Bureau of Mines
Report of Investigations 4932

PRELIMINARY REPORT:

NONMETALLIC DEPOSITS ACCESSIBLE TO THE ALASKA RAILROAD AS POSSIBLE SOURCES OF RAW MATERIALS FOR THE CONSTRUCTION INDUSTRY

BY F. A. RUTLEDGE, R. L. THORNE, W. H. KERNS,
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United States Department of the Interior—March 1953

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by

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SUMMARY

As a part of the United States Department of the Interior program for the development and use of Alaska raw materials, the Bureau of Mines is conducting an investigation of deposits of nonmetallic minerals accessible to the Alaska Railroad for use in building materials in the Alaska Railroad-belt area. The results of the investigations, to date, indicate that raw materials for the production of brick products are in plentiful supply as clay in the Anchorage area, as fire clay at Sheep Mountain, and as shale in the Healy Creek coal formations near Healy, Alaska.

Lightweight Aggregate

Shale for the production of lightweight aggregate or Haydite occurs near mile 67 on the Glenn Highway, and preliminary tests give excellent results. Physical tests are now in progress on commercial-size concrete building units made with this aggregate. Another shale deposit in the same formation was located at mile 16 on the Matanuska Branch of the Alaska Railroad, and preliminary tests give comparable results.

Natural lightweight aggregate in the form of pumice and pumicite occurs in Katmai National Monument and has been used with excellent results in lightweight-building units in Anchorage and Fairbanks. These deposits will be investigated in more detail by the Bureau of Mines during 1952.

One small perlite deposit near Healy, Alaska, showed excellent expanding properties, and the product compares favorably with commercial perlites being used in the States for plaster and concrete aggregates. Additional investigation by the Bureau of Mines to delimit the known occurrence and, if possible, discover others were planned for the 1951 field season.

Pozzolan

The pumice from Katmai National Monument also was considered for use as a pozzolan in pozzolan-portland concrete. Tests by the Bureau of Reclamation indicate that the pumice sample submitted by the Bureau of Mines would be satisfactory in strength development but is not outstanding. Natural activity is good and is greatly improved by calcination at 1,400° F. Water requirements and shrinkage also are satisfactory. However, the material is ineffective in reducing expansion owing to alkali-aggregate reaction; and, if reactive aggregate is used to make concrete, it would not insure against excessive expansion. An attempt will be made during the 1952 field season to delimit pumicite deposits along the Alaska Peninsula more amenable for use in pozzolan-portland concrete.

Rock-Wool Insulation

Because the Railroad belt has such a rigorous climate, insulation for new construction is of prime importance. During the Bureau of Mines, investigation of building materials all samples were submitted for chemical analyses as possible sources of raw materials for the production of rock wool, one of the best insulation mediums. Four areas having deposits of the required constituents were located as follows; Anchorage area, with Potter limestone and argillite; Cantwell-Windy area, with limestone and shale; West Fork of the Chulitna River area, with limestone and agrillite; and Homer-Seldovia area, with Seldovia limestone and Homer clay. It was planned to take bulk samples of these formations and submit them for testing during the 1951 field season.

Cement

Investigation of raw materials for the local production of cement was given high priority in the Bureau of Mines program. Information from the principal large consumers of cement in Alaska indicate that Portland cement is specified for most types of concrete construction, The maximum content of magnesia in Portland cement is 5.0 percent MgO, which limits the magnesia in the limestone to 3.3 percent.

A limestone deposit in the Windy area near mile 323.1 on the Alaska Railroad was drilled and sampled by the Bureau of Mines from 1948-50, inclusive. Analyses of the samples indicate that distribution of magnesia in the limestone is extremely erratic and that most of the deposit is too high in magnesia content for manufacture of portland cement. Even the best beds contain sections in which the magnesia content is above the allowable limit. These sections could not be used unless large tonnages are mined and thoroughly mixed, with the grade of magnesia closely controlled.

Preliminary samples of a limestone deposit on the West Fork of Windy Creek near Foggy Pass indicate a large tonnage of good-grade limestone. The magnesia content of the limestone is within the limits of that required for the manufacture of Portland cement. This deposit was to be channel sampled during the 1951 field season. Diamond drilling was to follow if justified by the results of the channel samples.

Shale to furnish the argillaceous component necessary for the production of cement is plentiful in the Cantwell-Windy area. Preliminary samples indicate that many of the beds contain magnesia within the limits allowed for producing portland cement.

The alkali content of portland cement is not necessarily specified unless so desired by the purchaser. Maximum combined alkalies (Na_2O plus 0.658 K_2O) allowed when a low-alkali cement is specified is 0.60 percent. Most of the shale sampled in the Cantwell-Windy area, while suitable for portland cement in other respects, contains more alkali than allowed if a low-alkali cement is to be produced. Argillaceous materials were to be sampled during the 1951 field season to locate a supply of shale suitable for use in the production of low-alkali portland cement.

There is no known deposit of gypsum in the Alaska Railroad belt capable of furnishing gypsum for a cement plant. A gypsite deposit at Sheep Mountain on the Glenn Highway contains numerous small lenses of gypsum, but the lenses are too small and inaccessible to be economically attractive.

Aggregate

The Alaska Railroad area is extremely fortunate in having an abundant source of aggregate. The Bureau of Mines made no attempt during this investigation to sample or inventory the sand and gravel deposits in the Railroad belt. They are very plentiful and widespread, and it is almost impossible to find an area without a local supply of sand and gravel.

INTRODUCTION

Construction in Alaska has depended almost entirely on imported supplies, especially where the construction materials are of mineral origin; the exception is local use of sand, gravel, and some pumice. Both military and federal authorities have agreed that the use of local sources of building materials would benefit the stability and economy of the Alaska Railroad belt and should reduce materially the high cost of construction.

The United States Department of the Interior was instrumental in formulating a policy of development for the Alaska raw materials. The first part of this program consisted of having all Government bids for future construction include alternates that would provide for use of local materials where available; thus the local producers would have a chance to compete with the imported materials normally used. The second part of the program was directed toward ascertaining the potentialities of local resources of building materials and their use in the construction program. The Geological Survey was designated as the agency undertaking the preliminary exploration of the sources of nonmetalliferous raw materials. The program of the Bureau of Mines described by this report was directed toward development of the several deposits and the chemical analyses, fabricating tests, and other physical tests that were required to determine their capabilities.

The Bureau of Mines building-materials program was continued during the 1951 and 1952 fiscal years. In order that the data already obtained may be made available to the public, this preliminary report has been prepared. Each of the commodities listed above, with a brief resume of its properties and uses, is covered in this report. The various deposits investigated under each classification of raw materials are given for each commodity.

ACKNOWLEDGMENTS

The principal objective of the investigations described in this report was to determine the potentialities of local nonmetallic mineral deposits as sources of raw materials for the increased construction program, military, governmental, and civilian, in the Alaska Railroad belt, which was only a small part of the Department of the Interior program of development for Alaska.

K. J. Kadow, Alaska Field Staff, headed the Department's program and ably coordinated the various contributing agencies. He assembled much useful information on estimates of probable building-materials requirements and served as liaison between the different agencies.

There were many ramifications of the problem of determining the capabilities of the varied construction materials and the deposits containing the raw materials of the proper qualities for their production. Testing was diversified, and numerous divisions and branches of the Bureau of Mines were called upon to assist. Acknowledgments are made to the following stations and personnel for data contained in this report:

Northwest Experiment Station	H. F. Yancey Hal J. Kelly Earle G. Strandberg	Ceramic tests.
Salt Lake City Station	H. E. Peterson	Analyses.
Electrotechnical Laboratory	Hewitt Wilson E. F. Nichols	Bloating tests.
Mississippi Valley Experiment Station	R. G. Knickerbocker	Mineral wool.
Southwest Experiment Station	J. Bruce Clemmer	Perlite.

S. H. Lorain, Regional Director, supervised all Bureau of Mines activities in Alaska. Field work of the Mining Division was under the direction of G. D. Jermain, chief, until August 1950 and of J. A. Herdlick, chief, thereafter.

Special acknowledgment is made for the use of numerous bulletins and reports by the Geological Survey on the geology and deposits along the Alaska Railroad. Particular mention is made to the cooperation received from George O. Gates, geologist in charge, San Francisco Office, and the following geologists; E. H. Cobb, Robert Fellows, Clyde Wahrhaftig, W. S. Twenhofel, and R. M. Moxham.

Samples of pumice were tested for their pozzolanic qualities by the Bureau of Reclamation at Denver, Colo. Acknowledgment is given also to S. E. Hutton of the Bureau of Reclamation for a survey of the processing of raw materials for cement and determination of the specifications for the raw materials.

The Alaska Railroad was of great assistance to the Bureau of Mines during its program. Equipment and transportation of personnel were furnished without charge on several phases of the investigation. Since equipment was in short supply, this cooperation by the railroad and especially that given by the general manager, Col. J. P. Johnson, made possible certain parts of the program that otherwise would have been delayed until the following field season.

Arthur F. Waldron, president, Anchorage Sand & Gravel Co., furnished the Bureau of Mines with the results of its investigation of sources of material for the production of Haydite in the Anchorage area, which materially expedited the Bureau of Mines program in this field.

Acknowledgment is made also to Leo H. Saarela, commissioner, Alaska Territorial Department of Mines, for reports on nonmetallic deposits by that agency.

PROBLEM AND OBJECTIVE

Before any development program for a building-materials industry in Alaska was begun, several factors had to be considered, including the sources of raw materials of the proper quantity and grade, favorable location of plant sites, competent labor supply, and above all an adequate market for the finished product. The estimate of the probable markets for construction materials in the Railroad belt was a prerequisite for a well-planned development program.

The largest consumer of building materials in Alaska is the Government, either directly by military and government agencies or by civilian government-financed construction. At a building-materials conference at Fort Richardson, Alaska, May 9, 1950, with K. J. Kadow, director, Alaska Field Staff of the United States Department of the Interior, presiding, data were assembled on the estimates of building materials of mineral origin that would be required for construction in the Railroad belt during the next 6 years. This was the first time any advance information on quantities of required materials had been assembled. The various estimates are listed as follows:

Housing Agencies; Estimated Needs

3,000 units average 800 sq. ft. each per year[1]

Material	Unit	1951[2]	1952 - 56
Cement for foundations, slabs, and walks	Bbl.	56,000	24,000
Cement for foundation walls, or	do.	40,000	17,600
Blocks - with basements	8-8-16	3,500,000	1,500,000
Cement for foundation walls, or	Bbl.	20,000	9,600
Blocks - without basements	8-8-16	1,575,000	775,000
Brick (1/10 homes possible)	Each	7,000,000	3,000,000
Chimneys	Block	180,000	72,000
Do.	Brick	2,000,000	1,000,000
Fireplaces (in 1/10 homes)	Fire brick	42,000	18,000
Flue liners	1 per ft.	168,000	72,000
Insulation materials	Sq. ft.	17,500,000	7,500,000
Drain tile	Feet	125,000	125,000

Note: The above breakdown is purely an estimate. It would be up to local producers to create the actual demand for their products.

[1] This is entire Alaska program, with bulk of it expected in Railroad belt.

[2] Includes 3,500 housing units for the military personnel not listed elsewhere.

Alaska Road Commission - building-Materials Estimate1/

Material	Unit	1951 - 56
Cement..	Bbl.	2,000 to 4,000

1/ Program based on $25,000,000 annually and mostly confined to Railroad belt.

Alaska Railroad Estimate of Materials Need1/

Item	Unit	1951	1952	1953 - 56 (per yr.)
Cement..........................	Bbl.	8,000	8,000	3,000
Insulation.......................	Tons	15	15	5

1/ Entire program in Railroad belt.

General Services Administration Estimate of Building-Material Needs1/

Material	Unit	1951	1952 - 56 (per yr.)
Brick	Each	167,000	167,000
Block	do.	833,000	833,000
Cement.........................	Bbl.	83,500	83,000
Insulating materials...........	Sq. ft.	1,833,000	1,833,000
Lime and plaster...............	Tons	83	83
Sewer pipe.....................	Lin. ft.	116,670	116,670
Tile...........................	Each	3,330	3,330

1/ Program based on $10,000,000 per year with an estimated 60 percent of the program in the Railroad belt.

2/ Brick and block meeting Federal specifications will be acceptable. In many buildings estimated above as requiring block, brick will be listed as an alternate if available locally.

Bureau of Reclamation - building-materials estimated1/

Material	Unit	1951	1952	1953	1954	1955	1956
Insulation....	Sq. ft.	50,000	0	0	250,000	0	0
Cement........	Bbl.	650	1,800	1,100	31,000	146,000	465,000
Tile..........	Lin. ft.	4,000	0	0	0	0	0
Pozzolan......	Tons	0	75	0	1,450	6,800	26,500

1/ 90 percent listed above confined to Railroad belt.

Military Estimates

The military requirements are summarized in table 1.

The above estimates are not in any way stated to be anything but an appraisal of the probable building materials required as of May 9, 1950. Since that time (May 1951), the civilian-building program has been curtailed as a result of the world political situation. However, the construction by the military organizations has been expanded; consequently, the total estimated requirements should be approximately the same or even greater.

TABLE 1. - Summary of military requirements for building materials in Alaska (fiscal years)[1]

Material	Unit	1951	1952	1953	1954	1955	1956	Total
Cement...........	Bbl.	166,000	84,500	70,500	43,250	29,250	29,250	422,750
Brick............	Each	95,000	65,000	60,000	50,000	45,000	45,000	360,000
Sewer pipe........ (vitrified clay).	Lin. ft.	63,000	33,000	28,000	16,000	11,000	11,000	162,000
Lime and plaster.	Tons	75	45	33	23	18	18	212
Gypsum...........	Lb.	6,000	3,000	2,500	1,500	1,000	1,000	15,000
Insulation.......	Sq. ft.	4,929,000	2,528,300	2,127,700	1,326,300	926,300	926,300	12,763,900
Sewer pipe....... (concrete)	Lin. ft.	128,000	68,000	58,000	9,000	26,000	26,000	315,000
Concrete block[2].	Each	2,101,000	1,051,000	875,500	525,500	350,500	350,500	5,254,000
Pumice block[2]...	do.	300,000	150,000	125,000	75,000	50,000	50,000	750,000

[1] Based on following amounts of new construction and divided between Anchorage and Fairbanks as shown:

Year	$Millions	Anchorage, percent	Fairbanks, percent
1951	50	55	45
1952	25	40	60
1953	20	40	60
1954	15	50	50
1955	10	50	50
1956	10	50	50

[2] Any aggregate meeting Federal Specifications SS-C-621, type I and II, is acceptable.

On the basis of the foregoing estimates of requirements and on the basis of reconnaissance estimates of raw mineral materials that might be available in the Railroad belt, the Bureau of Mines program was designed to investigate the commodities listed below:

Commodity	Raw material
Brick and clay products	Clay. Shale.
Lightweight aggregate	Clay (Haydite). Shale (Haydite). Loess (Haydite). Argillite (Haydite). Pumice. Perlite.
Pozzolan	Pumice.
Mineral wool	Clay, shale, limestone, argillite, and conglomerate
Cement	Limestone, shale, and gypsum.
Aggregate	Sand. Gravel.

LOCATION AND ACCESSIBILITY

The Alaska Railroad was built to give access to the interior of Alaska throughout the year. Previously, transportation was seasonal because trails were impassable during the spring thaws and fall freeze-ups and water transportation on the rivers could be used only during the summer months. The Alaska Railroad was completed in 1923. It connects Fairbanks to the coast at Seward.

Figure 1 is an index map of Alaska, showing the location of the Alaska Railroad. The main surface transportation routes are shown in figure 2. Many towns and cities of Alaska now are served by well-maintained highways, but the Alaska Railroad is still the principal means of transportation from Seward to Fairbanks. For many places within the Railroad belt, it is the only method of transportation; several mining districts not on the highway routes but adjacent to the railroad are accessible only by short roads to stations on the Alaska Railroad.

Some of the principal stations on the railroad and the mileages from Seward are listed in table 2.

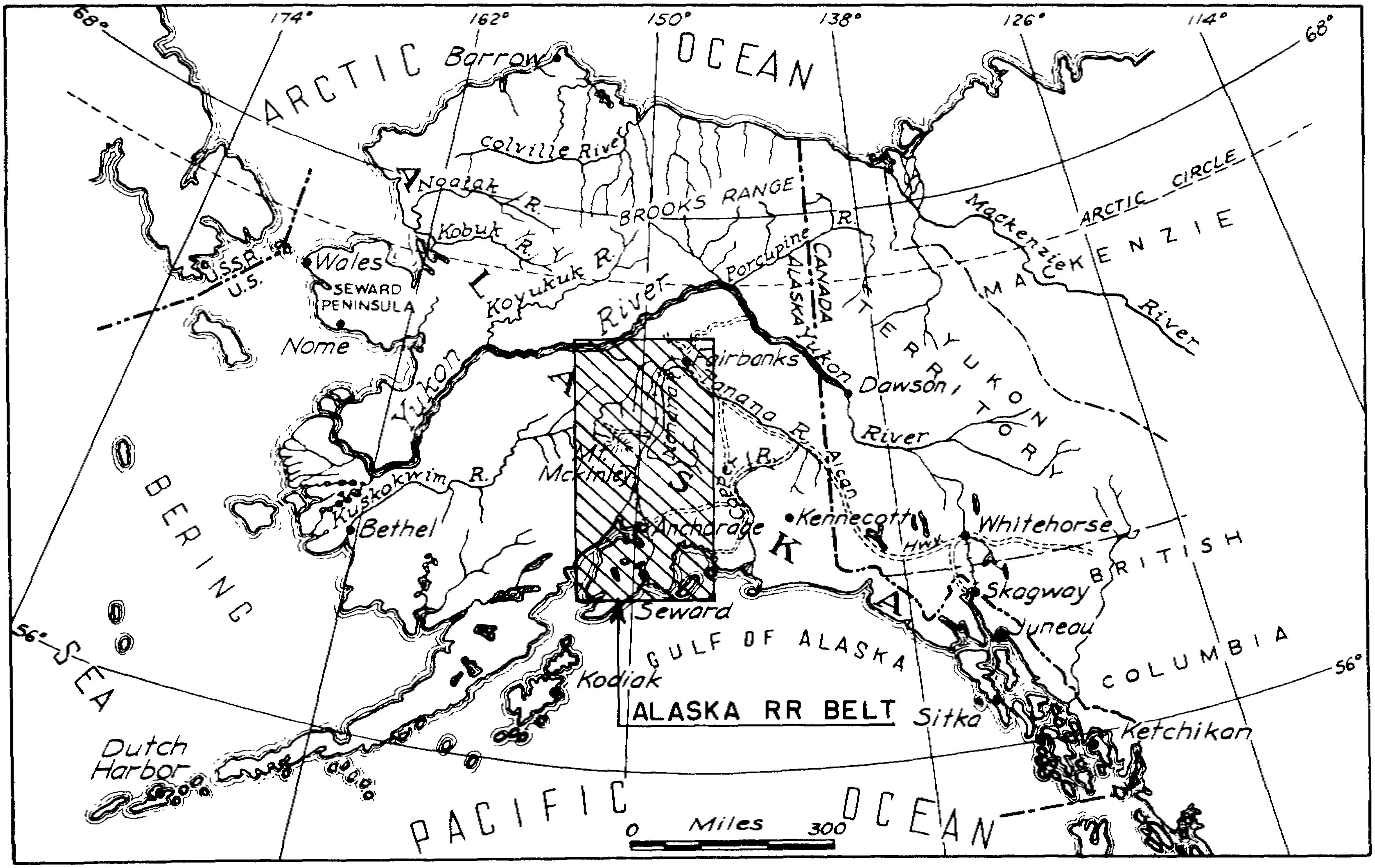

Figure 1. - Index map of Alaska.

