economic uses recommended—Chemical and petrographic analyses indicate that this limerock is favorable for agricultural use.

Geological and Topographical Relations:

Age—Silurian.

Position—Bluff 200′ - 300′ back from beach.
Steep grades to 500′ elevation at dock site.
Steep rise immediate from water along shore of bay.
Main mass rises to 1000′ elevation.

Structure—Northwest strike—low dip to east. Nearly horizontal beds.

Relations—Central portion of wide Silurian belt of sediments.
Underlain by andesitic volcanics.
Stratum contains extensive fault and fracture systems.

Overburden—Heavy timber—slight amount of subsoil.

Mining Methods Applicable:

Open pit quarry with 100′ - 600′ back.
Underground cave method utilizing gravity.
Uniform in grade, color, etc.

Accessibility to Dock and Harbor Facilities:

Adjacent to shore line, 10-20 fathoms.
Load direct with elevator belt from underground storage.
Concrete dock to deep water at camp site—300′ length to 20 fathoms.
Harbor for large and small ships.

Water Power and Supply:

Water power—none.
Camp water supply adequate at dock and camp site.

Camp Site:

Excellent camp sites on point and head of bay.

Available Fuel:

Adequate timber for lumber and fuel supply.

Estimated costs on 1000-ton daily production delivered 1½″ size to Pacific Coast ports 30% over pre-war cost figures.

Mining	.40
Crushing	.15
Loading	.10
	.65
Unloading	.10
	.75

Miles at 0.001 per ton-mile		Total
850 to Seattle	.85	1.60
970 to Portland	.97	1.72
1420 to Eureka, Cal.	1.42	2.17
1670 to San Francisco	1.67	2.42
2060 to San Pedro	2.06	2.81

No. 15 — Sketches Nos. 2 and 12

North side Heceta Island.

Directly opposite largest island along central north shore of Heceta Island.

1500-yd. beach outcrop on harbor.

300′ estimated thickness.

16, 875,000 tons estimated 1-mile radius above sea level.

Chemical Analysis

Sample No.	Width & Wt. of Sample	Location and Color	$CaCO_3$	$MgCO_3$	Insol.	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	S
15	30 lbs. across 300′	W. shore of bay opposite island—Dark gray	93.34	1.90	3.45	52.3	0.91	0.16	0.35	.012	.094

Description and classification—

Dark bluish gray—semi-crystalline.
Thinly banded and fractured.
Fractures easily.
Weathers to dark gray and very irregular.
Specific gravity—2.70.

Petrographic analysis—The groundmass of this limerock shows partial recrystallization. 70 percent consists of cryptocrystalline structure of which the fine anhedral calcite grains range from 30 to 50 microns in size. 20 percent of the groundmass consists of subhedral crystals of calcite averaging .5 mm. in size. Two percent of the volume consists of dolomite crystals which, together with pyrite, silica grains, iron oxide coloration, with a small amount of carbonaceous matter, make up the impurities.

Economic uses recommended—Chemical and physical analyses indicate an agricultural use for this limerock.

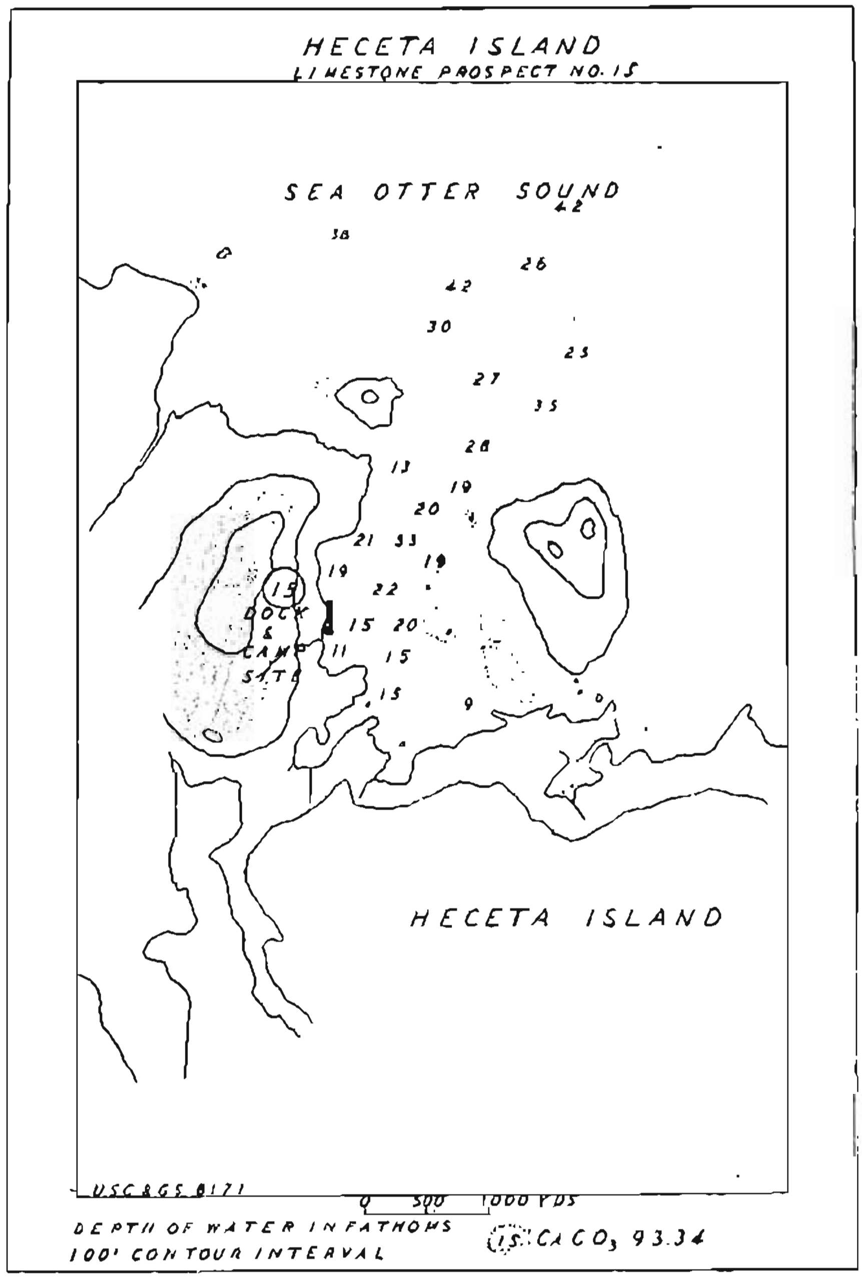
Geological and Topographical Relations:

Age—Silurian.

Position—Beach to 300′ elevation—bluffs 40′ - 50′ at edge of water.

Structure—Strikes slightly north of west—Dip 30° to 40° north.

SKETCH NO. 12


HECETA ISLAND
LIMESTONE PROSPECT NO. 15
SEA OTTER SOUND
DOCK & CAMP SITE
HECETA ISLAND
USC&GS 8171
0 500 1000 YDS
DEPTH OF WATER IN FATHOMS
100' CONTOUR INTERVAL
15 $CaCO_3$ 93.34

Relations—Base of limestone strata rests on 50′ lava agglomerate at head of bay. Central portion of extensive area of Siluran sediments contains a fault system—some faults filled with lava.

Overburden—Timber growth and slight amount of subsoil.

Mining Method Applicable:

Open quarry method with back up to 300′.
Dip favorable for easy breaking.

Accessibility to Dock and Harbor Facilities:

30′ - 50′ bluff immediately adjacent to 10 fathoms of water.
Storage bunkers can be built on bluff, allowing gravity loading.
Average water depth of bay over 20 fathoms.

Water Power and Supply:

Water power—none on island.
Camp water supply adequate at dock site.

Camp Site:

Camp site at head of bay adjacent to dock site.

Available Fuel:

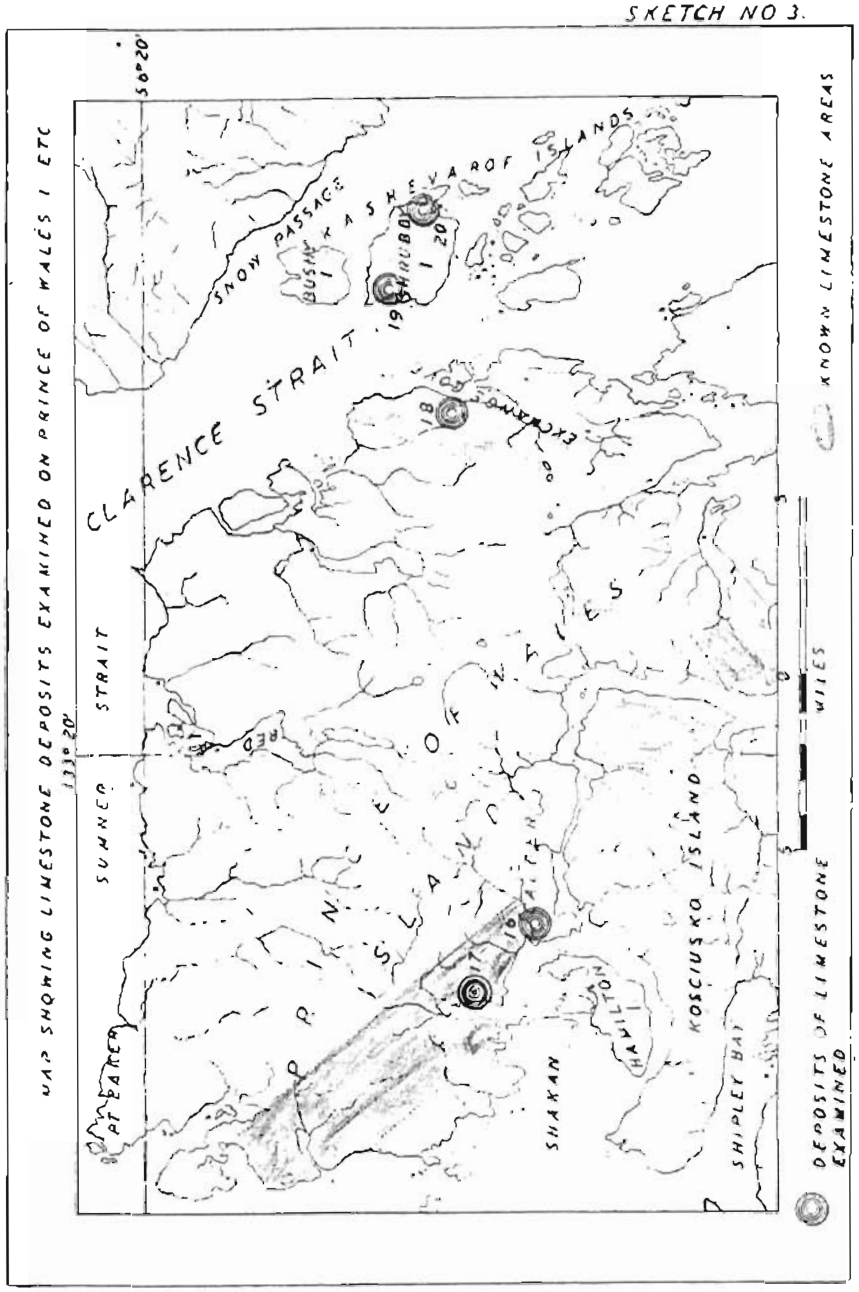
Medium growth spruce and hemlock available for lumber and fuel.

Estimated costs on 1000-ton daily production delivered 1½″ size to Pacific Coast ports 30% over pre-war cost figures.

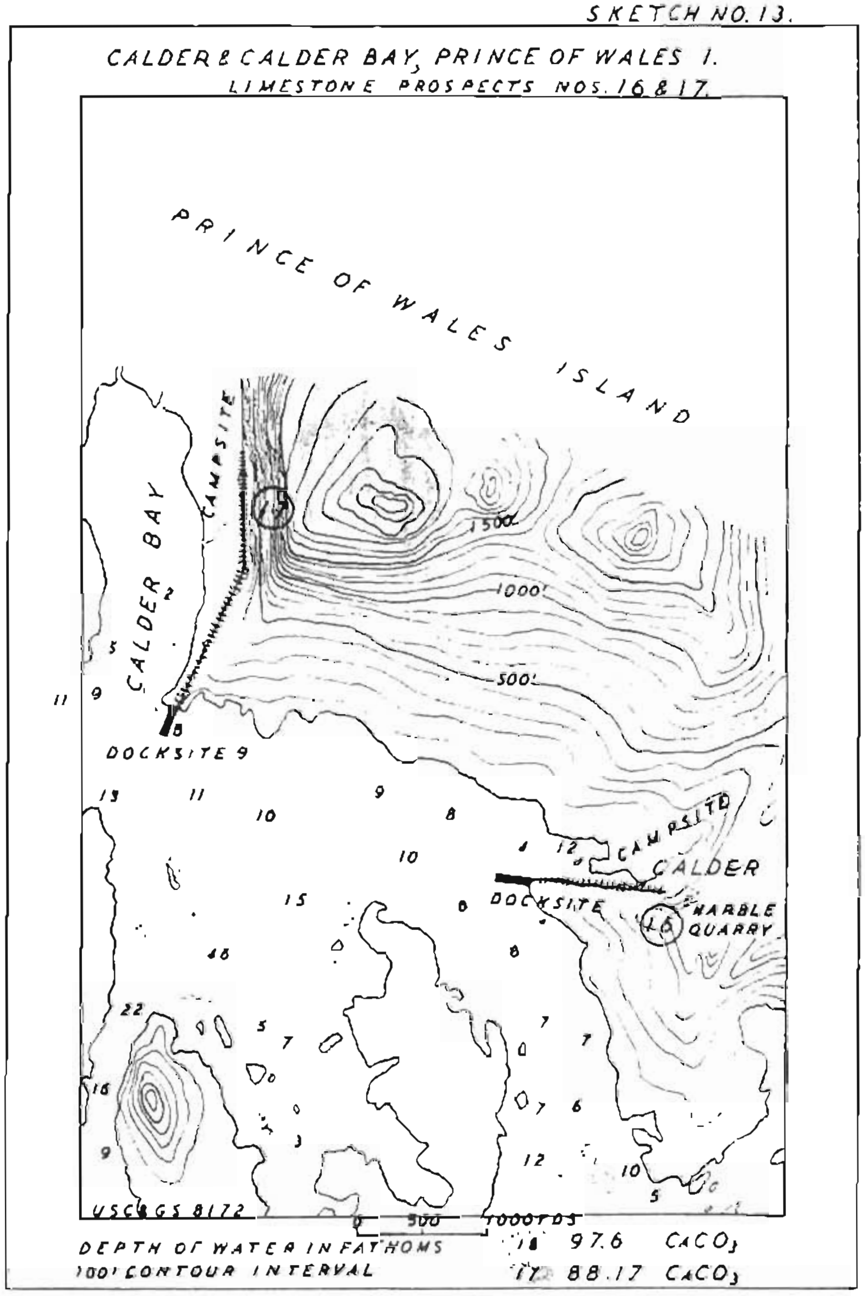
Mining	.40
Crushing	.15
Loading	.10
	.65
Unloading	.10
	.75

Miles at 0.001 per ton-mile		Total
850 to Seattle	.85	1.60
970 to Portland	.97	1.72
1420 to Eureka, Cal.	1.42	2.17
1670 to San Francisco	1.67	2.42
2060 to San Pedro	2.06	2.81

SKETCH NO 3.