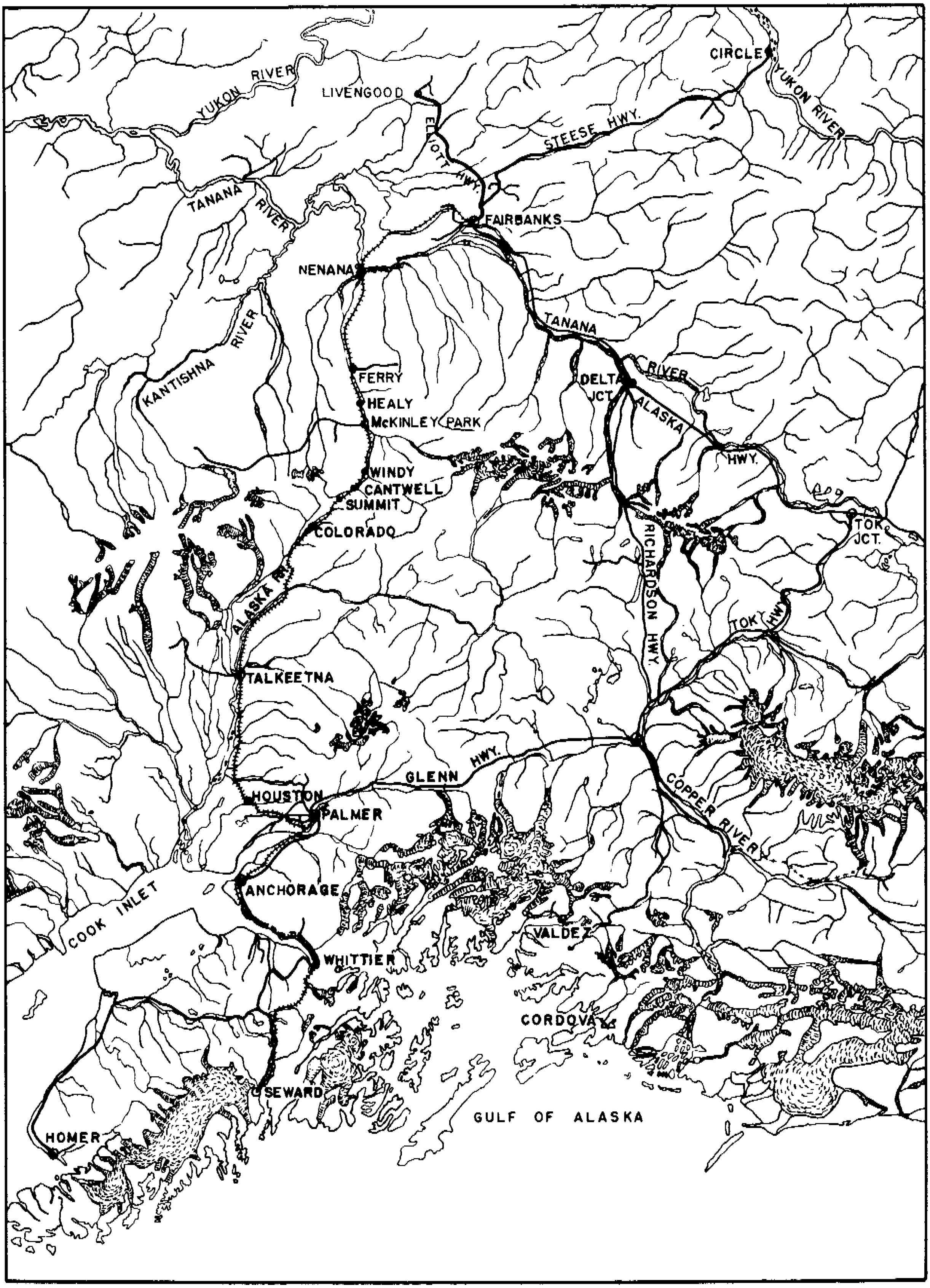

Figure 2. - Transportation routes in central Alaska.

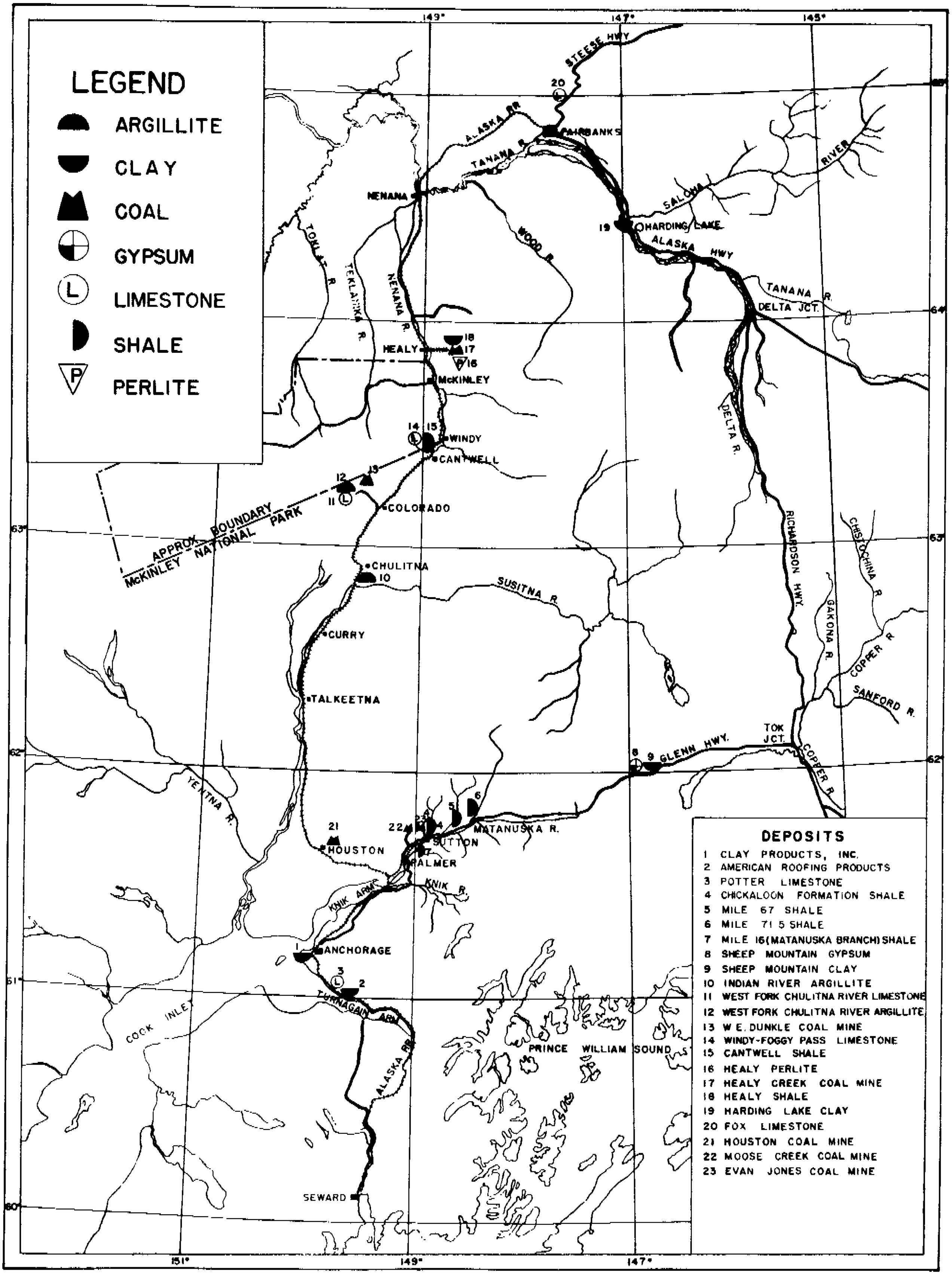

Figure 3. - Nonmetallic deposits in the Railroad belt.

TABLE 2. - Stations on the Alaska Railroad

Station	Miles from Seward	Elevation, feet	Population[1]	
			Town	District
Seward	0.0	20	2,063	2,653
Girdwood	74.8	40	-	-
Anchorage	114.3	38	11,060	31,561
Matanuska	150.7	36	-	-
Palmer[2]	156.7	300	-	2,511
Wasilla	159.8	339	-	576
Talkeetna	226.7	354	-	417
Curry	248.5	546	-	-
Broad Pass	304.3	2,127	-	-
McKinley Park	347.9	1,732	-	341
Healy	358.1	1,368	-	-
Nenana	411.7	362	239	697
Fairbanks	470.3	448	5,625	19,128

1/ Census figures for 1950, not complete.
2/ On branch line from Matanuska.

The location of each of the deposits investigated during the Bureau of Mines program is shown in figure 3.

PHYSICAL FEATURES AND CLIMATE

No attempt will be made in this report to record in minute detail the geography of the Alaska Railroad belt. Only a brief outline of the physical features of the area traversed by the railroad will be given, but a more detailed description of the area may be found in a report by Stephen R. Capps.[2]

The Alaska Railroad in its course from tidewater at Seward to Fairbanks in the interior, traverses the Pacific Mountain region of Alaska and enters the Central Plateau region.

After leaving Seward on Resurrection Bay, the railroad follows Snow Creek and crosses the Kenai Mountains to the head of Turnagain Arm. Following along the north shore of Turnagain Arm, the railroad traverses the Chugach Mountains, an extension of the Kenai Mountains. Together, the Kenai and Chugach Mountains form the south spur of the continuation of the Pacific mountain system.

From Anchorage, the railroad skirts the east shore of Knik Arm along the north flank of the Chugach Mountains to the head of Knik Arm. From the head of Knik Arm, the railroad follows up the valleys of the Susitna and Chulitna Rivers between Talkeetna Mountains and the Alaska Range. The Alaska Range forms the north continuation of the Pacific Mountain system and joins the south spur in the Wrengell Mountains.

At Summit on the Alaska Railroad, the railroad follows the old course of the Susitna glacier through Broad Pass into the valley of the Nenana River. Following down the Nenana River, the railroad traverses the Alaska Range and

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[2] Capps, Stephen R., Geology of the Alaska Railroad Region: Geol. Survey Bull. 907, 1940, 201 pp.

enters the Central Plateau region of Alaska, which is drained by the Yukon and Tanana Rivers.

Most of the Alaska Railroad belt shows the effects of glaciation. U-shaped and hanging valleys are common from Seward north to the northern flank of the Alaska Range. Only the Central Plateau region is unglaciated.

Vegetation throughout the region varies. Along the lowlands and valley floors are forests of spruce, hemlock, birch, poplar, and aspen. At higher altitudes, willows and alders with mosses and grasses mantle the slopes. Much of the interior is covered only by the vegetation typical of the tundra - mosses, grasses, and low shrubs.

The climate of the Railroad belt adjacent to the ocean and to Cook Inlet is characterized by mild winters and cool summers. Monthly and annual mean temperatures for several stations within this area are in table 3. Freezing temperatures may be expected from early in September until late in June. Rainfall is moderate but not excessive. Table 4 gives the monthly and annual mean precipitation, in inches, for the same stations listed in table 3. Table 5 lists other miscellaneous data.

The climate of interior valleys of Alaska is characterized by great extremes in temperature between summer and winter and by light to moderate precipitation. Summers are short and hot, and the winters are cold and long. Freezing temperatures may be expected from the middle of August to the end of June.

TABLE 3. - Average temperatures, °F., for stations within the railroad belt[1/]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Seward....	23.4	27.6	30.9	37.6	44.6	51.2	55.3	54.5	49.0	40.3	31.1	24.9	39.2
Anchorage.	11.6	18.6	23.7	35.4	45.0	53.5	57.0	55.6	47.8	36.0	22.4	13.3	35.0
Wasilla...	12.2	17.9	24.1	34.4	46.3	53.4	56.2	54.0	46.2	35.3	21.4	11.3	34.3
Palmer[2/]..	15.4	8.7	32.4	34.1	46.6	51.2	56.2	55.6	50.3	36.7	28.3	13.5	35.8
Matanuska.	13.3	18.7	24.5	36.2	46.8	55.2	57.5	55.3	48.0	36.4	21.9	13.4	35.6
Caswell[2/].	6.4	-1.0	26.4	31.0	45.6	53.1	58.6	57.6	50.9	33.3	21.2	-3.5	31.6
Talkeetna.	9.0	16.7	20.6	33.3	44.8	54.8	57.9	54.7	46.2	34.2	19.6	9.6	33.5
Summit....	4.3	8.9	11.4	22.6	37.2	49.3	52.1	48.3	40.5	25.5	8.7	2.5	25.9
McKinley Park....	3.0	7.8	12.9	26.6	41.5	52.6	54.7	50.7	41.9	27.1	11.0	3.3	27.7
Nenana....	-8.2	.2	8.8	27.2	46.1	57.9	60.6	55.7	44.3	27.1	4.3	-7.4	26.4
Fairbanks.	-11.3	-1.2	9.6	29.4	46.9	58.8	58.0	55.1	43.6	26.6	3.4	-8.0	25.9

[1/] 1949 only.

[2/] Weather Bureau, U. S. Department of Commerce, Climatological Data, Alaska: Annual Summary 1949, vol. 35, No. 13, 1950.

TABLE 4. - Precipitation for stations within the railroad belt, in inches[1]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Seward...	5.40	5.50	3.32	4.33	3.43	2.37	2.93	6.13	9.63	10.88	7.22	6.74	68.38
Anchorage	.82	.67	.55	.41	.50	.70	1.63	2.60	2.58	2.18	1.04	.86	14.56
Wasilla..	1.25	.82	.87	.39	.72	1.89	1.15	3.31	2.87	1.76	.86	.95	17.84
Palmer[2].	2.26	.89	.54	.82	.18	5.81	3.07	3.37	2.52	1.04	.31	.66	21.47
Matanuska	.91	.73	.55	.42	.68	1.27	1.97	2.88	-	1.74	-	1.00	-
Caswell[2]	7.39	1.51	2.79	2.03	.87	3.43	2.32	3.73	3.78	1.95	1.49	2.17	33.46
Talkeetna	1.87	1.90	1.92	.91	1.27	1.66	3.53	5.23	4.94	3.58	1.77	1.79	30.37
Summit...	1.07	1.94	1.48	.48	1.08	2.31	3.24	3.70	3.40	1.75	.88	1.37	21.89
McKinley Park...	.86	.61	.42	.70	.85	2.05	2.36	2.81	1.60	1.04	.68	.60	14.58
Nenana...	.64	.48	.56	.35	.70	1.31	2.91	1.54	1.21	.72	.49	.44	11.35
Fairbanks	.95	.46	.66	.30	.62	1.35	1.89	2.05	1.27	.84	.69	.63	11.71

[1] Weather Bureau, U. S. Department of Commerce, Climatological Data, Alaska: Annual Summary, 1949, vol. 35, No. 13, 1950.

[2] 1949 only.

TABLE 5. - Miscellaneous data, railroad belt[1]

	Elevation	Highest	Date	Lowest	Date	Freezing temperature		Length of growing season, days
						Last date in spring	First date in autumn	
Seward....	76	75	Aug. 10	-6	Jan. 7	May 11	Oct. 16	158
Anchorage.	134	78	July 5	-27	Feb. 9	May 7	Oct. 4	150
Wasilla...	330	80	Aug. 28	-	-	June 30	Sept. 9	71
Palmer[1]..	300	76	July 5	-25	Jan. 7	May 18	Sept. 29	134
Matanuska.	150	77	July 5	-30	Dec. 24	June 4	Sept. 29	117
Caswell[1].	290	90	Aug. 3	-37	Jan. 7	June 30	Aug. 14	45
Talkeetna.	345	77	July 5	-42	Feb. 8	June 30	Sept. 16	78
Summit....	2,401	73	July 9	-28	Jan. 7	June 26	Sept. 13	79
McKinley Park....	2,092	79	July 9	-32	Dec. 30	June 30	Aug. 15	46
Nenana....	358	81	July 7	-50	Feb. 17	May 15	Aug. 15	92
Fairbanks.	436	85	July 10	-46	Feb. 10	May 15	Sept. 9	117

[1] Weather Bureau, U. S. Department of Commerce, Climatological Data, Alaska: Annual Summary, 1949, vol. 35, No. 13, 1950.

HISTORY AND PRODUCTION

The Alaska Railroad was begun by private interests in 1903 to serve as a link between ocean transportation at Seward, Alaska, and the newly discovered gold placer-mining districts at Fairbanks and along the Yukon River and its tributaries in interior Alaska. After construction had progressed some distance north from Seward, the project was abandoned. In 1915, construction was resumed by the government, and the railroad was completed in 1923.

Until recently, metal mining was the major important basic industry in the area tributary to the Alaska Railraod. The value of the Mineral production from this region is listed in tables 6 and 7.

TABLE 6. - Mineral production from the area served by the Alaska Railroad up to and including 1949

	Up to and including 1936 (Geol. Survey Bull. 907)	1937-49 (incl.)	Up to and including 1949
Gold:			
Placers......................	$126,188,000	1/$60,416,000	1/$186,604,000
Lodes2/......................	12,517,300	3/13,925,000	3/26,442,300
	138,705,300	74,341,000	1/3/213,046,300
Silver (mainly from alloys with gold........................	845,000	4/	845,000
Coal...........................	9,835,000	21,651,000	31,486,000
Miscellaneous, including lead, antimony, tungsten, copper5/, and other products...........	225,000	6/468,000	693,000
	149,610,300	96,460,000	246,070,300

1/ Includes placer silver.
2/ Does not include production from Prince William Sound and Nuka Bay districts.
3/ Includes lode silver, copper, lead, and zinc.
4/ Included with gold.
5/ Does not include production from Prince William Sound district.
6/ Antimony only; all other miscellaneous included with lode gold.

TABLE 7. - Placer-gold production from the area served by the Alaska Railroad up to and including 1949

Districts	Region	Up to and including 1936 (Geol. Survey Bull. 907)	1937-49 (incl.)	Up to and including 1949
Valdez Creek, Willow Creek and Yetna-Cache Creek..........	Cook Inlet-Susitna	$3,730,600	1/$1,860,000	1/$5,590,600
Moose Pass-Hope and Turnagain Arm-Girdwood.............	Kenai Peninsula	2,213,200	1/56,000	1/2,269,200
Bonnifield-Nenana, Fairbanks, Hot Springs, Kantishna, Rampart, and Tolovana.............	Yukon River Basin	120,244,200	1/58,500,000	1/178,744,200
		126,188,000	1/60,416,000	1/186,604,000

1/ Placer silver included.

Beginning with the Japanese invasion of the Aleutian Islands in 1941, receiving renewed impetus as a result of the Korean War, the construction of military installations and housing within the Railroad belt has induced a large and rapid increase of population. The resulting demand for large quantities of construction materials has placed a heavy burden on transportation facilities. Furthermore, the necessity for importing large quantities of normally low-priced building materials has increased their delivered cost to the projects in Alaska by the transportation cost, an appreciable amount. This required use of high-cost building materials has imposed a heavy financial burden on all construction projects in the area.

GENERAL GEOLOGY

The area now served by the Alaska Railroad has been explored many times since Capt. James Cook sailed into Turnagain Arm in 1778. Investigations by the Geological Survey were begun in 1898, and field parties of the Survey have been active in this region since that date. The first comprehensive report covering the entire area was compiled by Stephen R. Capps and published in 1940.[3] This report and the numerous separate reports by the Geological Survey on areas within the Alaska Railroad region have been referred to throughout the development program by the Bureau of Mines and were found to be extremely helpful.

Rocks of many ages and classifications are exposed in the Railroad belt. The rocks range from pre-Paleozoic schist, such as the Birch Creek schist, to recent stream gravels. Table 8 is modified from a chart showing current correlation of stratigraphic units in Alaska by Philip S. Smith;[4] it shows the formations occurring in the Railroad belt area.

The deposits sampled have been identified with the containing formations and are mentioned as part of these formations in the text following table 8.

TABLE 8. - Generalized geologic table for the railroad belt

Era	Period	Epoch	District	Description
Cenozoic	Quaternary			Unconsolidated materials including glacial moraines, outwash gravels, and clay deposits; stream terrace gravel; beach and estuary deposits; and alluvium of present streams. SOURCE OF ALL SAND AND GRAVEL DEPOSITS. CLAY DEPOSITS IN ANCHORAGE QUADRANGLE AND NENANA VALLEY ARE OF GLACIAL ORIGIN.

[3] Work cited in footnote 2, p. 8.

[4] Smith, Philip S., Areal Geology of Alaska: Geol. Survey Prof. Paper 192, 1939, 99 pp. (Correlation chart.)

TABLE 8. - Generalized geologic table for the railroad belt

Era	Period	Epoch	District	Description
Cenozoic	Tertiary	Oligocene Miocene		Basaltic lava, and volcanic rocks; some rhyolitic flows near top of section. Arkose conglomerate, shale.
			Kantishna-Donnelly	NENANA GRAVEL. Loosely consolidated gravel and sand.
			Matanuska	Massive conglomerate. ESKA CONGLOMERATE.
			Kantishna	Coal-bearing series of shale, sandstone, and grit; comparable to KENAI FORMATION in part.
		Eocene	Seldovia-Hope	Sandstone, shale, some conglomerate and coal. KENAI FORMATION.
			Chulitna	Rhyolitic lave, trachyte, andesite, some interbedded with CANTWELL FORMATION.
			Matanuska	Shale, sandstone, and coal. CHICKALOON FORMATION.
				CHICKALOON FORMATION, KENAI FORMATION, AND EQUIVALENT SERIES IN KANTISHNA-HEALY AREA HAVE PRODUCED ALL COAL MINED IN RAILROAD BELT.
				SHALES FROM THESE SERIES SAMPLED FOR CLAY PRODUCTS, LIGHT AGGREGATE, MINERAL WOOL, AND CEMENT.
Mesozoic	Cretaceous	Upper	Donnelly-Kantishna	Coarse conglomerate, sandstone, and dark shale CANTWELL FORMATION.
			Matanuska	Sandstone and shale. Shale with subordinate sandstone. MATANUSKA FORMATION
			Anchorage-Nuka	Argillite, graywacke, shale, small amounts of conglomerate and grit.
				SHALES AND ARGILLITE FROM THESE SERIES SAMPLED FOR CLAY PRODUCTS, LIGHT AGGREGATE, MINERAL WOOL, AND CEMENT.
		Lower	Matanuska	Conglomerate, tuff, and arkose; some massive limestone. NELCHINA LIMESTONE.
				CASTLE MOUNTAIN LIMESTONE SAMPLE.