MAP SHOWING LIMESTONE DEPOSITS EXAMINED ON PRINCE OF WALES I ETC
56°20'
133°20'
CLARENCE STRAIT
SNOW PASSAGE
KASHEVAROF ISLANDS
BUSH I
SHRUBBY I
19
20
18
SUMNER STRAIT
PT BAKER
PRINCE OF WALES ISLAND
17
16
SHAKAN
HAMILTON I
KOSCIUSKO ISLAND
SHIPLEY BAY
MILES
5
0
5
DEPOSITS OF LIMESTONE EXAMINED
KNOWN LIMESTONE AREAS

SKETCH NO. 13.


CALDER & CALDER BAY, PRINCE OF WALES I.
LIMESTONE PROSPECTS NOS. 16 & 17.
PRINCE OF WALES ISLAND
CALDER BAY
CAMPSITE
1500'
1000'
500'
DOCKSITE
CAMPSITE
CALDER
DOCKSITE
MARBLE QUARRY
USC&GS 8172
0 500 1000 FDS
DEPTH OF WATER IN FATHOMS
100' CONTOUR INTERVAL
16 97.6 $CaCO_3$
17 88.17 $CaCO_3$

No. 16—Sketches Nos. 3 and 13

Calder—marble quarry—Shakan Bay, west coast Prince of Wales Island.

Northeast part of bay.

Marble quarry 1000 yards inland from deep-water dock site.

500′ thickness above sea level.

2,000,000 tons above sea level—1000-yd. radius.

Chemical Analysis

Sample No.	Width & Wt. of Sample	Location and Color	$CaCO_3$	$MgCO_3$	Insol.	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	S
16	20 lbs. across 300′	Quarry 1000′ from head of bay—Gray white	97.6	1.27	0.06	54.7	0.61	0.04	0.03	.008	.017

Description and classification*—

Light bluish gray marble—crystalline and variable in color—dense—veined and mottled.

Contains thin dikes of diabase occasionally with pyrite—not numerous.

White variety friable.

Weathers to light gray.

Specific gravity—2.71.

Petrographic analysis—Thin section shows this limerock to be totally recrystallized into marble. The calcite crystals have distinct borders and are fairly even in size, ranging from .33 to .8 mm. This is a very pure limerock, with the only impurity noted being grains of magnetite amounting to less than one percent of the volume. The color is nearly pure white.

Economic uses recommended—Chemical and petrographic analyses show this limerock to be of chemical grade. Satisfactory burning qualities are very doubtful, which limits its economic uses to agricultural, possibly pulp and paper, and minor chemical uses.

Geological and Topographical Relations:

Age—Silurian.

Position—Rises from beach to quarry, elevation 250′—rises to 700′ elevation.

*—Note Bib. No. 9.

Structure—Strikes northwest and dips southwest.

Relations—Marble belt 3000′ thick between granodiorite to east and younger Silurian sediments to west. Shore line to west. To north are overlying beds of conglomerate. Marbleized zone decreases away from granodiorite to east. Small dikes of diabase occur occasionally in marble. Some fracturing.

Overburden—Second growth timber and considerable brush—slight amount of subsoil.

Mining Method Applicable:

Quarry method at site of old quarry face. Uniform grade.

Back of 200′ - 300′, 500′ possible.

Accessibility to Dock and Harbor Facilities:

3000′ rail or truck road necessary.

Grade to quarry established.

8 to 9 fathoms of water at dock site.

Concrete dock in bedrock recommended with rock-fill approach.

Harbor and dock facilities for medium and shallow-draft vessels only.

Water Power and Supply:

Few horse power available from Calder Creek.

Adequate mill and camp supply of water.

Camp Site:

Site of old town of Calder at head of bay.

Available Fuel:

Abundant timber for fuel in near vicinity.

Estimated costs on 1000-ton daily production delivered 1½″ size to Pacific Coast ports 30% over pre-war cost figures.

Mining	.40
Crushing	.15
Loading	.10
	.65
Unloading	.10
	.75

Miles at 0.001 per ton-mile		Total
888 to Seattle	.89	1.64
1008 to Portland	1.01	1.76
1458 to Eureka, Cal.	1.46	2.21
1708 to San Francisco	1.71	2.46
2098 to San Pedro	2.10	2.85

No. 17—Sketches Nos. 3 and 13

Calder Bay—north shore Shakan Bay—west coast of Prince of Wales Island.

Bluff deposit inland from east shore.
1500′ bluff 1000′ inland.
2000′ estimated thickness.
112,500,000 tons within 1-mile radius.

Chemical Analysis

Sample No.	Width & Wt. of Sample	Location and Color	$CaCO_3$	$MgCO_3$	Insol.	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	S
17	26 lbs. 1500′ across base of bluff	Inland E. shore Calder Bay—Bluish gray	88.17	9.17	0.33	49.4	4.39	0.09	0.11	.013	.008

Description and classification—
Bluish gray—massive—dense—semi-crystalline.
Rough fracture.
Calcite veinlets.
Weathers to dull whitish gray.

Petrographic analysis—Thin section reveals this limerock to be 40 percent recrystallized, crystal size ranging from .03 to .1 mm. These large crystals show considerable strain and many show curved outlines. 50 percent of the groundmass or matrix consists of fine anhedral grained calcite measuring from 6 to 10 microns. Portions of fossil outlines can be distinguished in the fine-grained groundmass. Dolomite crystals appear to be the only impurity, except a small amount of carbonaceous matter. Dolomite makes up 7 to 8 percent of the volume.

Economic uses recommended—Chemical and petrographic analyses show this limerock to be an ideal combination for agricultural use.

Geological and Topographical Relations:

Age—Silurian.

Position—Bluff 4000′ long, 1500′ high—main mass 1000′ to over 2000′ elevation.

Structure—Strikes northwest—Dip steep to southwest.

Relations—Deposit contained in central mass of Silurian sediments. In contact with younger Silurian sediments to west. Granodiorite mass to east. Marble 2000′ to east. Some recent fracturing due to faulting. Extensive talus at foot of cliff.

Overburden—Medium growth of spruce and hemlock. Talus at base—barren on top of mountain.

Mining Methods Applicable:

Excellent site at face of bluff for underground cave method.
Amenable to very cheap mining.
Elimination of mucking.
Open quarry method or bench quarry method 1500′ back.
Load direct from bench level onto cars.
4000′ face to operate along.

Accessibility to Dock and Harbor Facilities:

4000′ rail or roadway required along 100′contour to 60′ bluff at dock site.
8 to 10 fathoms of water at dock site.
Concrete dock and rock fill required.
Excellent site for storage bunkers or rapid loading from cars.
Excellent harbor for small boats.
Bay navigable for all except large deep-draft vessels.

Water Power and Supply:

Water power—none.
Adequate camp water supply along east shore of bay.

Camp Site:

On east shore of Calder Bay.

Available Fuel:

Abundant timber for fuel in near vicinity.
Estimated costs on 1000-ton daily production delivered

1½" size to Pacific Coast ports 30% over pre-war cost figures.

Mining	.40
Crushing	.15
Loading	.10
	.65
Unloading	.10
	.75

Miles at 0.001 per ton-mile		Total
888 to Seattle	.89	1.64
1008 to Portland	1.01	1.76
1458 to Eureka, Cal.	1.46	2.21
1708 to San Francisco	1.71	2.46
2098 to San Pedro	2.10	2.85

No. 18—Sketches Nos. 3 and 14

Exchange Cove, Prince of Wales Island.
Steep hillside over 2 miles in length.
Inland 1000′ to 2000′ from west shore.
1000′ + estimated thickness.
75,000,000 tons estimated within 1-mile radius.

Chemical Analysis

Sample No.	Width & Wt. of Sample	Location and Color	$CaCO_3$	$MgCO_3$	In-sol.	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	S
18	20 lbs. across 2000′	From 100′ elevation to top: 1500′ central portion of bay—Light bluish gray	95.5	1.7	0.47	53.5	0.81	0.14	0.12	.011	.013

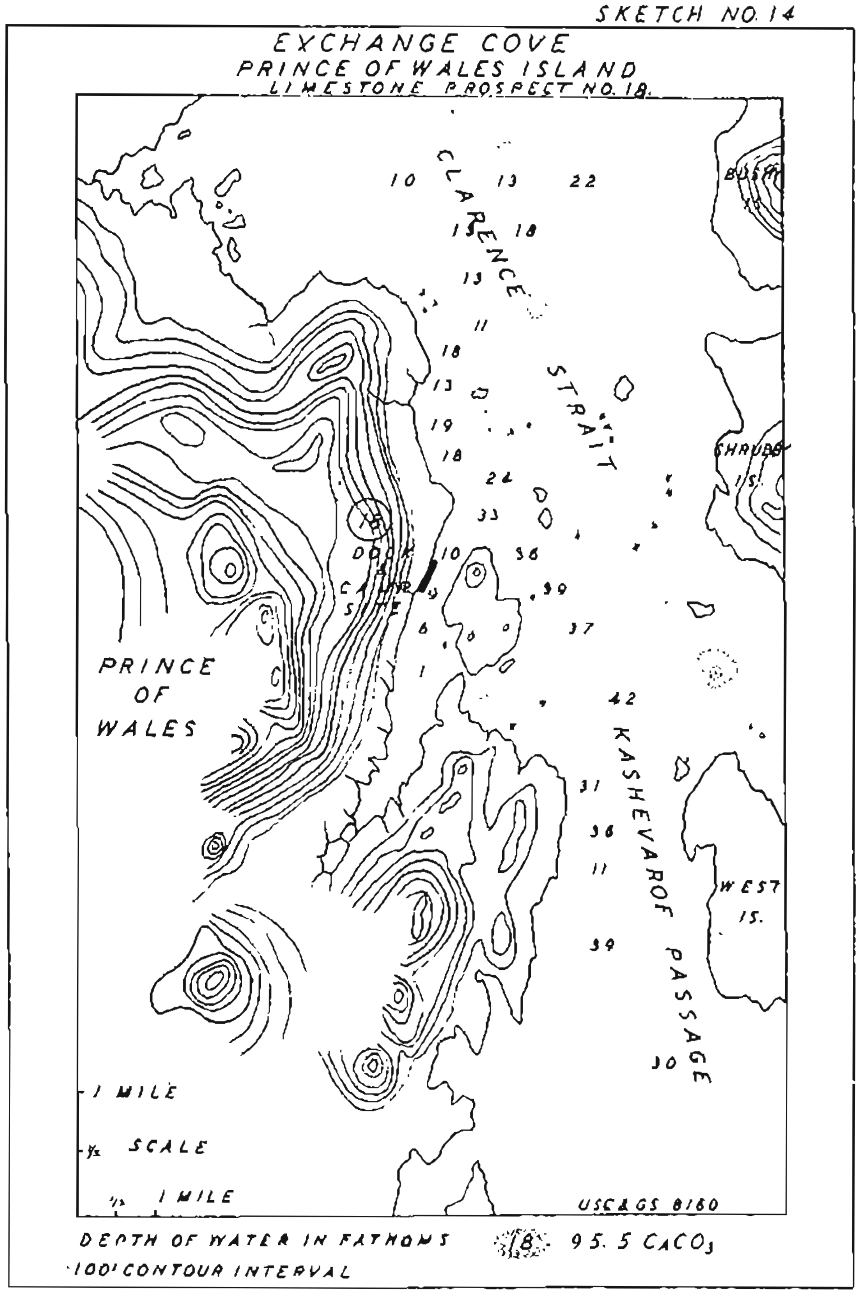
Description and classification—

Light bluish gray, highly fractured and semi-crystalline.
Weathers smooth surface in an unfractured area.
Contains mottled colored areas.
Specific gravity—2.70.

Petrographic analysis—The groundmass of this limerock shows a highly fractured and strained pattern. The crystal and grain size is exceedingly variable, ranging from 10 microns up to 400 microns. Due to strain the larger crystals have become elongated and show extremely wavy extinction. Veining, mainly fracture filling, is much in evidence. One to two percent dolomite crystals are in evidence. Small quartz grains and iron oxide staining are present as impurities.

Economic uses recommended—Petrographic analysis indicates that this limerock has poor burning qualities due to strain

SKETCH NO. 14


EXCHANGE COVE
PRINCE OF WALES ISLAND
LIMESTONE PROSPECT NO. 18.
CLARENCE STRAIT
KASHEVAROF PASSAGE
PRINCE OF WALES
WEST IS.
SHRUBBY IS.
DOCK
CAMP SITE
1 MILE
SCALE
1 MILE
USC&GS 8160
DEPTH OF WATER IN FATHOMS
18 95.5 CaCO3
100' CONTOUR INTERVAL

and fractures and great variety in grain size. Industrial uses would be ground raw limerock for agricultural and possibly metallurgical purposes.

Geological and Topographical Relations:

Age—Silurian.

Position—First 100′ bench is 650′ from shore line; second 100′ bench is back 1260′; thence the mountain rises to 1500′.

Structure—Northerly strike—low dip west.

Relations—Limestone strata overlain to west by younger Silurian sediments. Covered by lava to the south. Lava filled fractures present.

Overburden—Heavy timber growth—light subsoil.

Mining Methods Applicable:

Extensive mining by open quarry bench method.
100′ natural benches—uniform grades over extensive width.

Accessibility to Dock and Harbor Facilities:

Deposit is 600′ to 2000′ back from dock site at beach.
Dock site in well-protected harbor for all except large vessels.
Average water of bay 9 to 10 fathoms.
Favorable pile dock site on rock fill.

Water Power and Supply:

Water power—none in immediate area.
Adequate camp water supply at dock site.

Camp Site:

Low shore line and good beach at camp site.

Available Fuel:

Heavy growth of hemlock and spruce.

Estimated costs on 1000-ton daily production delivered 1½″ size to Pacific Coast ports 30% over pre-war cost figures.

Mining	.40
Crushing	.15
Loading	.10
	.65
Unloading	.10
	.75

Miles at 0.001 per ton-mile		Total
820 to Seattle	.82	1.57
940 to Portalnd	.94	1.69
1390 to Eureka, Cal.	1.39	2.14
1640 to San Francisco	1.64	2.39
2030 to San Pedro	2.03	2.78

No. 19—Sketches Nos. 3 and 15

Mud Bay, Shrubby Island, Kashevarof Islands, Clarence Strait.

Northwest section of Shrubby Island.