TABLE 8. - Generalized geologic table for the railroad belt (Cont.)

Era	Period	Epoch	District	Description
Mesozoic	Jurassic	Upper	Chulitna	Sandstone, shale, argillite, little chert, some conglomerate, and limestone lenses.
			Matanuska	Green sandy shale. Shale, sandstone, little conglomerate.
		Middle	Matanuska	Sandstone, shale, small amount of conglomerate.
		Lower	Matanuska	Lava, breccia, tuff, interbedded sandstone, and shale. TALKEETNA FORMATION.
			Seldovia	Tuff and volcanic agglomerate interbedded with thin limestone, shale, and sandstone.
				GYPSIFEROUS DEPOSITS AND CLAY AT SHEEP MOUNTAIN IN ALTERED PHASE OF TALKEETNA FORMATION.
	Triassic	Upper	Chulitna	Argillite, clayey sandstone, lenses of tuff and conglomerate. Argillaceous rocks, limy white and rusty sandstone. Limestone.
			Seldovia	Limestone with volcanic material. Chert with thin films of argillite. Ellipsoidal greenstone.
				TRIASSAC ARGILLITES AND LIMESTONES IN WEST FORK OF CHULITNA RIVER REGION SAMPLED FOR LIMESTONE, LIGHT-AGGREGATE, AND MINERAL-WOOL PRODUCTION
Paleozoic	Carboniferous	Permian	Chulitna	Tuff, volcanic breccia, lava, some argillite, limestone, chert, and conglomerate.
				ARGILLITE FROM THIS SERIES SAMPLED FOR MINERAL-WOOL AND LIGHT AGGREGATE PRODUCTION.
		Missis-sippian	Yukon-Tanana	Undifferentiated schist, shale, chert, quartzite. Chert with minor amount of limestone and shale. LIVENGOOD CHERT.
	Devonian	Middle	Kantishna-Nenana	Limy shale, more calcareous at top. Slate, argillite, graywacke, quartzite. Black conglomerate, white conglomerate, shale, and graywacke.
			Chulitna	Siliceous and argillaceous sediments, age highly problematical.

TABLE 8. - Generalized geologic table for the railroad belt (Cont.)

Era	Period	Epoch	District	Description
Pre-Paleozoic			Wasilla	Schists in vicinity of Willow Creek; age extremely doubtful, probably early Paleozoic or older.
			Kantishna-Tok	Metamorphic rhyolitic effusives and related rocks. TOTALANIKA SCHIST and regular BIRCH CREEK SCHIST.
			Yukon-Tanana	Schist, quartzite, and other highly metamorphic rocks. BIRCH CREEK SCHIST. Some associated basic volcanics.

Quaternary Deposits

The unconsolidated deposits of the Quaternary period have furnished all of the sand and gravel so necessary to the construction programs of modern civilization. Deposits consist of glacial moraines, outwash gravels, estuarine clay, stream-terrace gravel, and the alluviums of present streams. The marine clays sampled in the Anchorage quadrangle and the clay beds in the Nenana Valley are of glacial origin.

Glaciation took a large part in the formation of these Quaternary deposits. The major part of the Alaska Railroad region has been glaciated several times by the major ice fields, which extended south from the Alaska Range to the Pacific Ocean. Ice also covered the north flank of the Alaska Range, with small lobes extending for short distances down many of the present valleys. One of these lobes occupied the present course of the Nenana River and marked the north limit of the Susitna Glacier where it flowed through a gap in the divide to form Broad Pass and leave an easy grade for the rail route to central Alaska.

The glaciers produced enormous quantities of debris, which remain as terminal and lateral moraines and outwash gravels. Terrace gravel deposits were formed by many of the present streams and were left in their elevated position as the valleys were lowered by continued erosion.

Ceaseless erosion and stream action are continually forming new alluvial deposits of sand and gravel.

Tertiary Coal Measures

According to Philip S. Smith,[5] the Tertiary coal beds in the Cook Inlet area are considered to belong to the upper part of the Eocene series. Composed predominantly of sandstones and shales, the beds contain interbedded conglomerate at irregular intervals; they also contain numerous coal beds. The

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[5] Work cited in footnote 4, p. 61.

Kenai formation probably is 2,300 feet thick. Measured stratigraphic sections by Martin[6] demonstrate that 3 to 5 percent of the total thickness of rock consists of coal beds 3 to 7 feet thick.

A bed of blue clay exposed in the sea cliff south of Miller's Landing near Homer is a member of the Kenai formation. Samples of this clay were taken for testing for clay products and the production of lightweight aggregate. The bed of blue clay is approximately 30 feet thick.

The Chickaloon formation in the Matanuska Valley has been described by Martin[7] as consisting of a rather monotonous succession of shales and sandstones. The shales, which predominate over the sandstones in aggregate thickness, are gray to drab, rather soft and inclined to disintegrate on exposure, poorly bedded, and without well-defined joint planes. Most of the beds are rather gritty and vary in grain along the bedding. They contain many nodules and lines of nodules of iron carbonate, some of which form fairly persistent beds. The sandstones are yellowish, rather soft, of diverse grain in the different beds and of varying grain in the same bed, and for the most part feldspathic; in general, the individual beds are not very persistent. The formation appears to be at least 2,000 feet thick.

The coal beds of the Chickaloon formation are numerous. Except in the relatively small areas now being mined, there is no accurate evidence as to their exact position within the formation or as to the persistence of individual beds or group of beds.

Samples were taken of several of the shale members of the Chickaloon formation for investigation as a source of raw material for a brick or tile industry and also were tested for lightweight-aggregate production. The samples were taken in the vicinity of the Eska coal mine and along the railroad from Sutton to the mine.

The coal-bearing Tertiary formation in the Healy area probably is Miocene.[8] It is composed of sandstone, clay, fine conglomerate, and coal beds. Samples were taken of several clay beds near the Suntrana coal mine for the production of lightweight aggregate and clay products. Samples of the clay and some of the sandstone beds were analyzed for possible use in the mineral-wool industry.

Upper Cretaceous

The Upper Cretaceous formation in the Donnelly-Kantishna area in the Alaska Range is composed of a group of nonmarine sedimentary rocks.[9] This group (Cantwell formation) includes conglomerates, sandstones, and shales. Associated igneous material is included in many parts of the formation. The shale sampled for use in the production of cement in the Cantwell-Windy area is a member of this formation. Samples were tested for production of lightweight aggregate and clay products from this shale.

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[6] Martin, G. D., Johnson, B. L., and Grant, U. S., Geology and Mineral Resources of Kenai Peninsula, Alaska; Geol. Survey Bull. 587, 1915, p. 68.

[7] Martin, G. D., and Katz, F. J., Geology and Coal Fields of the Lower Matanuska Valley, Alaska; Geol. Survey Bull. 500, 1912, p. 43.

[8] Work cited in footnote 2, p. 122.

[9] Work cited in footnote 2, p. 77.

The Matanuska formation, representing the upper Cretaceous in the Matanuska district, contains marine fossils.[10] The upper part of the formation is predominantly sandstone with thin shale beds. Conglomerate and grit facies are found also. The base of the formation is composed of shale with subordinate sandstone. The shale at mile 67 on the Glenn Highway is a member of the Matanuska formation. This shale was investigated as a possible source of lightweight aggregate and was tested also for the production of brick and other clay products.

The argillite, graywacke, shale, and associated small amounts of conglomerate and grit in the Anchorage area are part of the Matanuska formation.

Lower Cretaceous

The base of the Lower Cretaceous section in the Mantanuska district consists of conglomerate, tuff, and arkose overlain by several hundred feet of a massive, dark, fine-grained limestone.[11] The Castle Mountain limestone sample is from a part of this limestone unit, which is named the Nelchina limestone.

Lower Jurassic

The Talkeetna formation of interbedded lavas, tuff, and breccia with thin beds of black carbonaceous shale and sandstone represent the Low r Jurassic in the Matanuska district.[12] Much of this formation has undergone alteration to greenstone. The gypsiferous deposits and clay at Sheep Mountain are in a an altered phase of the greenstone of the Talkeetna formation.

Upper Triassic

The mountains along the northwest border of the West Fork of the Chulitna River area are composed mainly of dark-gray to black argillite and argillaceous sandstone, which Ross[13] considers to be of the Upper Triassic period. These rocks are interbedded at their base with Triassic limestone. At and immediately above the contact are lenses of tuff. The argillite was sampled for the production of mineral wool and lightweight aggregate.

The base of the Upper Triassic is represented by prominent beds of limestone.[14] A few of these beds are somewhat more coarsely crystalline than the others and form conspicuous white outcrops. The rest of the limestone weathers in brownish cliffs, is gray to black on fresh fractures, and is interbedded with the argillite. This limestone is impure, with some sandy and argillaceous beds.

Samples of the limestone beds were collected for analyses as possible materials for cement and mineral-wool production.

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[10] Work cited in footnote 4, pp. 49 and 50.

[11] Work cited in footnote 14, p. 49.

[12] Paige, Sidney, and Knopf, Adolph, Geologic Reconnaissance in the Matanuska and Talkeetna Basins: Geol. Survey Bull. 327, 1907, pp. 16 and 17.

[13] Ross, Clyde P., Mineral Deposits near the West Fork of the Chulitna River, Alaska: Geol. Survey Bull. 849-E, 1933, pp. 300-302.

[14] Work cited in footnote 13, pp. 298-299.

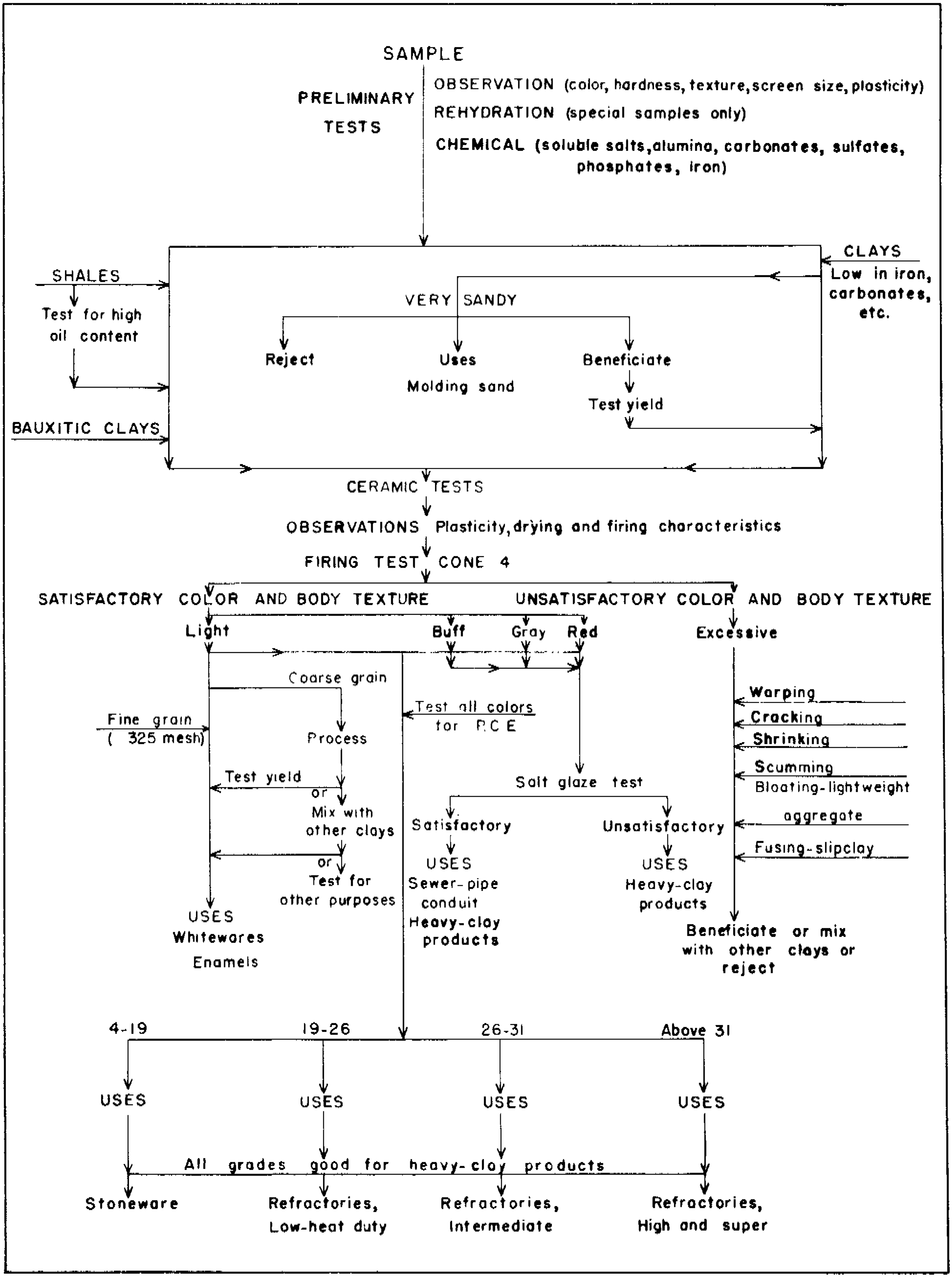

Figure 4. - Classification of clays, by uses.

Carboniferous

The central part of the area mapped by Ross[15] on the West Fork of the Chulitna River is composed of a thick series of Permian tuff, volcanic breccia, lava, argillite, limestone, chert, and conglomerate. The tuff, volcanic breccia, and lava predominate, but the argillite and limestone are plentiful locally. These beds were divided by Ross into several units. The argillite samples in the West Fork of the Chulitna River area were taken from two of these units: D and E.

BRICK AND CLAY PRODUCTS

The use of clay for producing building materials is one of the oldest of the arts. Clay has been employed for centuries to make brick, tile, pottery, and other related ceramic products. For some of the products, the finer grades of clay are required; but the building materials ordinarily utilize the lower-grade clays and shales, which are widely distributed.

Various divisions have been made of the raw materials used for clay products. They have been segregated on the basis of use, origin, mineral composition, and a combination of these. In the search for new deposits, the geologic or geographic origin classification is the most helpful, because deposits of the same relative age and origin may often be of similar composition. The description and geologic age is given for all samples tested during this investigation.

For test purposes, the Bureau of Mines has devised a general outline[16] in which the main and final classification is on the basis of use. The part of this outline that relates to tests for ceramic uses is given in figure 4. By following the outline given for testing in this syllabus,[17] the general uses of a clay may be determined.

In testing ceramic products, the temperature at which the material is fired is given in terms of the pyrometric cone equivalent (P.C.E.). The deformation point or fusion point of the standard cone or cone being tested is known as the pyrometric cone equivalent. The P.C.E. is determined also in lieu of the melting point of the product and indicates the use to which it may be put. In this test, small cones of the material being tested are heated at a prescribed rate with standard pyrometric cones. The point of its deformation is then compared with that of the nearest standard cone. The P.C.E. of the sample can be given as approximately equal to or as between two of the standard cones.

The standard cones are prepared to melt or deform at definite temperatures. The cones are specially prepared; and, in determining the deformation point, the heating rate is maintained at a constant rate. Table 9[18] gives the

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[15] Work cited in footnote 13, pp. 294-298.

[16] Klinefelter, T. A., O'Meara, R. G., Gottlieb, Sidney, and Truesdell, Glenn C., Syllabus of clay testing - Part 1: Bureau of Mines Bull. 451, 35 p., 1943.

[17] Work cited in footnote 16.

[18] Handbook of Chemistry and Physics: 18th ed., 1933, p. 820.

pyrometric cone equivalents in degrees centigrade and Fahrenheit for the two middle classes of standard cones. Below these is the soft series from cone 011 to 022, inclusive, and above is the high-temperature series from cone 23 to 42, inclusive. Pyrometric cones do not give an accurate measurement of temperature but are used for comparative purposes. In spite of the care used, it is not unusual for different laboratories to fail to check one another closer than within one cone.

TABLE 9. - Pyrometric cone equivalents for the two middle classes of standard cones

No. of cone		°C.	°F.
Low-temperature series	010	890	1,634
	09	930	1,706
	08	945	1,733
	07	975	1,787
	06	1,005	1,841
	05	1,030	1,886
	04	1,050	1,922
	03	1,080	1,976
	02	1,095	2,003
	01	1,110	2,030
Intermediate-temperature series	1	1,125	2,057
	2	1,135	2,075
	3	1,145	2,093
	4	1,165	2,129
	5	1,180	2,156
	6	1,190	2,174
	7	1,210	2,210
	8	1,225	2,237
	9	1,250	2,282
	10	1,260	2,300
	11	1,285	2,345
	12	1,310	2,390
	13	1,350	2,462
	14	1,390	2,534
	15	1,410	2,570
	16	1,450	2,642
	17	1,465	2,669
	18	1,485	2,705
	19	1,515	2,759
	20	1,520	2,768

NOTE: Table based on work of Fairchild and Peters, Jour. Am. Cer. Am. Socl., 9, 1946, pp. 701-74. Heating rate, 20 C. per hour.

The P.C.E. for low-duty fire clay brick has been set at 19. This is on the basis of a heating rate of 150° C. per hour, which gives a temperature of 1,520° C. and compares to a P.C.E. of 20 in table 9, which is based on a 20° C. per hour heating rate.

The absorption-coefficient test for brick indicates its possible resistance to weathering. The absorption coefficient is the ratio between the absorption after a 24-hour cold-water soak and the absorption by boiling for 5 hours, or, absorption coefficient = $\frac{\text{cold-water absorption}}{\text{5-hour boil absorption}}$. This coefficient should not exceed 0.8 for any ceramic piece expected to withstand severe weathering conditions.

Freezing-and-thawing tests were performed in accordance with A.S.T.M. specification C67-44, method B, except for laboratory reduction in specimen size and corresponding water level during freezing. Method B calls for a representative selection of five or more commercial-size brick to be oven-dried to a constant weight at 110°-115° C., cooled, weighed, and then submerged in clear water at 15.5 to 30° C. for 4 hours before beginning the freezing-and-thawing test. Test specimens are to be stood on edge in 1/2 inch of water and properly spaced in trays exposed to the temperature of the freezing chamber. Initial temperature on introduction of the charge shall not exceed 32° C., and temperature 1 hour after introduction shall not exceed -9° C. Alternate freezing and thawing shall be continued for 50 cycles, a cycle consisting of 20 hours of freezing, complete immersion in the thawing bath for 4 hours, and inspection for defects before replacing in the freezing chamber. Following each consecutive five cycles, the specimens are to be air-dried at 16-32° C. with a relative humidity of 30-70 percent for 24 hours, oven-dried for 72 hours, and then weighed before the submersion beginning the next cycle. Inspection and periodic weighing shall determine breaks, disintegration, or loss of more than 3 percent of initial weight of each specimen.

Federal specifications SS-B-656 for brick grades H, M, and S are given in table 10. The specifications state that a sample shall consist of 10 bricks.

TABLE 10. - Federal specifications SS-B-656 for brick grades H, M, and S

Grade	Maximum absorption, percent		Modulus of rupture, lb. per sq. inch	
	Average of 5	Individual maximum	Average of 5	Individual minimum
H	10 or less	12	600 or more	400
M	16	20	450 to 600	300
S	No limit	No limit	300 to 450	200

Compressive strength requirements and other specifications covering brick are those set up by A.S.T.M. designation C 62-49.[19] Three grades of brick are covered (table 11):

> Grade SW: Brick intended for use where a high degree of resistance to frost action is desired and the exposure is such that the brick may be frozen when permeated with water.

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[19] American Society for Testing Materials, 1949 Book of A.S.T.M. Standards, Philadelphia, Pa., part 3, 1949, pp. 564-568.

Grade MW: Brick intended for use where exposed to temperature below freezing but unlikely to be permeated with water or where a moderate and somewhat nonuniform degree of resistance to frost action is permissible.