1500′ beach outcrop as low bluff.

15,000,000 tons in 1-mile radius.

Chemical Analysis

Sample No.	Width & Wt. of Sample	Location and Color	$CaCO_3$	$MgCO_3$	Insol.	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	S
19	16 lbs. across 1500′	Along beach East shore Mud Bay—Light bluish buff	95.53	1.05	1.48	53.5	0.50	0.44	0.18	.016	.040

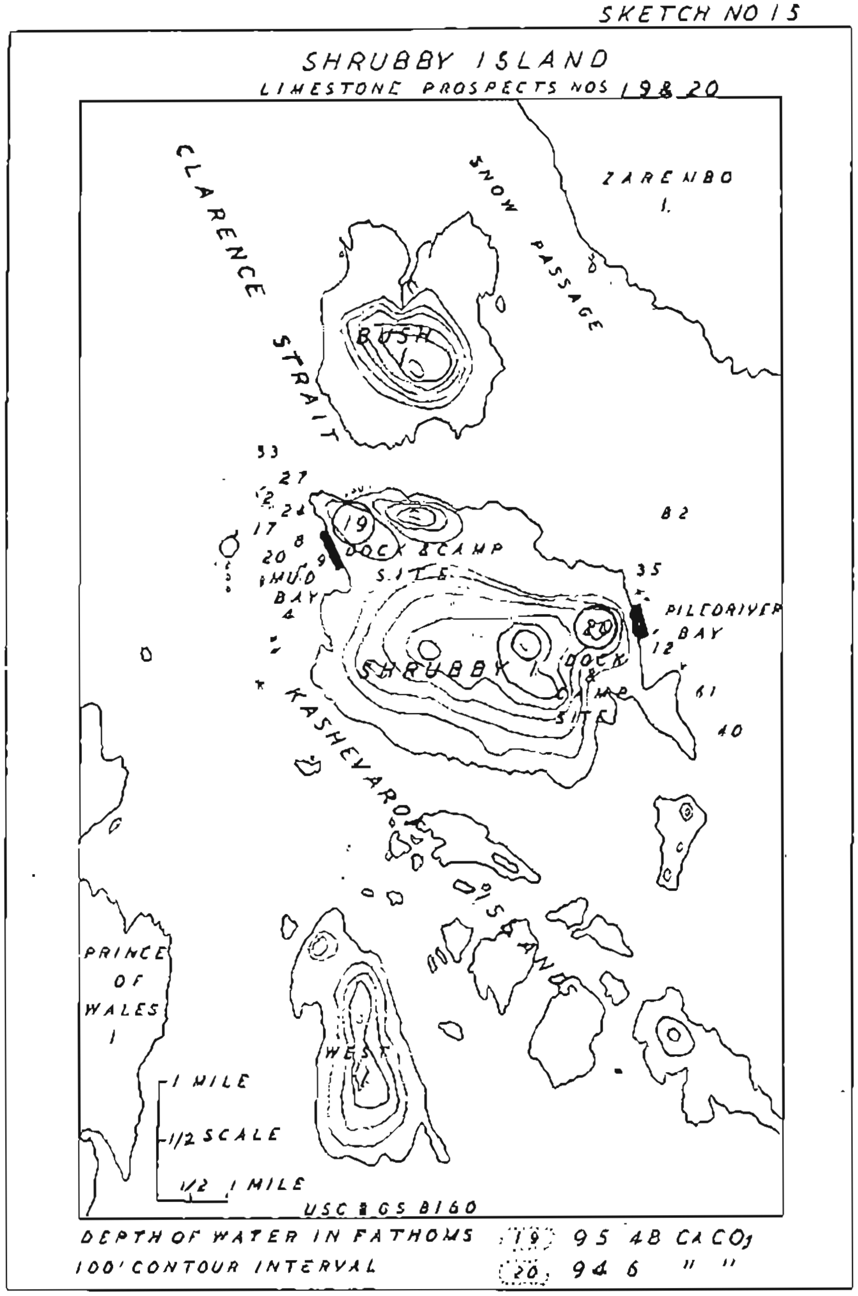
Description and classification—

Light bluish buff—fine crystalline.
Highly fractured and brittle.
Hard and uneven fracturing.
Weathers to gray color and rough surfaces.
Specific gravity—2.68.

Petrographic analysis—The groundmass of this limerock consists of 85 percent anhedral grains of calcite of an average size of 100 microns. Another 10 percent of the volume consists of larger calcite grains with subhedral form and an average size of 225 microns. Small veinlets are indicative of strain together with fracture-curved crystal faces and wavy extinction. Iron oxide, pyrite, dolomite, and small amounts of black staining, probably manganese, make up the known impurities.

Economic uses recommended—Agricultural, water treatment

SKETCH NO 15


SHRUBBY ISLAND
LIMESTONE PROSPECTS NOS 19 & 20
CLARENCE STRAIT
SNOW PASSAGE
ZARENBO I.
BUSH I.
DOCK & CAMP SITE
MUD BAY
PILEDRIVER BAY
SHRUBBY I.
DOCK & CAMP SITE
KASHEVAROF ISLANDS
PRINCE OF WALES I
WEST I.
1 MILE
1/2 SCALE
1/2 1 MILE
USC & GS 8160
DEPTH OF WATER IN FATHOMS
100' CONTOUR INTERVAL
19 95 48 CA CO3
20 94 6 " "

and possibly some metallurgical uses are indicated by chemical and physical analyses of this limerock.

Geological and Topographical Relations:

Age—Silurian.

Position—Rises from tidewater to 400′ elevation, 100′ rise close to tidewater.

Structure—Strike NW.-SE. Low dip to northeast.

Relations—Entire island Silurian limestone underlain by andesitic volcanics; formerly overlain by younger Silurian sediments. Green lava dikes present but widely scattered. NW. and SE. fault zones.

Overburden—Some timber, heavy brush and light subsoil.

Mining Methods Applicable:

Open quarry method, 100′ - 200′ backs.
Possibly slight amount of selective mining.

Accessibility to Dock and Harbor Facilities:

Adjacent to shore-line and bluff with 9 fathoms of water.
Fair harbor, accessible to all except large deep-draught vessels.
Storage facilities can be built on bluff, eliminating expensive dock—gravity loading.

Water Power and Supply:

Water power—none on island.
Natural spring water supply adequate for camp use at head of bay.

Camp Site:

Favorable site at head of bay.

Available Fuel:

Surrounding area can furnish adequate lumber and fuel.

Estimated costs on 1000-ton daily production delivered 1½" size to Pacific Coast ports 30% over pre-war cost figures.

Mining	.40	Miles at 0.001 per ton-mile		Total
Crushing	.15	820 to Seattle	.82	1.57
Loading	.10	940 to Portland	.94	1.69
	.65	1390 to Eureka, Cal.	1.39	2.14
Unloading	.10	1640 to San Francisco	1.64	2.39
	.75	2030 to San Pedro	2.03	2.78

No. 20—Sketches Nos. 3 and 15

Piledriver Bay, Shrubby Island, Kashevarof Islands, Clarence Strait.

East portion of island.

2000' beach outcrop.

15,000,000 tons 1-mile radius of dock site above sea level.

Chemical Analysis

Sample No.	Width & Wt. of Sample	Location and Color	$CaCO_3$	$MgCO_3$	Insol.	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	S
20	15 lbs. across 1600'	E. shore island to top — Brownish gray	94.6	3.57	0.54	53.0	1.70	0.40	0.10	.015	.028

Description and classification—

Brownish gray—highly fractured and friable—semi-crystalline.

Mottled with blackish streaks.

Calcite veinlets in fractures.

Two sets of fracturing.

Clay-filled fractures at surface.

Weathers to reddish brown.

Specific gravity—2.67.

Petrographic analysis—Same as No. 19.

Economic uses recommended—Same as No. 19.

Geological and Topographical Relations:

Age—Silurian.

Position—50′ to 100′ bluff few feet back from high tide—gradual rise to 600′ elevation.

Structure—Strikes NW.-SW. Low dip to northeast.

Relation—Entire island Silurian limestone underlain by andesitic volcanics. NW. - SE. faults and fractures. Zones cut by NE.-SW. fracturing.

Overburden—Medium timber growth, heavy brush and fragmental material with some soil.

Mining Method Applicable:

Open quarry with 100′ to 400′ backs.

Accessibility to Dock and Harbor Facilities:

Bluff 50′ to 100′ in height a few feet back from shore line.
Concrete dock with rock fill adjacent to 10-12 fathoms of water.
Fair harbor for small boats.
Beach ideal for power scow loading.

Water Power and Supply:

No water power on island.
Small camp water supply at dock site.

Camp Site: ....

Favorable adjacent to dock site.

Available Fuel:

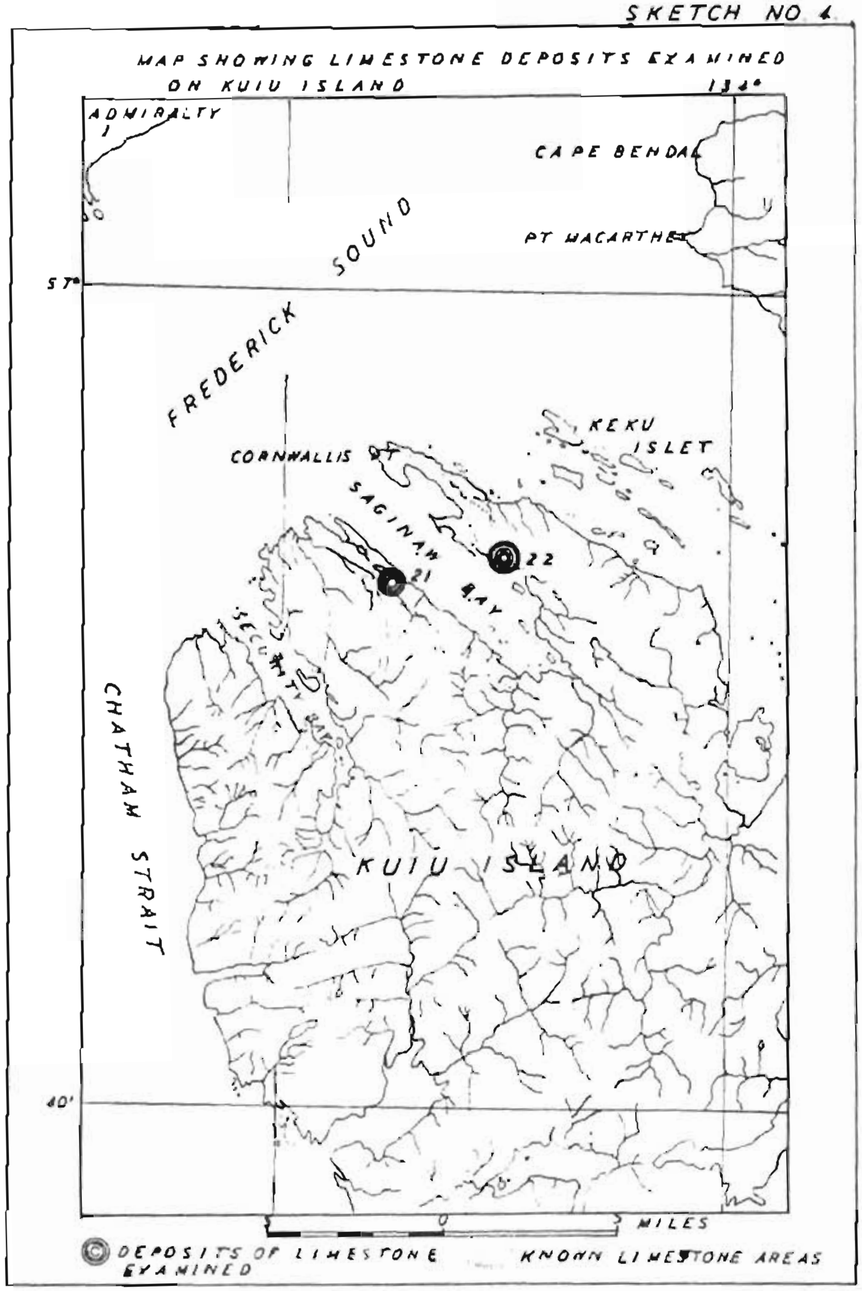
Surrounding area can furnish adequate lumber and camp fuel.

Estimated costs on 1000-ton daily production delivered 1½″ size to Pacific Coast ports 30% over pre-war cost figures.

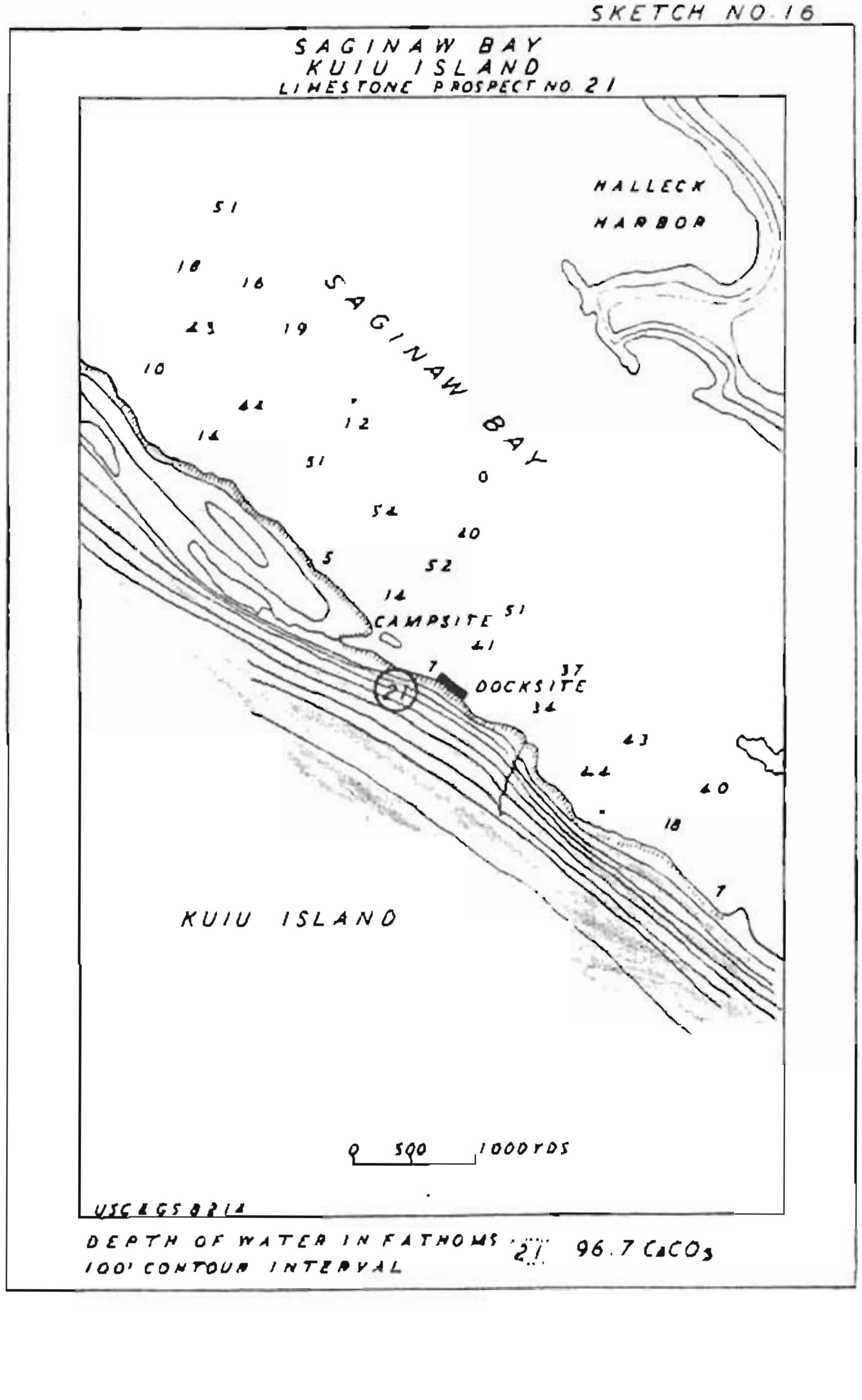
Mining	.40
Crushing	.15
Loading	.10
	.65
Unloading	.10
	.75