Grade NW: Brick intended for use as back-up or interior masonry, or, if exposed, for use where no frost action occurs; or if frost action occurs where the average annual precipitation is less than 20 inches.

TABLE 11. - Physical requirements for brick, A.S.T.M. designation C 62-49

	Minimum compressive strength (brick flatwise), p.s.i., gross area		Maximum water absorption by 5-hr. boiling, percent		Maximum saturation coefficient	
Designation	Average of 5 brick	Individual	Average of 5 brick	Individual	Average of 5 brick	Individual
Grade SW	3,000	2,500	17.0	20.0	0.78	0.80
Grade MW	2,500	2,200	22.0	25.0	.88	.90
Grade NW	1,500	1,250	No limit	No limit	No limit	No limit

In addition, the following requirements have been set up for freezing and thawing tests:

Grade SW. No breakage and not greater than 1.0 percent loss in dry weight of any individual brick.

Grade MW. No breakage and not greater than 3.0 percent loss in dry weight of any individual brick.

During the Bureau of Mines investigation, samples were taken from all known potential sources of ceramic material that are accessible from the centers of population and consumption in the Railroad belt. If preliminary tests indicated that the material sampled was favorable for production of brick and tile products, more-extensive physical tests were performed to check the qualifications of the product against standard specifications for brick products. The following deposits were tested for ceramic uses.

Clay Products, Inc.

Location and Accessibility

The clay pit and plant of Clay Products, Inc., are on the shore of Knik Arm 4.2 miles by road from the Alaska Railroad terminal in Anchorage. The area is served by a good gravel road and is accessible throughout the year. Figure 5 is an index map of the Anchorage area, showing the location of the property. A plat of the Simonson homestead subdivision and a Brunton survey of the deposit are shown on figures 6 and 7.

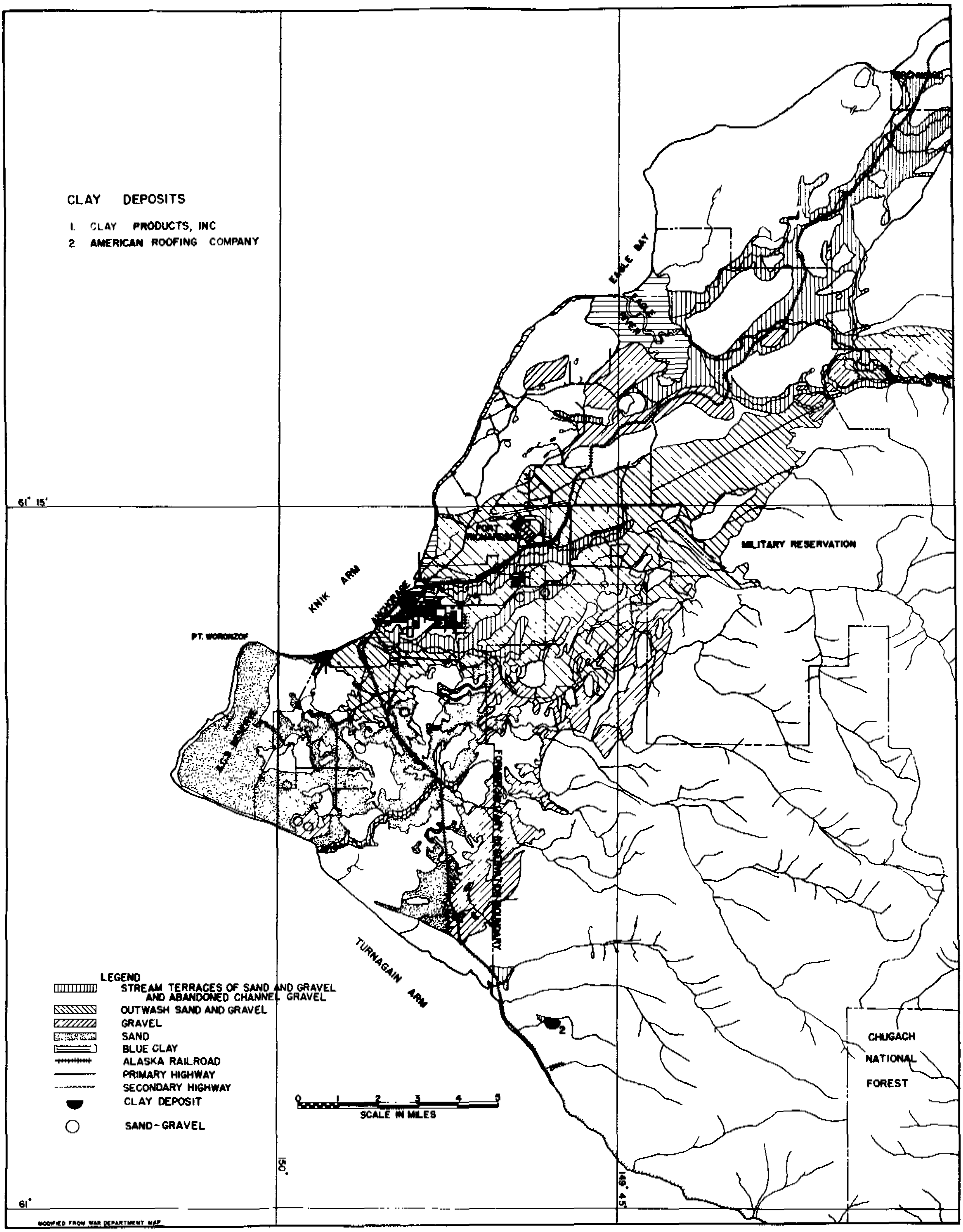

Figure 5. - Deposits of building materials in the Anchorage area.

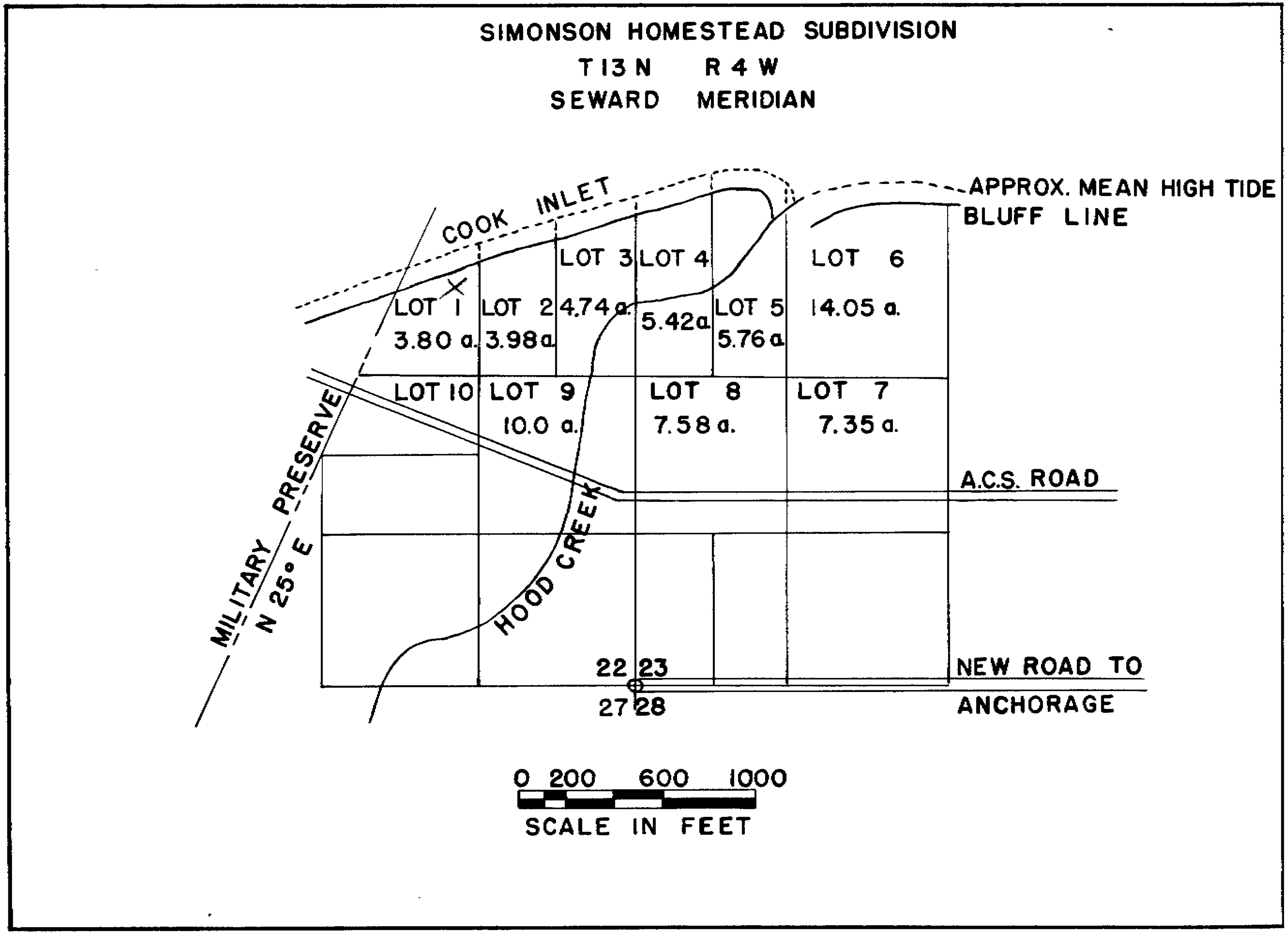

Figure 6. - Plat of Simonson subdivision, Clay Products, Inc., property.

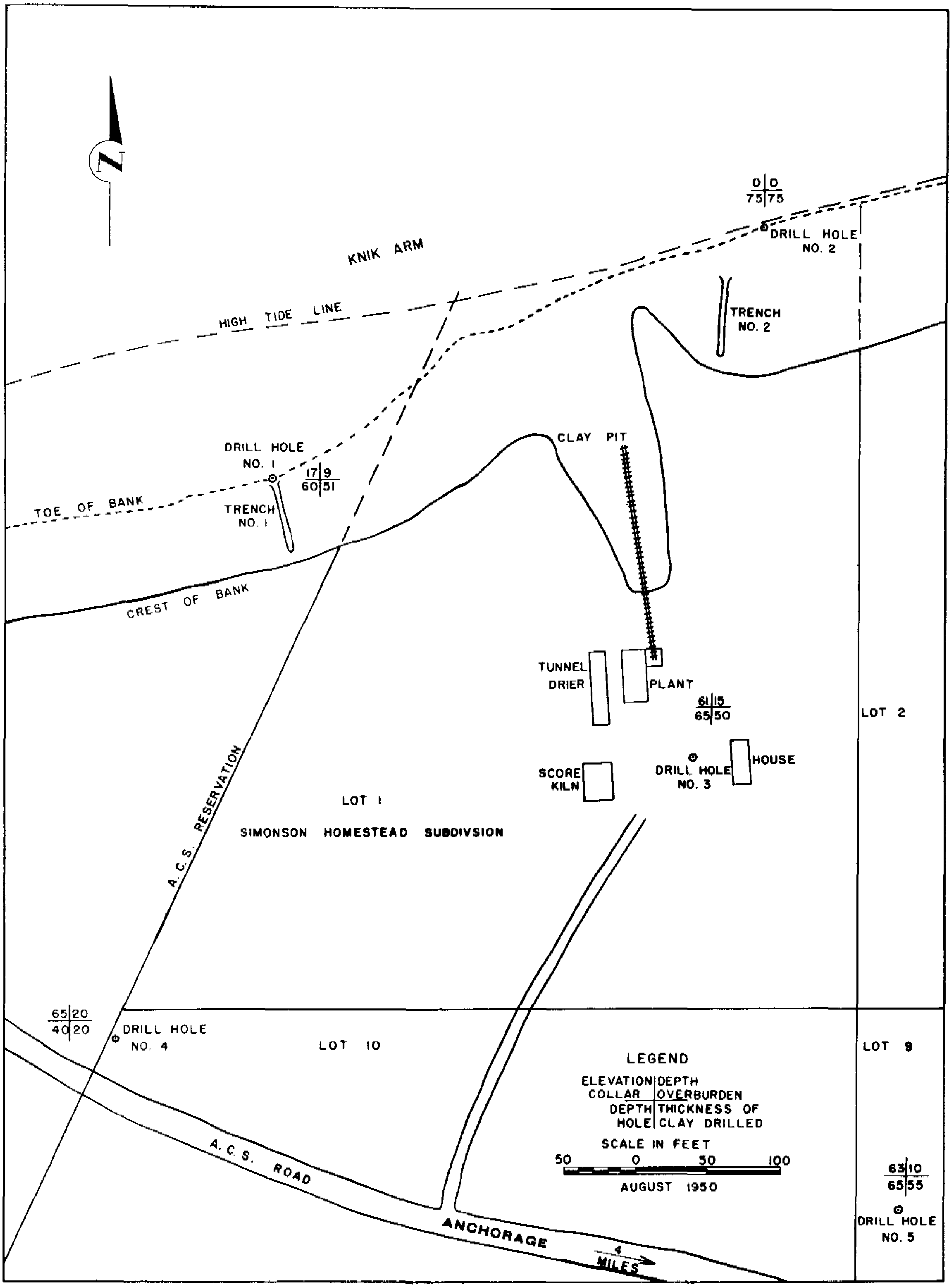

Figure 7. - Brunton survey, Clay Products, Inc., property.

Figure 8. - Clay pit and plant of Clay Products, Inc.

Figure 9. - View of Point Woronzof from Clay Products, Inc., property.

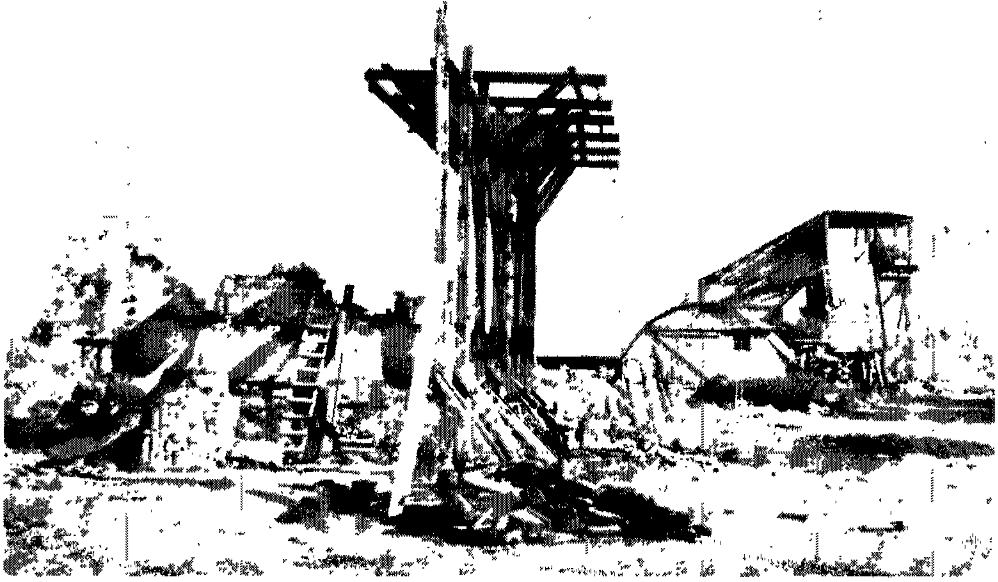

Figure 10. - Clay Products, Inc., scove kiln and brick plant.

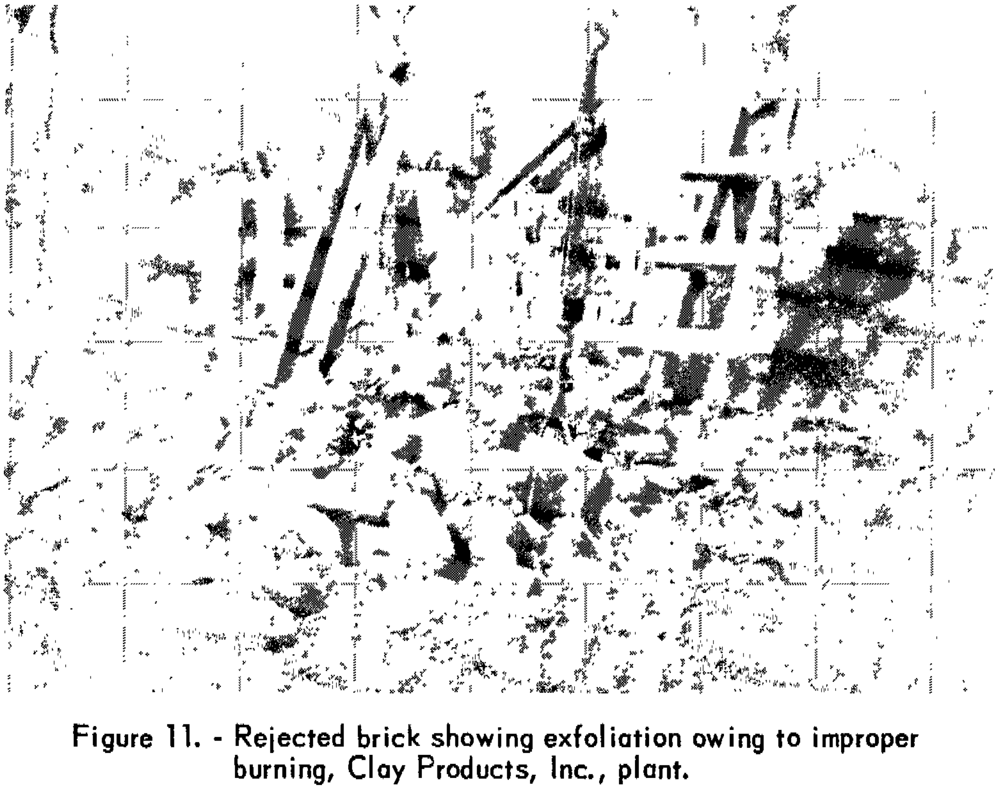

Figure 11. - Rejected brick showing exfoliation owing to improper burning, Clay Products, Inc., plant.

Physical Features and Climate

The property is on the bluff of a sea cliff on the outwash plain at the base of the Chugach Mountains. At the plant site (fig. 8) the level of the plain is 60 to 65 feet above extreme high tide. The plain slopes gently to the southwest. (See fig. 9.)

Climatic conditions at Anchorage are not rigorous. Monthly and annual precipitation and monthly average temperatures are given in the general section on physical features and climate for the Railroad belt. The data include a list of the earliest dates in the autumn and the last dates in the spring on which freezing temperaturs have been recorded.

History, Production, and Ownership

Clay Products, Inc., was incorporated on July 15, 1946, for 50,000 shares of common stock at $5.00 par value. Cameron A. Rich and Howard J. Brown of Anchorage were president, and vice president and general superintendent, respectively.

A disintigrator, pugmill, hand cutter, and auger were secured, and the brick plant began operations in May 1947. (See fig. 10.) Plant operations were limited to May through October of 1947 and 1948. The company was severely handicapped owing to lack of financing and modern equipment. Hand labor was used extensively to mine and process the clay. As a result, although the auger for producing the brick was rated at 8,000 per 8-hour shift, it actually produced approximately 2,000 a day.

Although the clay has a short firing range, the firing was done in an unroofed scove kiln. Consequently, losses due to overfiring, underfiring, and rain were excessive. An example of underfired brick is shown in fig. 11.

Approximately 207,000 brick were produced before the plant ceased operations in November 1948. Of these, 25,000 were made of clay from Sheep Mountain and were sold as fire brick. Common brick (grade M) were sold at $75.00 per M, face brick (grade H) at $80.00 per M, and fire brick at $250.00 per M.

The brick were used mainly in constructing chimneys and fireplaces. In 1948, the first brick building in Anchorage was constructed, using brick from Clay Products, Inc. Approximately 26,000 brick were used in this building - the Telephone Exchange.

Clay Products, Inc. owns 3.8 acres in sec. 22, T. 13 N., R. 4 W., Seward meridian. It can be described more fully as lot 1 of the Simonson Homestead Subdivision (fig. 6). At one time, the company also held a clay-mining option on lots 2 and 3 and those portions of lots 9 and 10 lying north of the Alaska Communication System road. This option has been reliquished.

Description of Deposit

Pleistocene marine clay of estuarine origin is exposed along the sea cliff on Knik Arm from Point Woronzof to the mouth of Eagle River (fig. 5). Several small deposits of clay are farther north along the coast, but the best deposits are near Anchorage. The clay is blue to gray, is very sticky when wet, and containes a varying amount of fine silt, which occurs as thin laminations in the clay.

Frost action on the clay forming the bluff at the property of Clay Products, Inc., has produced blocks of clay 2 inches to 3 feet in diameter. The blocks are now separated by sand, which has been washed in from the overburden.

Bureau of Mines auger-drill holes indicate approximately 49 feet of clay above extreme high tide and at least 75 feet below extreme high tide. This indicates a total thickness of more than 124 feet at this location.

Work by Bureau of Mines

Preliminary examination of the clay deposit on the property of Clay Products, Inc., by the Bureau of Mines indicated that the clay exposed in the sea cliff could be trenched and sampled. Two trenches were excavated by hand near the limits of the property; but digging was slow, as the face of the bluff is covered with 2 to 8 feet of loose sand, which caved and ran into the trenches.

No samples were taken from these trenches. It was found that frost action had broken the clay into blocks and that the voids between were filled with sand from the overburden. Therefore, a representative sample of the clay could not be taken.

Five 6-inch auger-drill holes were sunk by the Bureau of Mines to procure the samples necessary for testing and to develop clay reserves. The location of the holes, with elevation and depth of overburden and clay, is shown in figure 7. All holes were still in clay when stopped.

Clay-Utilization Tests

The following samples were taken from the deposit of Clay Products, Inc., and submitted for investigation of uses. The sample number, hole number, and position of sample in the drill hole are given in table 12.

TABLE 12. - List of samples from deposit of Clay Products, Inc.

Sample No.	Hole No.	From-	To-	Feet
14	1	9.0	24.0	15.0
15	1	24.0	38.0	14.0
16	1	38.0	48.0	10.0
17	1	48.0	60.0	12.0
18	2	.0	20.0	20.0
19	2	20.0	35.0	15.0
20	2	35.0	50.0	15.0

TABLE 12. - List of samples from deposits of Clay Products, Inc. (Cont.)

Sample No.	Hole No.	From-	To-	Feet
21	2	50.0	60.0	10.0
22	2	60.0	70.0	10.0
23	2	70.0	75.0	5.0
24	3	15.0	30.0	15.0
25	3	30.0	40.0	10.0
26	3	40.0	50.0	10.0
27	3	50.0	65.0	15.0
72	4	20.0	40.0	20.0
73	5	10.0	40.0	30.0
74	5	40.0	65.0	25.0

In taking the samples, a ball of clay was taken from each pull of the auger. Each run represents approximately 5 inches. Duplicate and triplicate samples were taken to provide test material for products other than brick.

The results of preliminary tests by the Bureau of Mines laboratory at Seattle are given in table 13.

TABLE 13. - Results of clay-utilization analyses of samples from Clay Products Inc., deposit

Sample number	Fired to cone	Absorption, percent		Absorption coefficient	Modulus of rupture, p.s.i.	Remarks
		24-hour soak	5-hour boil			
14	010	13.9	14.0	0.99	919	Underfired.
14	05-06	11.2	11.6	.96	1,288	Good.
14	2	1.9	2.5	.77	2,487	Overfired.
15X[1]	010	14.9	16.2	.92	2,275	Underfired.
15	09	14.4	15.0	.96	825	Do.
15X	05	13.4	13.8	.97	2,509	Slightly underfired.
15	04	10.4	11.1	.94	1,509	Good.
15	2	-	-	-	-	Overfired.
16	09	15.1	15.4	.98	1,227	Underfired.
16	05-06	10.8	12.6	.86	1,362	Fair, slightly underfired.
17X	010	15.1	16.3	.92	2,247	Underfired.
17	010	14.8	15.0	.99	1,326	Do.
17	05-06	11.2	11.7	.96	1,351	Good.
17X	03	5.9	6.9	.85	4,124	Slightly overfired.
17	02	Bloated slightly				Overfired.
18	09	14.0	14.1	.99	925	Underfired.
18	02	3.9	4.6	.85	2,099	Fair, slightly overfired.
19X	010	15.8	16.9	.93	2,264	Underfired.
19	09	15.0	15.3	.98	1,323	Slightly underfired.
19X	06	14.9	15.1	.99	2,875	Do.
19	05	8.9	9.4	.95	1,929	Good.

[1] All clay samples contain 20 percent of Ottawa sand, except those marked which contain no sand. Sand added to reduce plasticity and drying and firing shrinkage.

TABLE 13. - Results of clay-utilization analyses of samples from Clay Products Inc., deposit (Cont.)

Sample number	Fired to cone	Absorption, percent		Absorption Coefficient	Modulus of rupture, p.s.i.	Remarks
		24-hour soak	5-hour boil			
20[2]	08	14.1	14.6	0.96	2,965	Underfired.
20[2]	05	12.4	12.7	.98	2,819	Fair.
20	08	15.5	15.7	.99	1,326	Underfired.
20	05	8.8	9.2	.96	2,046	Good.
20[2]	02-03	Bloated slightly				
20[2]	2	Bloated				
21	010	15.3	15.9	.96	1,118	Underfired.
21	02-03	Bloated				
22	09	14.7	15.3	.96	1,075	Underfired.
22	02	4.4	5.1	.84	2,180	Slightly overfired.
23	010	14.4	15.3	.94	578	Underfired.
23	02	9.7	11.2	.86	1,856	Good.
23[3]	010	14.3	15.5	.92	504	Underfired.
24X	08	14.0	16.0	.92	1,313	Do.
24	010	14.0	14.2	.98	343	Do.
24X	03	8.5	9.1	.93	3,904	Slightly overfired.
24	02	7.2	8.2	0.86	1,038	Good.
25X	010	14.7	16.1	.91	1,554	Underfired.
25	09	14.3	14.6	.98	698	Do.
25	04	8.6	9.6	.87	1,689	Good.
25X	03	3.1	3.2	.97	5,017	Overfired.
26	010	14.4	15.0	.96	1,119	Underfired.
26	05	10.3	10.8	.94	1,355	Good.
27X	010	15.1	16.2	.93	2,794	Underfired.
27	010	14.1	15.1	.99	1,082	Do.
27	05	9.4	9.8	.94	1,764	Good.
27X	03	1.8	1.8	1.0	6,406	Overfired.
27	2	.3	.4	.83	2,813	Do.
72X	09	14.0	13.6	.93	1,947	Underfired.
72X	05	12.7	15.1	.93	2,734	Fair.
72X	01	8.1	9.6	.85	3,884	Slightly overfired.
73X	09	13.7	14.4	.91	2,758	Underfired.
73X	05	12.1	13.2	.95	3,770	Fair.
73X	01	8.0	8.9	.90	5,360	Slightly overfired.
74X	09	15.0	15.2	.98	2,834	Underfired.
74X	05	11.4	12.4	.92	4,148	Good.
74X	01	8.7	9.6	.90	5,571	Slightly overfired.

[2] Contains 20 percent Alaska sand.

[3] Contains 25 percent Ottawa sand.

All clay samples from the property of Clay Products, Inc., at Anchorage exhibited a short firing range. Optimum firing temperatures ranged from cone 06 (1,841° F.) for sample 16 to cone 02 (2,003° F.) for sample 23. The relative altitudes of the samples in the clay deposit and their respective firing temperatures are compared in figure 12. The results of the preliminary testing indicate that cone 02 would be the best firing treatment for the upper part of the formation and cone 05 for the main body.

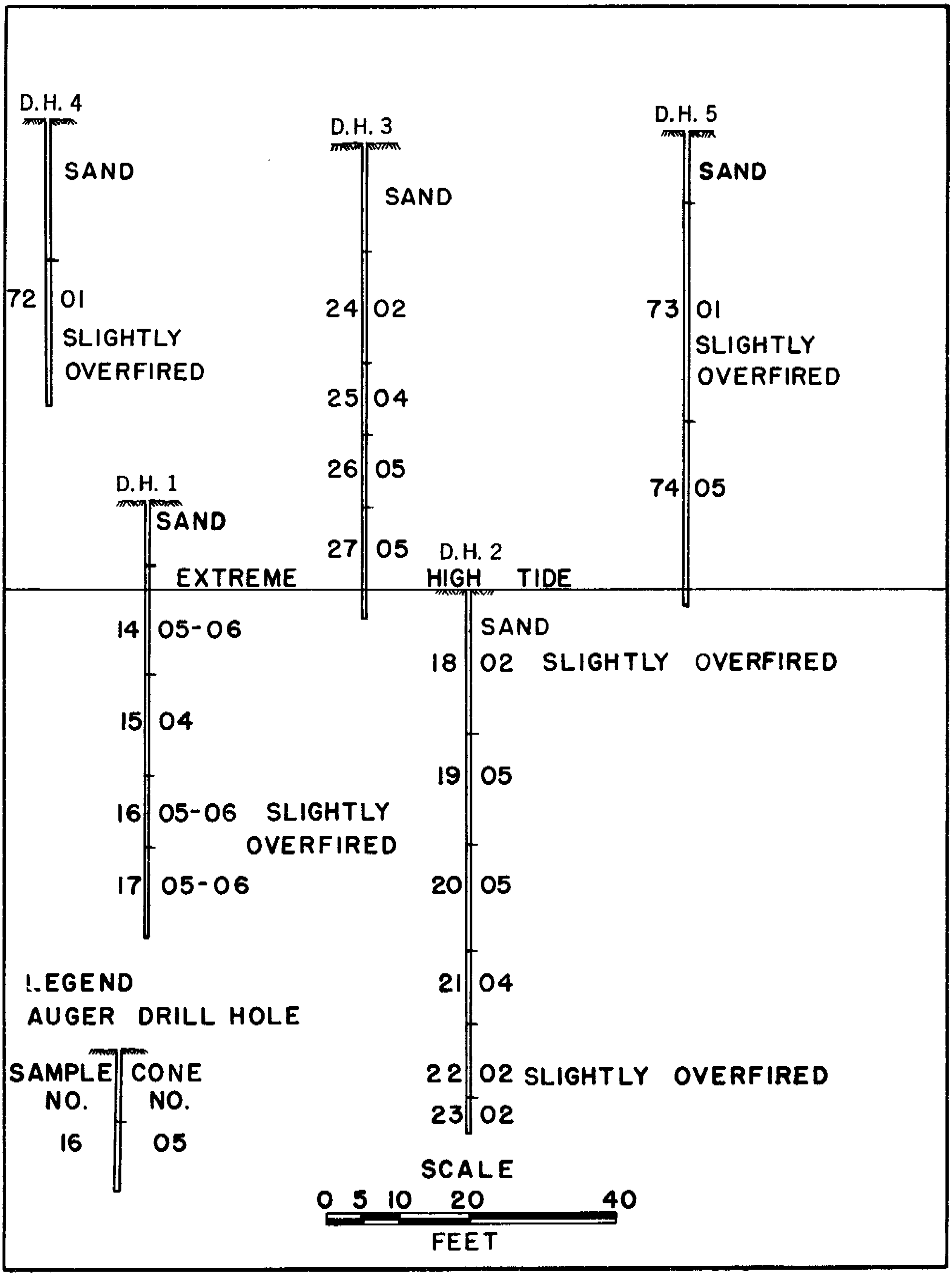

Figure 12. - Optimum firing temperatures of clay samples from deposit of Clay Products, Inc.

Anchorage sand obtained from the overburden of the clay deposit was added to sample 20, but there were no indications that shrinkage was reduced materially by this addition. Ottawa sand, a pure, sized, silica sand, was added to the samples as indicated in table 13. The sand was added to reduce plasticity and drying and firing shrinkage. The drying shrinkage was decreased, but the sand did not improve the firing characteristics materially and only slightly extended the firing range.

At the lower temperatures, cone 010-08 (1,634°-1,733° F.), the absorption was high and firing shrinkage was just becoming apparent. Strength was good when no sand was added but poor in samples containing 20 percent Ottawa sand.

At the higher temperatures of cone 06-05 (1,841°-1,886° F.), the test pieces were usually slightly underfired but probably would be acceptable if their freezing and thawing resistance was satisfactory. When fired to cone 05, the absorption remains slightly above that recommended but is probably the best firing temperature.

Color of the fired pieces was not good; it ranged from a light salmon, at the lower firing temperature, to a very dark red or brown at the higher temperatures. Slight variations in temperature resulted in marked changes in color and quality of the fired product. For this reason, these clays would require very careful firing.

Although the results of the above tests indicated a short firing range and high absorption coefficients, with resultant poor weathering qualities, the location of the deposit, its extent, and the past production of over 200,000 brick warranted additional testing.

Freezing and Thawing Tests

Accelerated weathering tests were performed on brick made from clay collected at the pit of the Anchorage Clay Products Co., Anchorage, Alaska. Four of the 15 bricks tested failed. Failure occurred when the test brick lost more than 3 percent, by weight. All failures were due to lamination in the brick resulting from forming.

The bricks were formed from samples 14, 15, 16, 18, 19, 24, 25, 26, and 27. The first five samples were combined for form composite 1 and the last four, composite 2. Equal portions of composites 1 and 2 were used to make up composite 3. Preliminary testing showed that inert material would have to be mixed with each composite to reduce drying shrinkage. Hence, grog made of burned clay from the deposit with an equal weight of sand was mixed with each composite before forming. Additions of 22-1/2 percent of grog and sand reduced laminations somewhat, but further additions to 32 percent were necessary to form the brick. Additions above this amount made the formed piece too weak.

All brick that failed in 50 cycles or less of freezing and thawing showed weight losses on the top surface of the brick rather than in the part submerged. Spalling began, in every case, at small surface cracks and followed laminations within the brick.

The short firing range, high shrinkage, and sticky plasticity of clay from the Anchorage deposit will make manufacture of a good brick extremely difficult, but a well-formed and properly fired brick made from this clay will withstand the accelerated weathering tests. The percent weight losses recorded for the brick tested are shown in the following table. All testing was done according to A.S.T.M. designation 067-44 Method B[20], except that weight losses were measured after each 10 cycles instead of the prescribed five.

Weight loss after testing, percent

Composite No.	Sample No.	Cycles				
		10	20	30	40	50
1	1	0.0	0.0	0.0	1.4	2.2
1	2	.0	.0	.0	.4	9.0
1	3	.0	.0	.0	.1	.8
1	5	.0	.0	.0	.0	.0
1	7	.0	.0	.1	.1	.1
1	8	.0	.0	.1	.1	.1
2	1	.0	.0	.0	7.3	-
2	3	.0	.0	.1	.1	4.2
2	4	.0	.0	.1	6.7	-
2	5	.0	.0	.0	.0	.1
2	6	.0	.0	.0	.1	.1
3	1	.0	.0	.0	.1	2.1
3	2	.0	.0	.0	.0	-
3	4	.0	.0	.0	.0	1.3
3	5	.0	.0	.0	.1	.1

One of the six bricks made from composit 1 failed and one more exceeded 1 percent loss after 50 cycles of freezing and thawing. In composite 2, three of the five bricks tested failed in 40 or more cycles. None of the bricks made of composite 3 failed, but two had weight losses over 1 percent.

A well-formed and fired brick, free from surface cracks can be expected to withstand the weathering tests. Composite 2 showed more failures than did 1 or 3 due to the greater tendency to laminate.

The following data have been furnished through the courtesy of Clay Products, Inc. They are the results of test for the army by Fay, Spofford, & Thorndike, Anchorage, Alaska, on brick produced by Clay Products, Inc., during its operations.

Materials Testing Laboratory
FAY, SPOFFARD & THORNDYKE
Anchorage, Alaska

A 600.95

30 June 1948

Test of Clay Brick

Source........................ Clay Products, Inc., Anchorage, Alaska
Sampled and submitted by...... Clay Products, Inc.
Date received................. June 12, 1948
Test.......................... For conformity with Federal Spec. SS-B-656 Grade H or M, plus compressive strength.
Sample description............ 14 wire-cut clay brick, with penciled notations on each as follows:

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[20] American Society for Testing Materials, 1949 Book of A.S.T.M. Standards, Part 3: 1949, pp. 585-591.

Sample	Notation
A, B	Underfired, from top, est. 10 percent kiln, high sand mixture.
C, D	Upper 1/3 of kiln, high sand mixture.
E, F	Upper 1/3 of kiln, low sand mixture.
G, H	Center of kiln, high sand mixture.
I, J	Lower 1/4 of kiln, low sand mixture.
K, L	Lower 10 percent of kiln.
M, N	Arch brick, est. 3 percent of kiln.

Test Data

Sample	Dimension, inches	Percent absorption 5-hr. soak	Mod. of Rupture, lb. per sq. in.	Comp. Strength, lb. per sq. in.
A	8.3 x 4.0 x 2.5	13.6	412	3,110
B	8.2 x 4.0 x 2.5	14.1	495	2,650
C	8.2 x 4.0 x 2.5	14.1	529	3,380
D	8.3 x 4.0 x 2.5	14.2	648	3,530
E	8.2 x 4.0 x 2.5	14.6	630	5,300
F	8.2 x 4.0 x 2.5	15.1	810	4,530
G	8.3 x 3.9 x 2.5	11.7	1,162	5,800
H	8.3 x 4.0 x 2.5	12.5	758	4,660
I	7.9 x 3.8 x 2.4	7.3	1,763	7,000
J	7.9 x 3.9 x 2.4	7.8	1,940	7,100
K	7.8 x 3.8 x 2.4	6.0	2,120	11,580
L	7.9 x 3.8 x 2.4	7.0	1,420	10,040
M	7.9 x 3.8 x 2.4	5.00	1,353	9,500
N	7.7 x 3.8 x 2.3	6.4	2,300	9,920

Requirements, Federal Spec. SS-B-656

Grade	Maximum absorption		Mod. of rupture, lb. per sq. in.	
	Average of 5, percent	Individual maximum, percent	Average of 5	Individual minimum
H	10 or less	12	600 or more	400
M	16	20	450 to 600	300
S	No limit	No limit	300 to 450	200

(No compressive strength specified in Federal Spec. SS-B-656)

Compressive strength requirement, A.S.T.M. C 62-49

Designation	Minimum Compressive Strength, lb. per sq. in. gross area.	
	Average of 5 bricks	Individual
Grade SW	3,000	2,500
MW	2,500	2,200
NW	1,500	1,250

Remarks: All bricks conform to the requirements of Federal Specifications SS-B-656, Grade M. Bricks I to N inclusive meet the requirements of Grade H.

All bricks meet the compressive strength requirements of A.S.T.M. C 62-44, Grade SW, with the exceptions of bricks A and B, which can be classed as Grade MW in compressive strength.

Conclusions

The sticky, plasticity and resultant high shrinkage properties of the Anchorage clay samples presents a serious difficulty in forming structurally sound brick. The clay has a strong tendency to laminate in forming because it adheres to the auger blades. This tendency can be reduced by adding non-plastic material, such as grog or sand. These additions should be controlled carefully, as an excess will seriously reduce the green strength of the piece.

An extremely short firing range will hamper production of a good fired piece. Satisfactory brick, however, may be and have been produced from the Anchorage clay.

American Roofing Co.

Location and Accessibility

The clay area under lease to the American Roofing Co. is on both sides of the Potter Highway where it crosses Edmonds Creek. It is approximately 11 miles from Anchorage by a well-maintained road which is kept open for travel throughout the year.

Production and Ownership

The following land is held under a mining lease from the Bureau of Land Management; Unsurveyed lands on the Potter Highway near the junction of highway and Edmonds Creek. Approximately 1,475 feet at a bearing of N. 10° 45' E. from the 101.5 post on the Alaska Railroad to the southwest corner of area requested; then N. 02° 28' W., 2,640 feet; S. 87° 32' W. 1,920 feet; and S. 02° 28' E. 1,920 feet to point of beginning. An area of 300 feet on each side of the Potter road is excluded, leaving an area of 80 acres more or less. The lease is held by A. T. Van Dolah, an individual trading as the American Roofing Co., of Anchorage, Alaska. He has more recently staked placer claims covering the area held under lease.

The Bureau of Land Management has indicated that although the lease excluded an area of 300 feet on each side of the road, the clay adjacent to the road might be used if an operating concern is established. This was an important concession, as the road reservation covers the major portion of the clay.

There has been no production from this deposit.

Description of Deposit

The clay deposit on the lease of the American Roofing Co. at Edmonds Creek on the Potter Highway is on both sides of the road and is exposed in several road cuts. The clay deposit represents a clay bed of glacial origin that has been partly removed by surface erosion. The greater part of the clay now known is in several small, rounded knolls covered with glacial gravel in an area 1,000 feet long and approximately 800 feet wide, parallel to the highway. Maximum depth of clay measured was 14 feet. Between the knolls the clay has been entirely eroded, leaving a mixture of clay, peat, and gravel.

The clay is in part very impure; it contains over 10 percent glacial gravel.

Clay-Utilization Tests

Four samples were taken from the clay deposit on the lease of the American Roofing Co. The first two samples, 1 and 2, were taken along the point of the knoll 100 feet north of the American Roofing Co. plant site. The results of tests on these samples are given in table 14.