Miles at 0.001 per ton-mile		Total
820 to Seattle	.82	1.57
940 to Portland	.94	1.60
1390 to Eureka, Cal.	1.39	2.14
1640 to San Francisco	1.64	2.39
2030 to San Pedro	2.03	2.78

SKETCH NO. 4


MAP SHOWING LIMESTONE DEPOSITS EXAMINED
ON KUIU ISLAND
134°
ADMIRALTY I
CAPE BENDAL
PT MACARTHER
FREDERICK SOUND
57°
KEKU ISLET
CORNWALLIS PT
SAGINAW BAY
21
22
CHATHAM STRAIT
KUIU ISLAND
40'
MILES
0
DEPOSITS OF LIMESTONE EXAMINED
KNOWN LIMESTONE AREAS

SKETCH NO. 16


SAGINAW BAY
KUIU ISLAND
LIMESTONE PROSPECT NO 21
HALLECK
HARBOR
SAGINAW BAY
CAMPSITE
DOCKSITE
KUIU ISLAND
0 500 1000 YDS
USC&GS 8214
DEPTH OF WATER IN FATHOMS
100' CONTOUR INTERVAL
21 96.7 CaCO3

No. 21—Sketches Nos. 4 and 16

Saginaw Bay, Kuiu Island—west side opposite Halleck Harbor.
15,000-ft. beach outcrop.
1000′ thickness.
25,000,000 tons estimated within 1-mile radius.

Chemical Analysis

Sample No.	Width & Wt. of Sample	Location and Color	$CaCO_3$	$MgCO_3$	Insol.	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	S
21	15 lbs. across 1500′	Small bay W. shore — Light bluish buff to light gray	96.7	0.63	1.03	54.2	0.30	0.21	0.12	.011	.010

Description and classification—

Light buff to bluish gray.
Fractured and weathered seams.
Hard—breaks uneven.
Slightly friable.
Weathers angular and rough to light gray.
Specific gravity—2.69.

Petrographic analysis—Thin section reveals this limerock is highly fossiliferous with small percentage of oolites among other unidentified fossils. Recrystallization has consumed 40 percent of the volume with large crystals of calcite measuring up to 750 microns. The remaining volume consists of calcite grains and calcium carbonate grains up to 125 microns in size. A slight amount of veining and fracturing is present with a small amount of iron oxide staining. A few grains of silica or quartz are present and dolomite is indicated in minor amounts.

Economic uses recommended—Chemical and physical analyses indicate good burning limerock which, with the calcium content, would be favorable for the metallurgical, structural products and glass industries.

Geological and Topographical Relations:

Age—Silurian.

Position—Formation rises abruptly, with 50′ to 100′ bluff on beach line, to 800′.

Structure—Strikes northwesterly — low dip to northeast.

Relations—Deposit laid down upon non-conformity with Ordovician sediments to volcanics. Overlain by Devonian and Carboniferous sediments. Impure near base in contact with volcanics.

Overburden—Medium timber growth on part of deposit—other part covered by vegetation.

Mining Methods Applicable:

Ideal for open-bench quarry method or open-pit quarry.
Uniform grades in minable widths.

Accessibility to Dock and Harbor Facilities:

100′ to 150′ bluff—50′ to 100′ from high tide level, adjacent to 7 to 10 fathoms of water.
Underground storage, using belt conveyor for loading.
Ideal small boat harbor.

Water Power and Supply:

Water power—none.
Camp and mill water supply adequate, with small lake inland from camp site.

Camp Site:

Camp site available at head of small bay near dock site.

Available Fuel:

Medium growth of timber, adequate for lumber.

Estimated costs on 1000-ton daily production delivered 1½″ size to Pacific Coast ports 30% over pre-war cost figures.

Mining	.40
Crushing	.15
Loading	.10
	.65
Unloading	.10
	.75

Miles at 0.001 per ton-mile		Total
850 to Seattle	.85	1.60
970 to Portland	.97	1.72
1450 to Eureka, Cal.	1.45	2.20
1670 to San Francisco	1.67	2.42
2060 to San Pedro	2.06	2.81

No. 22—Sketch No. 4

Saginaw Bay, Kuiu Island—east side.
South of Halleck Harbor.
5000-ft. beach outcrop.
Tonnage not estimated.

Chemical Analysis

This limestone was found to contain abundant fossil remains together with considerable chert. The high percentage of fossils indicated a possible phosphate content which would make a favorable limerock for agriculture. The formation is of the Carboniferous age and very accessible to transportation.

Chemical analysis indicates it to be high in silica and to have a P^2O^5 content of nearly one percent. Therefore, the deposit cannot be classed as either a phosphate or high calcium limerock.

No. 23—Sketch No. 5

Towers Arm, Duncan Canal, Kupreanof Island.
West and east shores of bay.
Two miles of bluff, beach outcrop.
2000′ estimated thickness.
50,000,000 tons estimated within 1-mile radius.