TABLE 14. - Results of clay-utilization analyses, of samples from American Roofing Co. deposits

Sample number	Fired to cone	Firing shrinkage, percent	Absorption, percent		Absorption coefficient	Modulus of rupture, p.s.i.	Remarks
			24-hour soak	5-hour boil			
1	010	nil	15.7	16.3	0.95	741	Slightly underfired
	07	0.3	15.5	15.7	.99	1,191	Do.
	03	5.8	5.9	6.6	.89	3,866	Overfired.
	02	-	-	-	-	-	Badly bloated.
2	010	.5	14.8	14.9	.99	1,793	Underfired.
	07	.7	14.1	14.3	.99	2,717	
	03						Severely bloated.

Two additional samples were taken 400 and 500 feet, respectively, south of the plant site. These samples were not tested because they were similar to those already tested.

Conclusions

Neither sample tested is suitable for making structural clay products, because of a very short firing range.

The coefficient of absorption after firing, which is the ratio between absorption after a 24-hour soak and the absorption after a 5-hour boil, is too high in all cases. The coefficient of absorption is a measure of the resistance to freezing and thawing. Specifications established by the A.S.T.M., require a maximum absorption coefficient of 0.78. These clays ranged from 0.89 to 0.99.

Chickaloon-Formation Shale

Introduction

In the search for raw materials for heavy-clay products, samples were taken from all favorable formations within a suitable radius of Anchorage. Among those sampled was the shale from the Chickaloon formation in the Matanuska Valley.

Location and Accessibility

The Chickaloon formation is well-exposed in the valleys of Moose and Eska Creeks. Sample 13 was taken on the road leading to the Evan Jones and Eska coal mines approximately 1.5 milles north of the paved Glenn Highway. A second sample, 33, was taken from the shale outcrop along the banks of Eska Creek behind the Eska coal mine. The area is connected by a good gravel road to the highway at Sutton, mile 61. The general location of this area is shown in figure 3.

Description of Deposits

The shales in the Chickaloon formation are rather silty and sandy. Beds are not uniform and vary in both thickness and composition within short distances. Although the Tertiary Chickaloon formation is composed mainly of sandstone and shale, conglomerate, claystone, and coal beds also are present.

Sample 13 was taken from a 10-foot zone of black shale dipping gently southeastward on the left limit of Eska Creek east of the bridge across Eska Creek. Here the banks of the creek are composed of a succession of sandstone, conglomerate, claystone, coal, and black shale. Sample 33 was taken from a 22-foot bed of rather sandy shale on Eska Creek east of the Eska coal mine.

Clay-Utilization Tests

The results of laboratory tests on sample 13 are given in **table 15**. Sample 33 developed only weak plasticity. Because it did not develop enough plasticity to form test pieces, an initial test with a 20-percent addition of sample 20 (Anchorage clay) was made. Enough plasticity still was not developed, and tests using 50 percent Anchorage clay also were unsuccessful.

TABLE 15. - Results of clay-utilization analysis of samples of Chickaloon-Formation Shale

Sample number	Fired to cone	Absorption, percent 24-hour soak	Absorption, percent 5-hour boil	Absorption coefficient	Modulus of rupture, p.s.i.	Remarks
13	06	12.7	15.7	0.81	503	Underfired.
13	02	4.9	8.7	.56	1,415	Good.
13	2	4.3	6.7	.63	2,442	Do.

Conclusions

Although sample 13 exhibited a short firing range, structural clay products probably could be made if firing were controlled carefully. After grinding, it develops fair plasticity and works well. Salt-glazing tests indicate that this shale will accept a salt glaze satisfactorily.

Sample 33 was not amenable for the production of clay products. The results obtained from sample 13, however, indicate that additional samples from this formation should be taken for investigation as a possible source of shale for sewer tile and other structural clay products.

Matanuska-Formation Shale

Introduction

Shale beds in the Matanuska formation of the Upper Cretaceous were among those tested as a source of clay products.

Location and Accessibility

The Matanuska formation is exposed along the lower Matanuska River for more than 22 miles. The base of this formation is represented in part by a series of black shale relatively free from sandstone and grit. Three samples of this material, 11, 53, and 54, were taken for investigation.

Sample 11 was taken along the road cut at mile 67 on the Glenn Highway. The area is 6 miles east of Sutton on the Matanuska Brance of the Alaska Railroad; it is accessible throughout the year on paved highway. The location of the area is shown on figure 20. The sample location is shown on figure 22.

The other two samples were from an outcorp at mile 16 on the Matanuska Branch of the Alaska Railroad.

Description of Deposits

The shale at mile 67 is exposed in the north end of a road cut. Probably it extends northward to the bluffs along Kings River (fig. 22). No bedding could be determined in the shale. The outcrops contained only a few, small, scattered grit facies. A zone of medium-grained, dark-gray, dirty sandstone (?) bounded by two vertical east-west faults occupies most of the road cut and terminates the shale on the south.

Samples 53 and 54 represent sections 500 feet apart across an 80-foot zone of similar black shale, which is 200 feet west of mile 16 on the railroad to Sutton. This formation strikes N. 75° E. and dips 85° northwest.

Clay-Utilization Tests

The results of tests for ceramic uses of the above samples are given in table 16.

TABLE 16. - Results of clay-utilization analyses of samples of Matanuska-formation shale

Sample number	Fired to cone	Absorption, percent		Absorption coefficient	Modulus of rupture, p.s.i.	Remarks
		24-hour soak	5-hour boil			
11	06	10.5	13.1	0.8	826	Soft, underfired.
11	02	-	-	-	2,494	Bloated.
11	2	-	-	-	-	Bloated and fused.
53	011	13.7	14.5	.95	518	Underfired.
53	01-02	1.1	2.5	.44	2,540	Overfired.
53	3	Bloated				Do.
54	011	14.0	14.7	.95	611	Underfired.
54	1-2	.4	1.3	.31	3,057	Overfired.
54	3	Bloated				Do.

Conclusions

These shales are so highly metamorphosed that it is not considered economic to use them to make structural clay products industrially. When ground to pass 20-mesh and worked with water, they do not develop enough plasticity to allow shapes to be formed.

The range between cones 011 and 01-02 might yield a satisfactory product, but high resistance to grinding, weak plasticity, and poor fired color are factors that make this shale undesirable for use in structural-clay products.

Sheep Mountain Clay

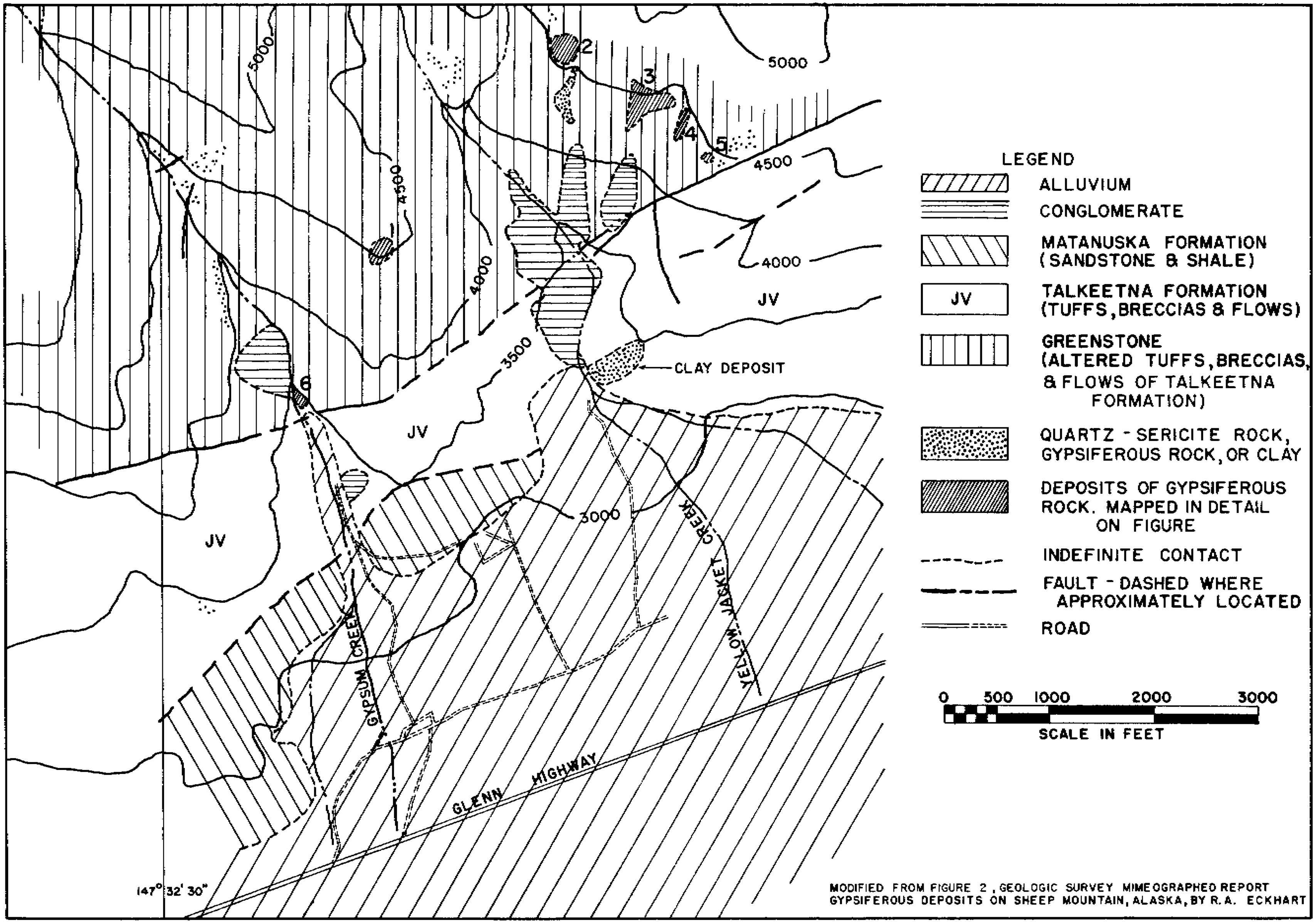
Introduction

During 1948, 50 tons from a clay deposit on Sheep Mountain was sold to Clay Products, Inc., of Anchorage for fire clay. Approximately 25,000 brick were produced from this material and sold for use as fire brick in the Anchorage area.

The Sheep Mountain area was investigated by the Geological Survey during the summer of 1949. A geologic map was prepared of the area containing the gypsiferous and clay deposits (fig. 13).

Location and Accessibility

Sheep Mountain is on the Glenn Highway 113 miles northeast of Anchorage. The principal clay deposit is 3,200 to 3,500 feet above sea level. Although the Glenn Highway is maintained throughout the year, access to the clay deposit over the steep, unimproved road would not be practicable during the winter months.



MODIFIED FROM FIGURE 2, GEOLOGIC SURVEY MIMEOGRAPHED REPORT GYPSIFEROUS DEPOSITS ON SHEEP MOUNTAIN, ALASKA, BY R. A. ECKHART

Figure 13. - Geologic map of Sheep Mountain, Alaska.

Physical Features

Sheep Mountain is a varicolored, northeast-trending ridge whose summit is over 6,000 feet above sea level. It is at the head of the Matanuska Valley between Caribou Creek and Tahneta Pass. The area is near the central part of the south flank of the mountain.

The slopes are precipitous; two deep ravines, which mark the paths of Gypsum and Yellow Jacket Creeks, traverse the gypsiferous area.

Although there is little vegetation on the steep slopes, the base of the mountain and the valley below is covered with scattered spruce, birch, cottonwood, and undergrowth of small brush and grasses.

History, Production and Ownership

The gypsiferous area on Sheep Mountain was partly covered by a group of 14 claims staked in 1946 by George H. Fennimore, Nellie Fennimore, and Leland Johnson of Anchorage, Alaska, and Robert Clem of Palmer, Alaska. The claims then were grouped under the Alaska Gypsum Queen Corp., which consists of Mrs. George H. Fennimore, president, George H. Fennimore, Leland Johnson, and Robert Clem.

The Alaska Gypsum Queen Corp. leased the claims to Anchorage Gypsum Products. Anchorage Gypsum Products had been formed by George H. Fennimore, Don H. Goodman, and Edwin Johanson of Anchorage to produce gypsum products for the building-materials industry.

A small calcining plant was constructed on Gypsum Creek, and over 50 tons of calcined gypsiferous material was produced from the deposit along Gypsum Creek.

From the clay deposit on Yellow Jacket Creek, 50 tons of clay was sold to Clay Products, Inc., of Anchorage for the production of brick, and approximately 5 tons of clay was sold in Palmer for lining boiler fire boxes.

Description of Deposit

The clay deposit on Yellow Jacket Creek is shown on figure 8. This deposit is composed of clay minerals, gypsum, and quartz-sericite rock, which are alteration products of the volcanic rocks in the Lower Jurassic Talkeetna formation. The color of the material ranges from white through yellow to a light orange. It is very plastic.

The deposit forms the nose of a spur ridge on the left limit of Yellow Jacket Creek, 3,200 to 3,500 feet above sea level. It is exposed throughout a vertical range of about 300 feet, a length of about 500 feet, and a width of about 250 feet. The average thickness of the deposit is 1.5 feet.

Sample 35 was taken from the clay pit of Alaska Gypsum Products near the lower extremity of the deposit. It is representative of the material sold for fire clay. Sample 38 was taken at an altitude of 3,400 feet.

Clay-Utilization Tests

The results of preliminary tests of samples 35 and 38 from the clay deposit at Sheep Mountain are given in table 17.

TABLE 17. - Results of clay-utilization analyses of samples of Sheep Mountain clay

		Absorption, percent				
Sample number	Fired to cone	24-hour soak	5-hour boil	Absorption coefficient	Modulus of rupture, p.s.i.	Remarks
35	06	8.1	10.8	0.75	3,136	Good.
35	03-04	7.4	9.6	.77	3,281	Do.
35	2	6.9	9.4	.73	3,955	Do.
35	3	6.4	10.0	.64	3,623	Do.
38	06	6.4	7.6	.84	3,289	Do.
38	03-04	5.8	7.2	.81	3,610	Do.
38	2	4.1	4.7	.87	4,143	Do.
38	3	4.7	5.5	.86	4,430	Do.

The above samples showed good possibilities in making structural-clay products. Additional tests to determine their resistance to weathering were made. The results of the tests covering the firing to temperature that resulted in low absorption are given in table 18; the tests that resulted in higher absorption are given in table 19. In both cases, samples 35A and 38A contain 15 percent grog additions (prefired clay to reduce shrinkage) of their own respective material.

TABLE 18. - Freezing-and-thawing tests on samples 35 and 38 of Sheep Mountain clay, firing for low absorption

			24-hour absorption			
Sample No.	Specimen No.	Weight loss, percent	Before test	After test	Absorption coefficient	Structural failure No. of cycles
35	5	1.09	7.14	7.70	0.78	None.
	10	1.10	7.78	8.30	.78	Do.
	11	.33	8.56	8.56	.77	Do.
	12	1.26	7.68	8.53	.76	Do.
	13	1.13	7.46	8.12	.77	Do.
	14	1.04	7.07	7.72	.75	Do.
	15	1.14	7.63	8.44	.74	Do.
35A	6	1.48	8.93	9.78	.72	Do.
	7	1.30	8.25	9.17	.71	Do.
	8	1.41	9.17	10.21	.71	Do.
38	9	.35	8.50	8.73	.77	Do.
	10	.30	8.52	8.70	.82	Do.
	11	.25	8.14	8.56	.80	Do.
	12	.25	7.24	7.51	.78	Do.
	13	.31	6.95	7.58	.74	Do.
	14	.35	7.22	8.47	.76	Do.

TABLE 18. - Freezing-and thawing tests on samples 35 and 38 of Sheep Mountain clay, firing for low absorption (Cont.)

Sample No.	Specimen No.	Weight loss, percent	24-hour absorption		Absorption coefficient	Structural failure No. of cycles.
			Before test	After test		
38A	7	.39	8.71	8.89	0.79	Do.
	8	.24	8.63	8.85	.77	Do.
	9	.27	8.26	8.26	.77	Do.
	10	.27	9.25	9.33	.79	Do.
	11	.22	8.47	8.54	.78	Do.
	12	.35	8.30	8.53	.78	Do.

TABLE 19. - Freezing-and-thawing tests on samples 35 and 38 of Sheep Mountain clay, firing for higher absorption

Sample No.	Specimen No.	Weight loss, percent	24-hour absorption		Absorption coefficient	Structural failure No. of cycles.
			Before test	After test		
35	1	1.15	8.58	9.35	0.79	None.
	2	.99	9.04	9.85	.79	Do.
	3	.99	8.94	9.61	.81	Do.
	4	.99	8.04	8.74	.76	Do.
	6	1.13	8.42	9.09	.79	Do.
	7	1.19	9.41	10.15	.81	Do.
	8	1.26	9.11	9.98	.81	Do.
35A	1	1.87	12.03	13.10	.84	Do.
	2	1.79	11.78	12.77	.80	Do.
	3	1.92	12.47	13.39	.85	Do.
	4	2.14	12.14	13.15	.85	Do.
	5	1.46	10.38	11.33	.82	Do.
38	1	.25	9.28	10.05	.86	Do.
	2	.05	10.07	10.58	.91	Do.
	3	.10	10.22	11.13	.90	Do.
	4	.25	10.41	11.09	.91	Do.
	5	.15	9.91	10.18	.93	Do.
	6	.10	10.04	10.26	.91	Do.
	7	.20	11.17	11.49	.93	Do.
	8	-	10.26	-	.91	35
38A	1	.20	12.09	12.09	.90	None.
	2	.20	12.75	12.75	.90	Do.
	3	.15	11.64	11.64	.90	Do.
	4	.20	11.80	11.80	.90	Do.
	5	.20	11.94	11.94	.90	Do.
	6	-	13.32	-	.91	42

Of the two failures indicated, samples 38-8 and 38A-6 failed in virtually identical manner, owing no doubt to structural faults. Cracking began horizontally across the face of the bars and halfway down each side at approximately the center of the bar with respect to length. The crack increased gradually, sample 38-8 failing completely 5 cycles later; sample 38A-6 failed 10 cycles later.

Samples of the brick made of the clay from the Sheep Mountain deposit by Clay Products, Inc., of Anchorage were submitted to the Corps of Engineers for testing as fire brick. The results are given in table 20 by permission of the Army Engineers.

TABLE 20. - Clay Products, Inc., fire brick, P.C.E.

Sample	Cone number and temperature
515 - 1	Cone 15+[1], or 1,420°C.
515 - 2	Cone 15+, or 1,420°C.
515 - 3	Cone 15+, or 1,420°C.
515 - 4	Cone 15+, or 1,420°C.
515 - 5	Cone 15+, or 1,420°C.

[1] Plus sign indicates sample withstood heat of cone indicated but failed to withstand heat necessary for next cone in series.

Note: Test performed in accordance with A.S.T.M. C 24-42, Standard method of test for pyrometric cone equivalent of refractory materials.

During the testing by the Bureau of Mines, clay samples 35 and 38 from Sheep Mountain also were tested for their P.C.E. The P.C.E. of sample 35 is cone 8 (2,237° F.). Sample 38 when washed was a cone 28+ (2,939° F.); the residue from the washing is cone 17 (2,669° F.).

Conclusions

The results of the above tests on the two samples of clay from Sheep Mountain, samples 35 and 38, indicate that the clay has excellent working characteristics and fired strength. Both samples show merit for most ceramic uses. Sample 38 has merit for low-heat-duty refractory use. Although sample 38 is the more refractory of the two, it forms a denser body on firing, as denoted by lower absorptions, because of its higher clay content.

In the freezing-and-thawing tests, none of the samples tested exceeded the maximum permissible weight loss of 3 percent specified by A.S.T.M. No partial failures occurred, except in samples 38-8 and 38A-6, as already noted. Modulus of rupture of the respective samples before and after freezing-and-thawing was consistent. This indicates no appreciable decrease in strength as result of the weathering tests.

In view of the severity of the A.S.T.M test, which involves repeated complete saturation, immersion during freezing equivalent to 1/2 inch on commercial-size brick, comparatively sudden and complete freezing, and constant handling, these samples have successfully withstood the equivalent of a rigorous climate.

Although the tests indicate that the material represented by sample 38 shows possibilities for low-heat-duty refractory use, the clay mined (sample 35) was not of such refractory character. This is shown also by the P.C.E. obtained during the tests by the Army Engineers - cone 15 on brick produced from similar material. A cone of 19 is required for refractory use. Bureau of Mines tests on sample 35 gave a cone of 8.

The Sheep Mountain clay with proper preparation, such as washing, is capable of producing a brick of high-heat duty for refractory use. The P.C.E. of washed sample 38 was cone 28.

Cantwell Shale

Introduction

Shales from a series of conglomerates, sandstone, and shales, which included igneous material in the Cantwell area, were sampled for their possible ceramic use. Sample 51 was taken along the road cut at mile 321.1 on the Alaska Railroad 1.4 miles north of Cantwell, Alaska. Another sample, 52, was taken on the right limit of Little Windy 1 mile above the railroad.

Description of Samples and Deposits

Shale, intruded by several narrow zones of igneous rocks, outcrops along the Alaska Railroad almost continuously between miles 321.1 and 322.

A 250-foot bed of shale beginning at mile 321.1 was sampled and numbered 51. This shale strikes N. 60° to 75° E. and dips steeply northward.

Sample 52 was taken across a 200-foot bed of shale, which forms a cliff on the right limit of Little Windy 1 mile upstream from the Alaska Railroad.

Clay-Utilization Tests

The results of ceramic tests for samples 51 and 52 from the Cantwell area are given in table 21. Inasmuch as neither sample developed enough plasticity to form test pieces, 10 percent of sample 35 (Sheep Mountain clay) was added to sample 51, and a total of 17.5 percent of samples 35 and 38 (50-50) was added to sample 52 before tests could be made.

TABLE 21. - Results of clay-utilization analyses of samples of Cantwell shale

Sample number	Fired to cone	Absorption, percent		Absorption coefficient	Modulus of rupture, p.s.i.	Remarks
		24-hour soak	5-hour boil			
51+35	06	14.7	16.6	0.88	493	Underfired.
51+35	1-2	10.4	13.4	.78	1,579	Good.
51+35	3	Fused and bloated				Overfired.
$52+{}^{35}_{38}$	04	14.9	16.7	.89	583	Underfired.
$52+{}^{35}_{38}$	1-2	11.0	13.5	.81	1,645	Good.
$52+{}^{35}_{38}$	3	Fused and bloated				

Conclusions

The results from these tests indicate that this shale is not amenable for ceramic uses. The poor plasticity and short firing range rule these samples out as raw material for use in structural-clay products.

Healy Shale

Introduction

The Tertiary coal-bearing formation in the Healy River Valley is composed of a series of sandstones, grits, shales, claystones, fine conglomerate, and coal beds that probably are Miocene.[21] Shale and clay from this series were first investigated for use in brick and tile production in 1931 by Gerald A. Waring.[22] Samples were submitted, with very encouraging results, to the Ceramic Experiment Station of the Bureau of Mines, Columbus, Ohio.

The Healy Creek area was examined more extensively by the Geological Survey during the summer of 1944. On the basis of this examination, a geologic map and detailed sections of the formations were prepared.[23]

Samples from the two most prominent and persistant shale beds were taken by the Bureau of Mines for ceramic tests.

Location and Accessibility

The shale beds sampled in the Healy River Valley are adjacent to the Suntrana coal mine, which is connected to the Alaska Railroad at Healy by a 4-mile spur line. Healy, at mile 358.1, is 243.8 miles north of Anchorage and 112.2 miles south of Fairbanks (fig. 3). Rail transportation is available throughout the year. Figure 14 shows the location of the coal and shale formations in the Healy Valley relative to the Alaska Railroad.

Physical Features and Climate

The valley of the Healy River traverses the northern foothills of the Alaska Range. Healy River flows westward and joins the Nenana River at Healy.

The coal-bearing formations are in areas of moderate relief that tend to follow the east-west trend of the intervening ridges.

The climate is that of interior Alaska, which is characterized by hot, short summers and long, cold winters. The weather conditions at Healy should approximate the average of weather conditions at Nenana and at McKinley. Climatological data for Nenana and for Healy are given in the general section of this report.

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[21] Work cited in footnote 2, p. 122.

[22] Waring, Gerald A., Nonmetalliferous deposits in the Alaska Railroad Belt: Geol. Survey Circ. 18, 1947, p. 9.

[23] Wahrhaftig, Clyde, and Freedman, Jacob, Coal Deposits in the valley of the Healy River, Alaska: Geol. Survey mimeo. rept., 1945, 8 pp.

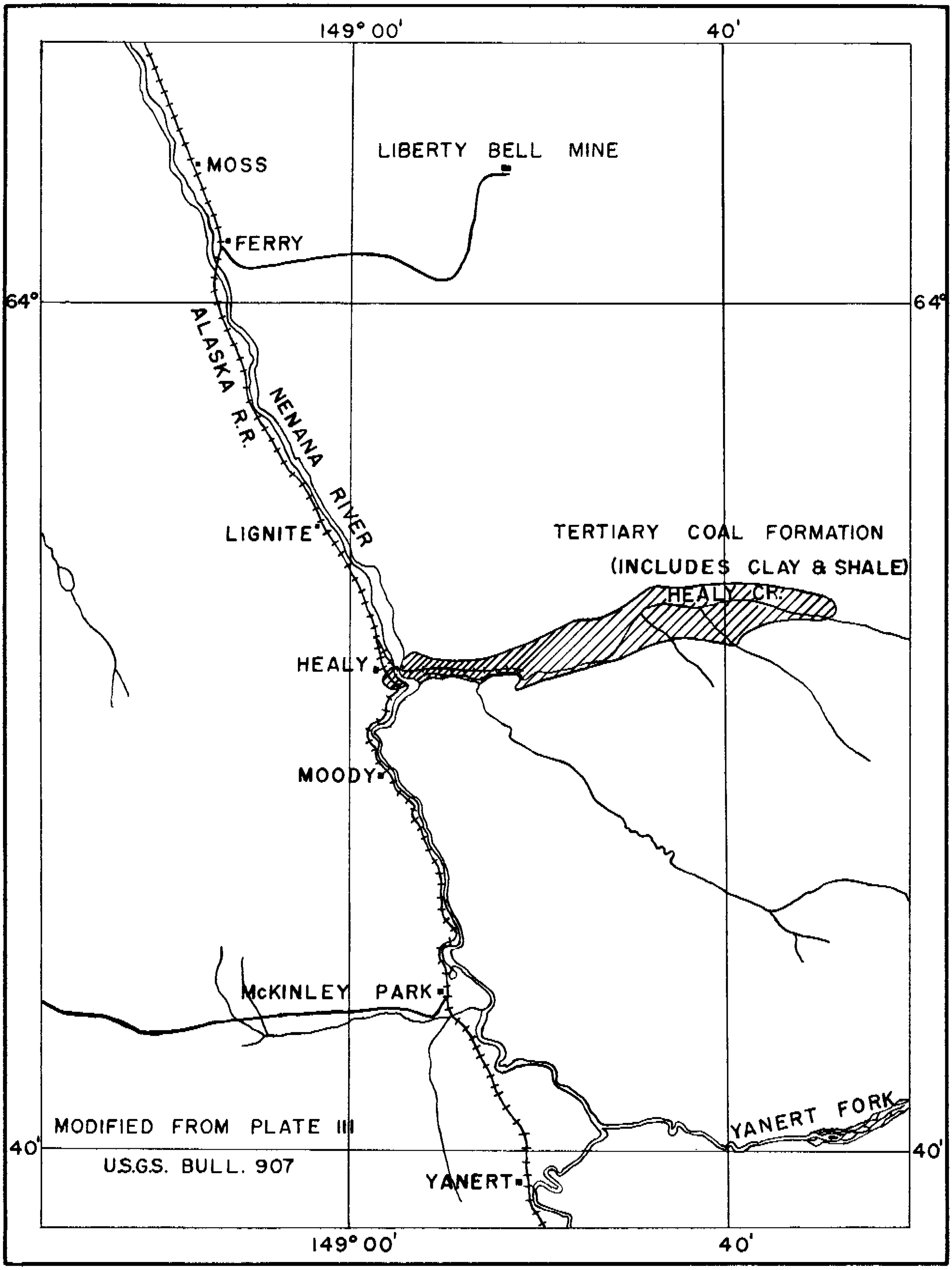
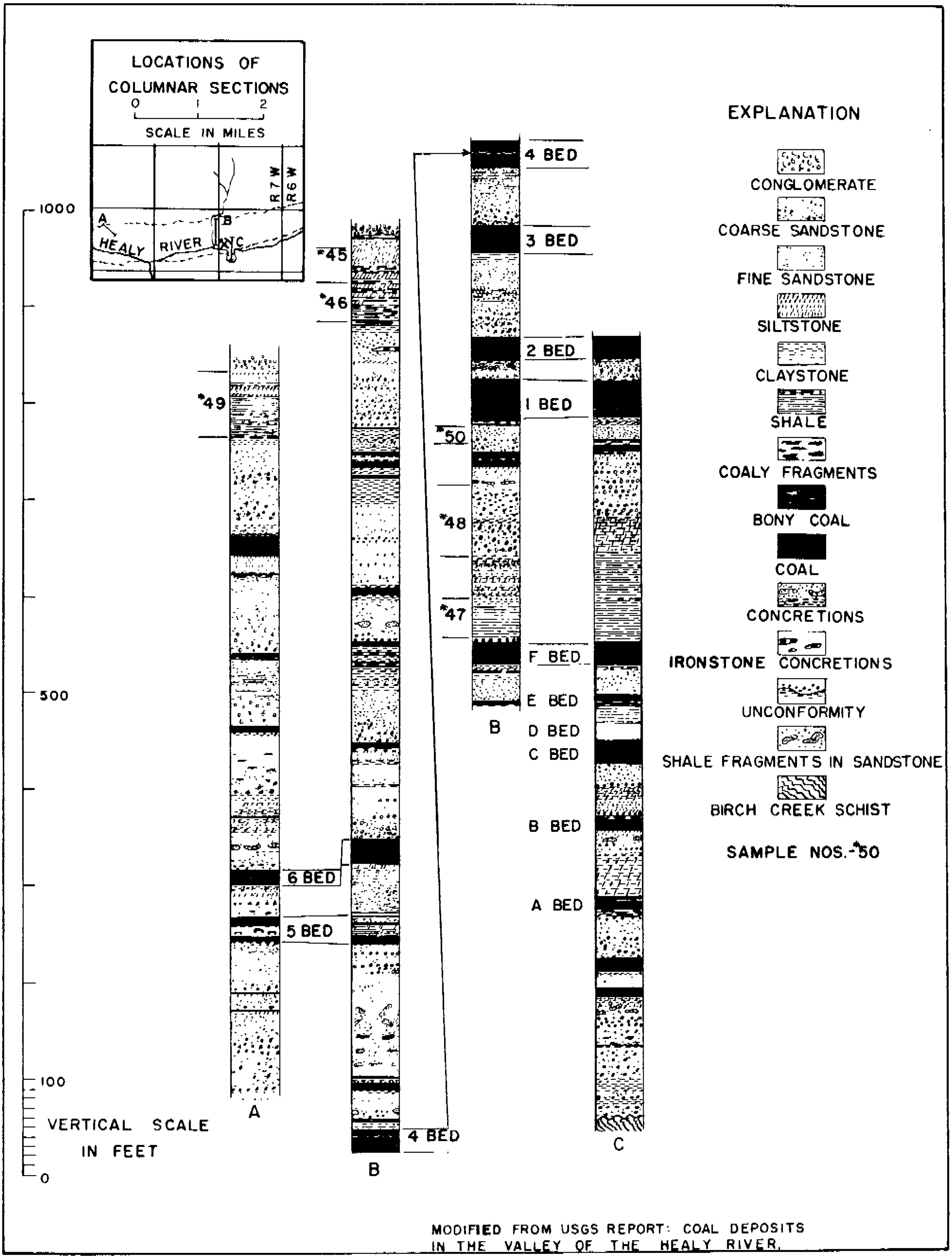


Figure 14. - Location map of Healy clay deposit, Healy Valley, Alaska.



MODIFIED FROM USGS REPORT: COAL DEPOSITS IN THE VALLEY OF THE HEALY RIVER.

Figure 15. - Stratigraphic sections showing Healy shale bed sampled.

Description of Deposits

A 65- to 80-foot shale bed lies near the top of the upper member of the coal-bearing formation in the Healy Valley. Numerous intercalated beds of silt and fine sand are in the upper part of this bed. Figure 15 shows geologic sections by Wahrahftig and Freedman[24/] through the two sample locations.

Sample 45 was taken from the top 35 feet of the upper main shale bed where it crops out in Suntrana Creek, stratigraphic section B. The overlying Nenana gravel is separated from this shale by 8 feet of sand. The shale represented by sample 45 is green to gray and contains thin seams of sand. Sample 46 was taken across the remaining 40 feet in this shale bed and is more uniform; it contains very little sandy material.

A third sample, 49, was taken from this shale bed at section A, 1-1/2 miles west of the first location. The shale bed at this point is 64 feet thick and immediately beneath the Nenana gravel.

The other prominent shale bed is approximately 1,300 feet stratigraphically below the first bed sampled and lies on coal bed F (see fig. 15). Sample 47 was taken across the lower 40 feet of this bed at section B and was relatively free of silty material. The upper 45 feet of this bed is very silty and was not sampled. Figure 16 is a view of this shale bed above the Suntrana coal mine.

Clay-Utilization Tests

Preliminary Bureau of Mines tests indicated that these shales show good possibilities for use in structural-clay products. Although underfired at cone 06 and overfired at cone 2-3, both the underfired and overfired products could be sold for certain uses. They have a probable firing range of cone 04 to cone 1, or a 5-cone range, in which a good quality product could be made. The results of the tests are given in table 22.

TABLE 22. - Results of clay-utilization analyses of samples of Healy shale

Sample number	Fired to cone	Absorption, percent		Absorption coefficient	Modulus of rupture, p.s.i.	Remarks
		24-hour soak	5-hour boil			
45....	06	20.5	22.8	0.90	1,001	Underfired.
45....	01	7.0	10.1	.69	3,302	Good.
45....	3	.56	.56	1.00	5,464	Overfired.
46....	04	15.6	17.3	.90	2,593	Slightly underfired.
46....	1-2	.3	.5	.67	5,690	Overfired.
46....	Bloated					
47....	04	12.1	14.6	.83	3,206	Good.
47....	01	8.2	10.8	.76	3,962	Do.
47....	3	2.9	3.8	.76	5,227	Overfired.
49....	06	16.5	18.2	.90	1,882	Underfired.
49....	01	5.5	5.5	.71	3,634	Good.
49....	3	.25	.25	1.00	5,467	Overfired.

[24/] Work cited in footnote 23, fig. 4.

Though the preliminary tests indicated that a good-quality product could be expected from these shales, freezing-and-thawing tests were made on fired test specimens to appraise their resistance to the vigorous climate found in the railroad belt. Table 23 contains the results of these tests.

TABLE 23. - Results of freezing-and-thawing tests on samples of Healy shale

Sample No.	Specimen No.	Weight loss, percent	24-hour absorption		Absorption coefficient	Structural failure. Number of cycles
			Before test	After test		
45	2	0.00	10.63	11.05	0.73	None
	4	.05	9.15	9.77	.69	Do.
	6	.19	8.36	9.38	.67	Do.
	7	.14	8.21	8.46	.64	Do.
	8	.09	8.79	9.36	.69	Do.
	9	.19	8.49	9.27	.68	Do.
	10	.23	9.95	9.95	.73	Do.
46	11	.09	11.62	11.87	.82	Do.
	12	.09	10.91	10.92	.83	Do.
	16	.05	8.62	8.76	.76	Do.
	17	.04	10.86	11.23	.80	Do.
	18	.09	11.63	12.01	.82	Do.
	19	.05	11.76	12.24	.82	Do.
	20	.09	10.01	10.58	.79	Do.
49	2	.35	18.54	19.00	.91	Do.
	4	.15	18.64	19.00	.91	Do.
	6	.10	19.00	19.16	.91	Do.
	8	-	19.57	-	.90	14
	9	.25	18.94	19.43	.92	None
	10	.05	4.62	4.87	.68	Do.
	11	.05	6.94	7.19	.74	Do.
	12	.05	5.60	5.75	.71	Do.
	13	.10	5.12	5.28	.70	Do.
	14	.05	6.29	6.55	.73	Do.
	16	.20	4.25	4.76	.67	Do.
47	12	.09	9.48	9.48	.72	Do.
	13	.14	10.57	10.57	.74	Do.
	14	.09	9.53	9.53	.72	Do.
	16	.09	11.17	11.18	.78	Do.
	17	.09	12.05	12.05	.84	Do.
	19	.09	10.46	10.70	.77	Do.
	21	.14	9.80	11.27	.73	Do.

The failure of sample 49-8 was due, no doubt, to a structural fault. After three cycles, a crack appeared. The crack penetrated about 1/4 inch into the bar normal to the long axis and continued from the end of this crack to the surface, about 1-1/2 inches. Some disintegration was visible after the sixth cycle. Complete failure occurred at 14 cycles.

There were no failures with the test bars from samples 45, 46, and 47. Spalling was not apparent, as evidenced by the minute weight losses indicated. Sample 45 showed considerable efflorescence, which could undoubtedly be overcome by adding barium salts in manufacture.

Conclusions

These shales show the best possibilities, next to the clay from Sheep Mountain, of all the samples from the railroad belt tested during this investigation.

None of the samples from Healy exceeded the maximum permissible weight loss of 3 percent specified by A.S.T.M.; except for 49-8, no partial failures occurred.

The modulus of rupture of the respective samples before and after freezing-and-thawing was consistent, which would indicate no appreciable decrease in strength as a result of the weathering tests.

Although the Healy shales represented by samples 45, 46, 47, and 49 have a short firing range, the results of the tests indicate that a satisfactory product that will withstand the rigorous climate of the railroad belt should be produced by adhering to good manufacturing procedures.

Harding Lake Clay

Introduction

Since one of the largest items in the cost of delivered brick along the Railroad belt is transportation, large cost advantages would be derived from brickmaking facilities using local deposits near the centers of population at both Anchorage and Fairbanks. Interest in the possible production of brick in the Fairbanks area had been shown in 1947 by two army officers, Lt. Col. J. H. Ford and Maj. Delmar R. Frazier. An investigation of sources of clay in their behalf was made by Irving Reed of Fairbanks.[25] Many samples were taken of probable deposits within a radius of 75 miles of Fairbanks, but only two showed promise. The first of these was 1/4 miles east of the Richardson Highway on the south side of Moose Creek Butte; the other sample was from the north bank of a gravel pit on the east side of the Richardson Highway 1/2 mile north of the entrance to the Harding Lake Road.

During this investigation, the Moose Creek deposit was not sampled because it is on or adjacent to the 26-mile military reserve. Only the similar deposit near Harding Lake was sampled.

Location and Accessibility

The Harding Lake clay deposit is 42.2 miles by the Richardson Highway southeast of Fairbanks, Alaska. The area, staked as placer claims by Delmar R. Frazier and Irving Reed, is 1/2 mile west of the paved Richardson Highway, which is kept open throughout the year. The relationship of the area to Fairbanks is shown on figure 3. The sample locations and claims are shown on figure 17.

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[25] Reed, Irving, Report of Investigation for Brick Clay Adjacent to Fairbanks, Alaska: Private rept., 1947.

Physical Features and Climate

The clay deposit is in the valley of the Tanana River above its confluence with the Salcha River along the north slope of a low hill west of Harding Lake. The immediate area is one of low relief with gentle slopes.

Climate data for the Fairbanks area are given in the tables in the general section. The area is characterized by the warm summers and long cold winters of the interior.

Property and Ownership

Two 40-acre association placer locations were made July 23, 1947, by Delmar R. Frazier and Irving Reed of Fairbanks, Alaska. The claims are the Terra Cotta Assoc. claim, SW1/4NW1/4 sec. 2, and the Kaolin Assoc. claim, SE1/4NE1/4 sec. 3; T. 6 S., R. 4 E., Fairbanks meridian.

Description of Deposit

The two association claims cover the north slope of a long, low, east-west ridge sloping down to Water Lily Lake. The clay sampled is a product of erosion of the underlying granite-diorite intrusive. It is orange to red and contains much micaceous material and numerous quartz pebbles.

Sample 39 represents cuttings taken from 1.0 to 17.0 feet in hole 1 (fig. 17). The remainder of the hole, 17.0 to 22.0 feet, contained a larger quantity of quartz pebbles, was less altered, and exhibited very poor plasticity. This section is represented by sample 40.

Sample 41 represents cuttings taken from 1.0 to 13.0 feet in hole 2. This sample exhibited even less plasticity than sample 40.

The remaining auger holes contained material that was mainly unaltered and could not be shaped by hand. These test holes were not sampled.

When this examination was made in July 1950, permafrost was encountered throughout the lower part of the slope. Therefore, the lower slope was not sampled. The material penetrated beneath the dirt was very similar to that found in hole 2.