Chemical Analysis

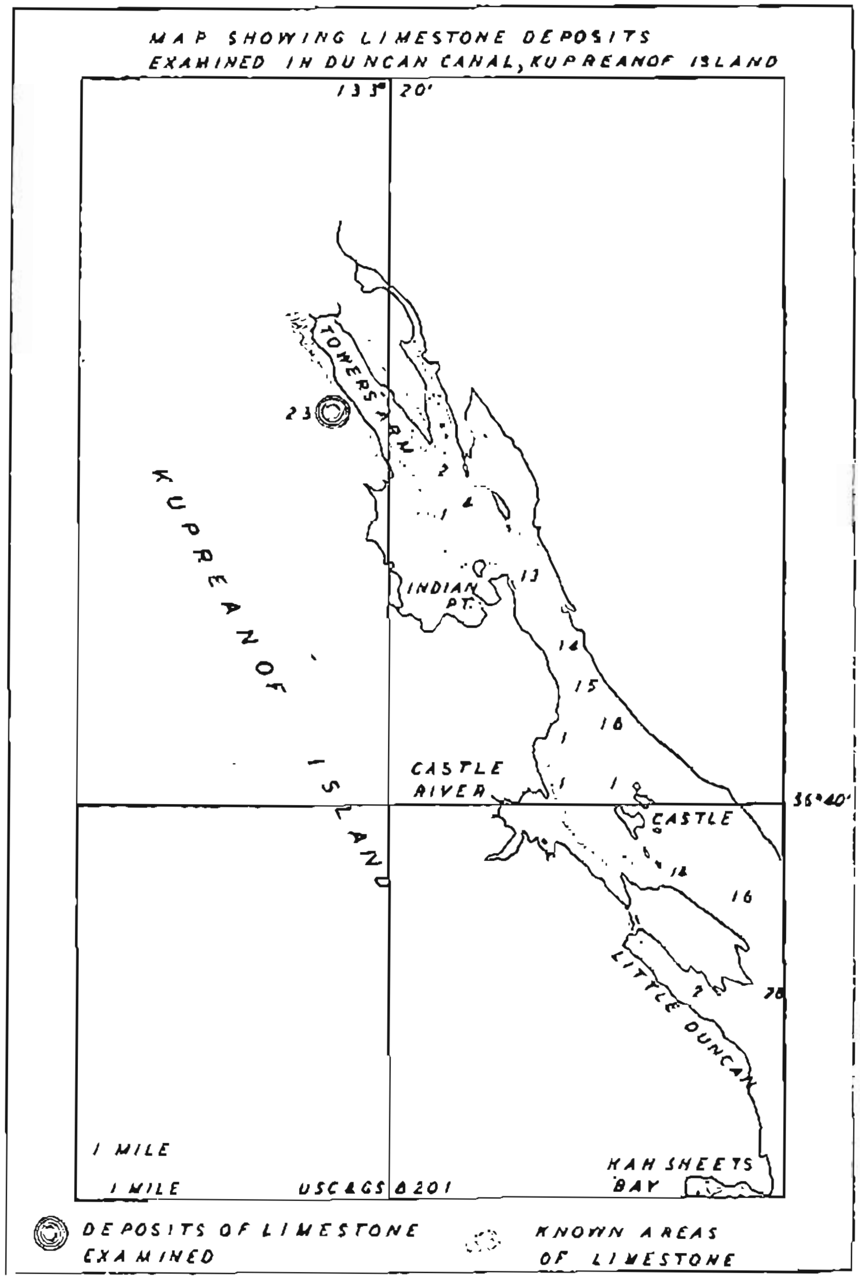
Sample No.	Width & Wt. of Sample	Location and Color	$CaCO_3$	$MgCO_3$	Insol.	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	S
23	20 lbs. over 2000′	West shore Towers Arm — Mottled dark gray	93.23	4.70	0.32	52.2	2.24	(1.07) (combined)		.287	.050

Description and classification—

Dark mottled gray, semi-crystalline and calcite-veined.
Intensely fractured and recemented.
Weathers to light gray.
Specific gravity—2.73.

Petrographic analysis—Thin section reveals that 60 percent of the volume of this limerock is recrystallized consisting of dis-

SKETCH NO. 5


MAP SHOWING LIMESTONE DEPOSITS
EXAMINED IN DUNCAN CANAL, KUPREANOF ISLAND
133° 20'
TOWERS ARM
KUPREANOF ISLAND
INDIAN PT.
CASTLE RIVER
CASTLE
LITTLE DUNCAN
KAH SHEETS BAY
1 MILE
1 MILE
USC&GS 8201
DEPOSITS OF LIMESTONE EXAMINED
KNOWN AREAS OF LIMESTONE

torted, curved and fractured calcite crystals showing considerable stress. The large crystals average in size between .1 and .2 mm. 34 percent of the volume consists of fine calcite grains measuring from 10 to 20 microns. Dolomite and iron oxide stains were the only impurities noted. Some veining in the fractures was noted.

Economic uses recommended—Favorable burning results are much in doubt. This limerock is suitable for agricultural purposes.

Geological and Topographical Relations:

Age—Middle Devonian.

Position—Two miles of outcropping bluffs, 50′ to 100′ in height along shore line. Rises to elevation of 300′ to 400′.

Structure—Strike NW.-SE. Dip NE. Highly complex folded area.

Relations—Deposit underlain by andesitic volcanics, slates and green schists. Overlain by graywacke and cherty series.

Overburden—Medium timber growth and considerable brush—some subsoil.

Mining Methods Applicable:

Open-cut quarry method—backs up to 300′.

Accessibility to Dock and Harbor Facilities:

Accessible only to power scow or shallow-draft barge at high tide only—mud bottom.
Poor small boat harbor.

Water Power and Supply:

Power—none in immediate vicinity.
Sufficient water for camp supply.

Camp Site:

Point at mouth of Towers Arm.

Available Fuel:

Medium growth of timber adequate for lumber and fuel. Estimated costs on 1000-ton daily production delivered

1½" size to Pacific Coast ports 30% over pre-war cost figures.

Mining	.40	Miles at 0.001		
Crushing	.15	per ton-mile		Total
Loading	.15			
	.70	840 to Seattle	.84	1.64
Unloading	.10	960 to Portland	.96	1.76
	.80	1410 to Eureka, Cal.	1.41	2.21

BIBLIOGRAPHY

United States Geological Survey Publications

1. Brooks, A. H., Preliminary Report on the Ketchikan Mining District, Alaska: Prof. Paper No. 1, 1902.
2. Wright, F. E. & C. W., Economic Development in Southern Alaska: Bull. 259, 1905.
3. Wright, C. W., Non-metallic Deposits of Southeastern Alaska: Bull. 284, 1906.
4. Wright, C. W., Non-metalliferous Mineral Resources of Southeastern Alaska: Bull. 314, 1907.
5. Wright, C. W., The Building Stones and Materials of Southeastern Alaska: Bull. 345, 1908.
6. Wright, F. E. & C. W., The Ketchikan and Wrangell Mining Districts, Alaska: Bull. 347, 1908.
7. Burchard, E. F., Marble Resources of Ketchikan and Wrangell Districts, Alaska: Bull. 542, 1913.
8. Chapin, Theodore, Mining Development in Southeastern Alaska: Bull. 642, 1916.
9. Burchard, E. F., Marble Resources of Southeastern Alaska: Bull. 682, 1920.
10. Buddington, A. F., Mineral Investigations in Southeastern Alaska: Bull. 783-B, 1924.

11. Buddington, A. F., & Chapin, T., Geology and Mineral Deposits of Southeastern Alaska: Bull. 800, 1929.

United States Bureau of Mines Publications

12. Bowles, O., & Banks, D. M., Limestone, Pt. I: I. C. 6723, 1933.

13. Bowles, O., & Banks, D. M., Lime: I. C. 6884, 1936.

14. Wilson, H., & Skinner, K. G., Occurrence, Properties and Preparation of Limestone and Chalk for Whiting: Bull. 395, 1937.

15. Bowles, O., & Coons, A. T., Graphic Survey of the Lime Industry: I. C. 7088, 1939.

16. Bowles, O., & Banks, D. M., Lime: I. C. 6884-R, 1941.

17. Bowles, O., & Tucker, E. M., Trends in Consumption and Prices of Chemical Raw Materials and Fertilizers: I. C. 7320, 1945.

Other Publications

18. Grout, Frank F., Petrography and Petrology: McGraw-Hill, Second Impression, 1932.

19. Hodge, E. T., Limestones of the Pacific Northwest, 1944.

20. National Lime Association, Lime in Agriculture: Bull. 190, 1939.

21. Cannon, J. Q., Jr., Standards and Specifications for Nonmetallic Minerals and their Products: No. 110, National Bureau of Standards, 1930.