Clay-Utilization Tests

Data from the preliminary tests of samples 39, 40, and 41 from Harding Lake are given in table 24.

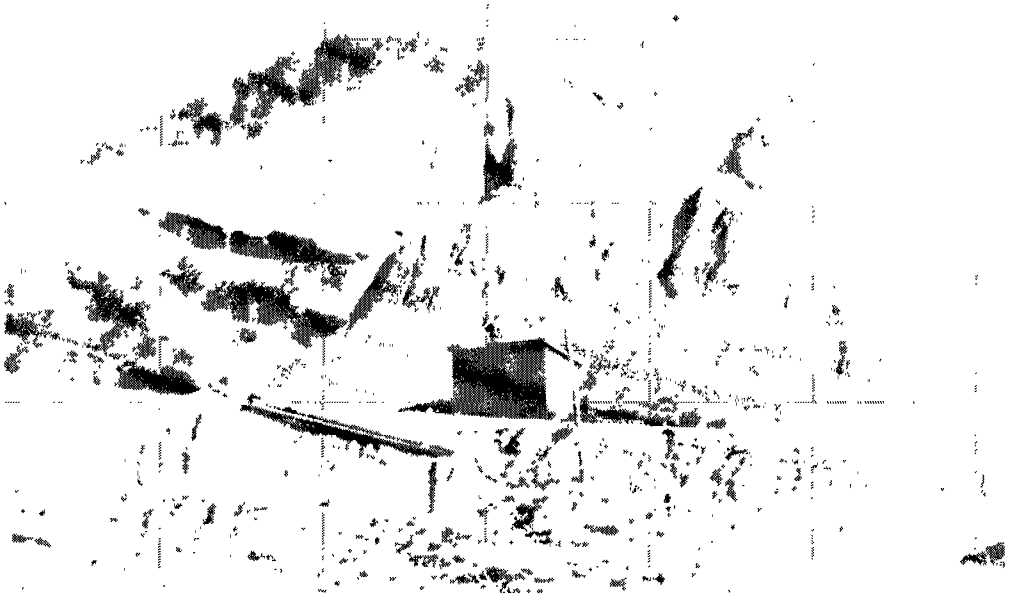


Figure 16. - Lower prominent shale bed at Suntrana, Alaska.

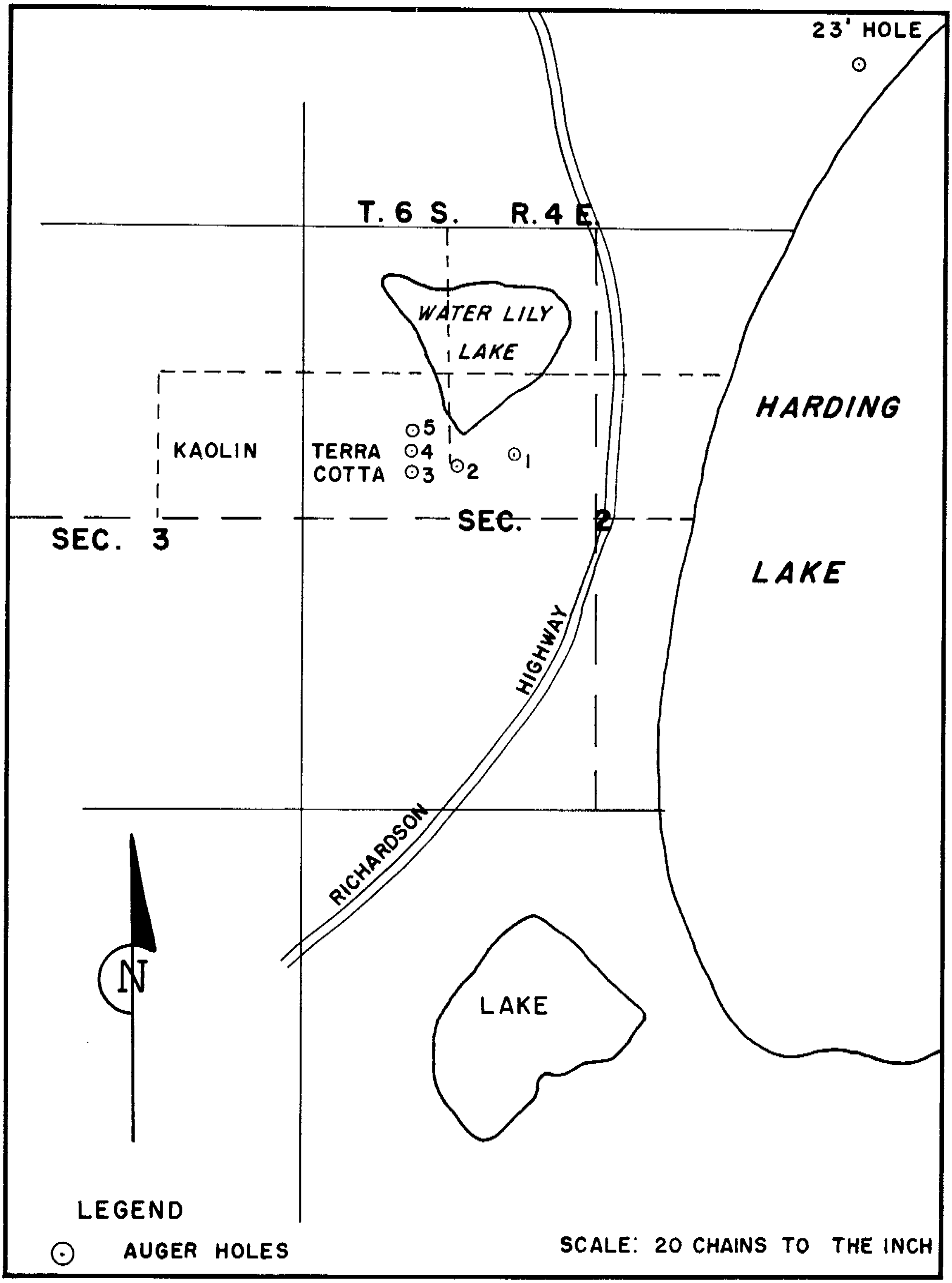
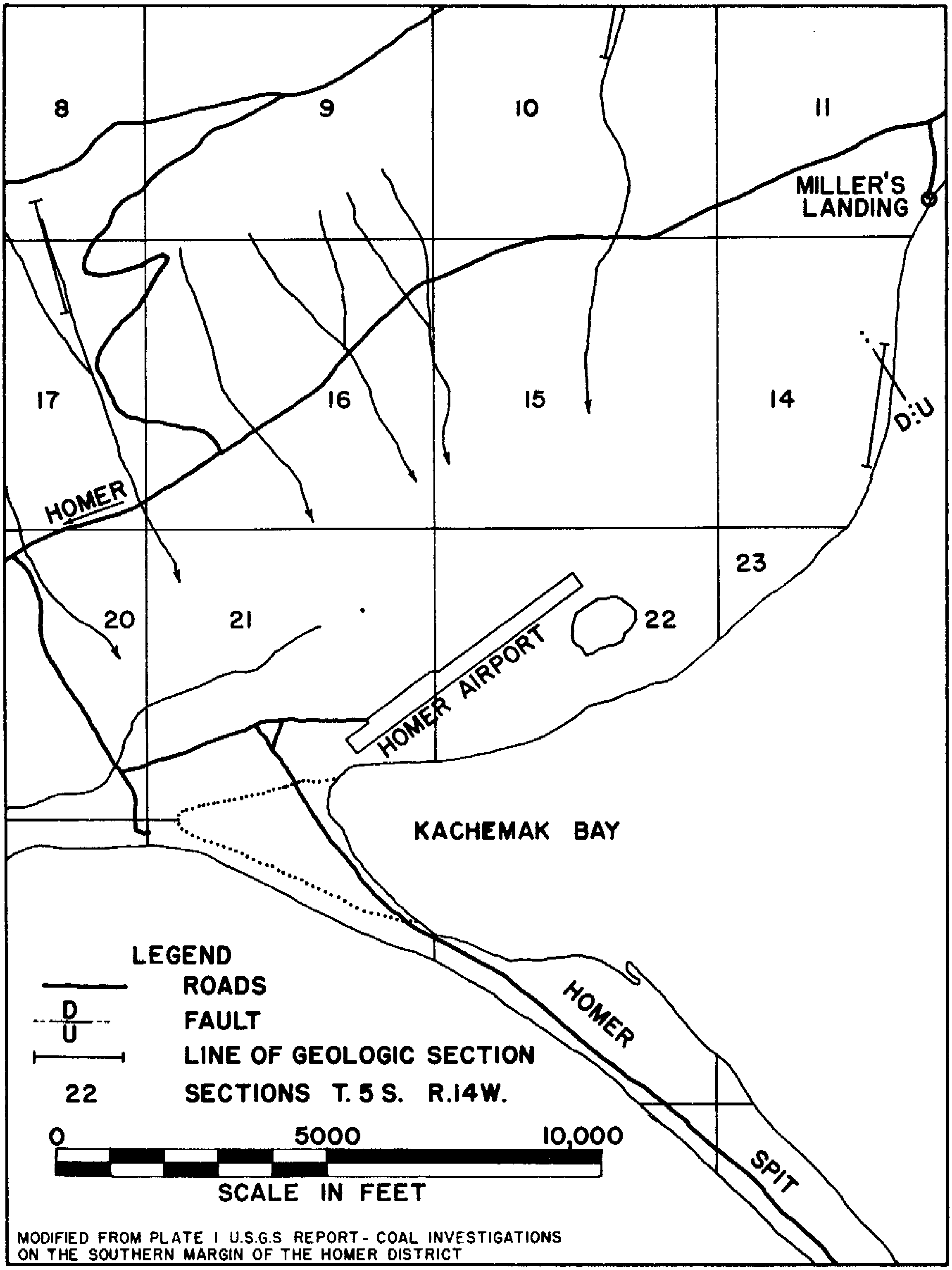


Figure 17. - Location map, Harding Lake clay deposit.



MODIFIED FROM PLATE I U.S.G.S REPORT - COAL INVESTIGATIONS ON THE SOUTHERN MARGIN OF THE HOMER DISTRICT

Figure 18. - Location map, Miller's Landing clay deposit.

TABLE 24. - Results of clay-utilization analyses of samples of Harding Lake clay

Sample number	Fired to cone	Absorption, percent		Absorption coefficient	Modulus of rupture, p.s.i.	Remarks
		24-hour soak	5-hour boil			
39	04	14.4	17.3	0.83	731	Underfired, weak.
39	03-02	12.5	15.7	.80	1,051	Slightly underfired.
39	1-2	10.1	13.3	.76	1,450	Good.
40	04	15.0	18.1	.83	560	Underfired, weak.
40	03-02	14.0	17.3	.81	686	Do.
40	01-02	11.3	14.4	.78	875	Do.
[1]41+16	04	14.8	17.1	.86	469	Do.
41+16	01-02	11.2	14.4	.79	763	Do.
41+16	3	2.7	5.8	.46	1,865	Overfired.

[1] Samples 40 and 41 had poor plasticity although test bars could be formed from sample 40, sample 41 had to be plasticized by addition of sample 16, Anchorage clay.

Conclusions

The test results indicate that the bulk of the material at Harding Lake is unsuited for ceramic products because of its low plasticity. Numerous quartz pebbles also are present as impurities. Several pits adjacent to the Richardson Highway in the same general area, were examined. Although the pits contained gravel from which clay could be washed, the quantity of clay that could be recovered would be small in proportion to the amount of material to be handled.

However, sample 39 shows possibilities for use in structural-clay products. An attempt should be made to delimit additional material of the same quality as sample 39.

Miller's Landing Clay

Introduction, Location, and Accessibility

The clay bed near Miller's Landing in the Homer area was the only deposit examined that was not directly within the Railroad-belt area. This clay deposit was sampled because of its location adjacent to Homer and because of its accessibility, by barge on Cook Inlet to Anchorage, or by the new Sterling Highway to both Anchorage and Seward. Homer is situated on the north shore of Kachemak Bay near the tip of the Kenai Peninsula.

The location of the clay outcrop near Miller's Landing is shown on figure 18.

Physical Features and Climate

Homer is at the southern end of the Kenai lowland, which is north of Kachemak Bay along the west flank of the Kenai Mountains on the Kenai Peninsula.

In the Homer area the sea cliffs along the north shore of Kachemak Bay are 50 to 200 feet high. A bench 1 to 2 miles wide parallels Kachemak Bay and slopes gently northward from the bluffs. This bench is crossed by several small, parallel streams that drain the uplands to the north.

The climate of the area is that characteristic of coastal Alaska. Summers are cool and the winters mild. Monthly and annual mean temperatures for Homer are given in table 25. Table 26 gives the monthly and annual total precipitation in inches. Freezing temperatures may be expected from early in September until the middle of June.

TABLE 25. - Mean temperatures, °F., for Homer, Alaska

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ave.
23.8	27.6	28.8	36.1	42.8	49.5	53.0	52.7	46.9	38.9	28.7	23.4	37.7

TABLE 26. - Precipitation, inches, for Homer, Alaska

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ave.
2.69	1.57	1.85	1.27	1.14	1.02	1.76	3.12	2.82	3.93	1.40	2.81	25.40

Description of Deposit

A 30-foot bed of blue clay outcrops 0.8 mile south of Miller's Landing in the bluff along Kachemak Bay. This clay bed is a part of the Kenai coal-bearing formation, which has been assigned by Smith[26] to the Tertiary period, probably Eocene. The Kenai formation consists of a series of sand, silt, and clay beds interbedded with a few beds of conglomerate and with numerous coal beds.

The clay bed sampled lies between two coal beds near the top of the stratigraphic section shown on figure 19. At this locality, the formation dips gently northward.

Clay-Utilization Tests

The results of ceramic tests on clay from the bed near Miller's Landing are given in table 27.

TABLE 27. - Results of clay-utilization analyses of samples of Miller's Landing Clay

Sample number	Fire to cone	Absorption, percent		Absorption coefficient	Modulus of rupture, p.s.i.	Remarks
		24-hour soak	5-hour boil			
77	09	12.3	14.1	0.88	2,830	Slightly underfired.
77	05	8.5	10.3	.83	3,725	Good.
77	01	Bloated				Overfired.

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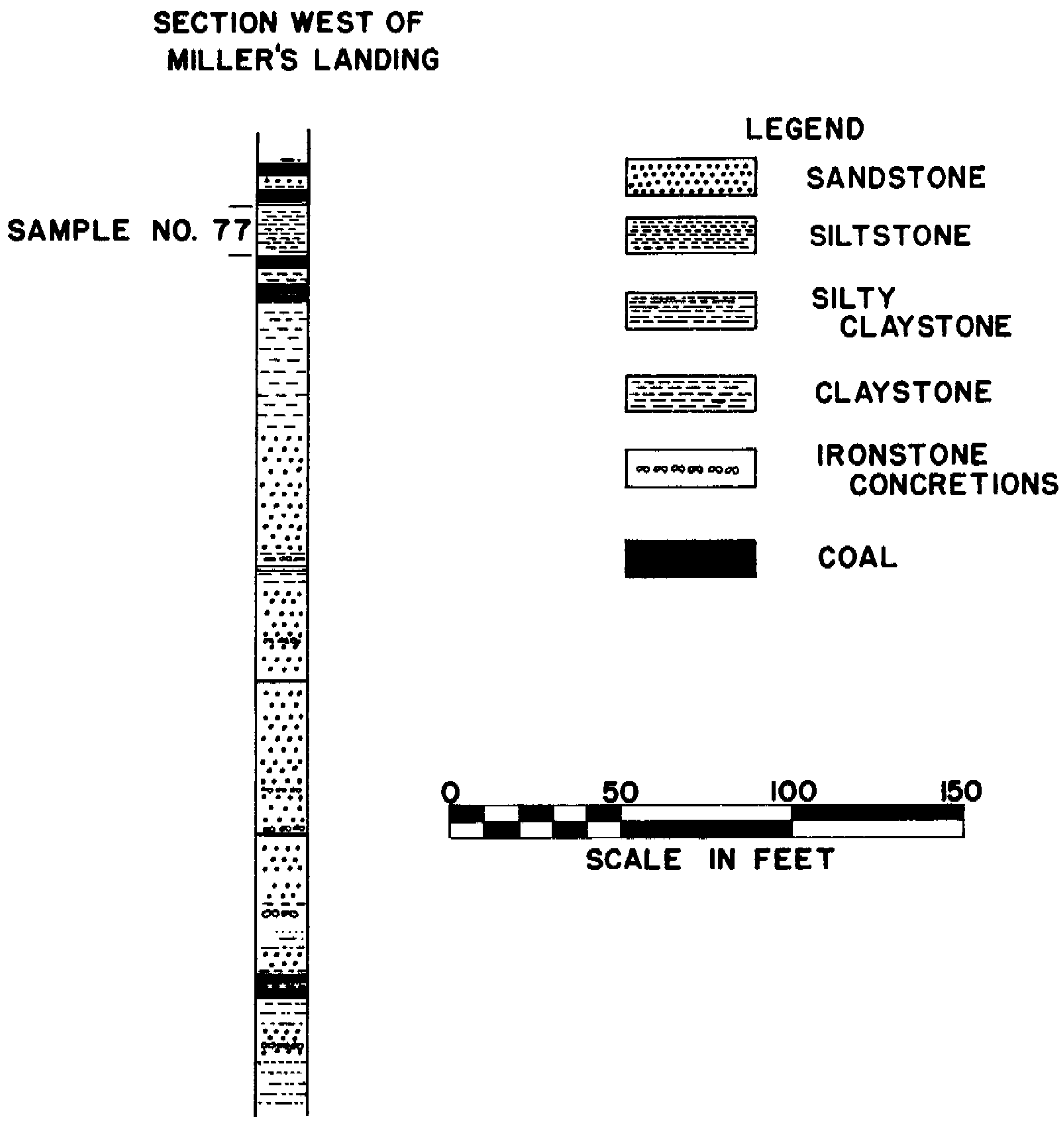
[26] Work cited in footnote 4, p. 61.



MODIFIED FROM PLATE 2 U.S.G.S. REPORT - COAL INVESTIGATIONS
ON THE SOUTHERN MARGIN OF THE HOMER DISTRICT

Figure 19. - Stratigraphic section near Miller's Landing.

Conclusions

The clay has a short firing range. At cone 09 the absorption is too high for use in a rigorous climate, although it would be acceptable in a climate similar to that of Seattle, Wash. The fired strength is very good with all firing treatments. When fired to cone 05, the absorption remains slightly above that recommended but probably is the best firing temperature. With the highest firing (cone 01), sample 77 bloated to such an extent that no data could be obtained.

Though the sample is not recommended because of its short firing range and tendency to bloat, it is probable that fair-quality brick could be produced if extreme care was taken during firing.

Summary and Comparison of Deposits Sampled for Ceramic Uses

Nine deposits or formations within the Railroad belt were investigated as sources of raw material for brick and tile products. As a result of the incomplete Bureau of Mines program, the following conclusions can be made:

The Anchorage area has clay that is satisfactory for the production of brick. Although this glacial clay, as represented by the samples from Clay Products, Inc., has a short firing range, closely controlled firing will produce brick that will withstand the rigorous climate of the area.

A sample from the Chickaloon formation near the road to the Evan Jones coal mine gave indications of a possible source of shale for structural-clay products. Additional sampling to locate a supply of material of this type is in order. Such a deposit should be readily accessible to the Anchorage area.

Clay from the Alaska Gypsum Queen Corp. claims on Sheep Mountain gave the best results of all the samples tested for ceramic uses. The clay has excellent working characteristics and fired strength. Preliminary tests indicate a firing range of nine cones from cone 3 to cone 06. Excellent resistance of the product to weathering is indicated by lengthy freezing and thawing tests. The Sheep Mountain clay, with proper preparation, such as washing, is capable of producing a brick of high heat duty for refractory use.

Next to the clay from Sheep Mountain, the shales from two of the most prominent shale members of the Healy coal formation show the best possibilities for the production of brick of all the deposits sampled. With a probable firing range of 5 cones, from cone 04 to cone 1, the results of freezing and thawing tests indicate that a product can be made that will withstand the rigorous climate of the Railroad belt.

LIGHTWEIGHT AGGREGATE

According to Webster's Dictionary, an aggregate is any hard, inert material for mixing in graduated fragments with a cementing material to form concrete or plaster. Aggregates normally used for concrete and concrete products are the sand and gravel produced through natural weathering of the rocks forming the earth's crust. These rocks also may be crushed by mechanical means and sized to produce equivalent products. The approximate weights per cubic yard for sand and coarse aggregate are given in table 28.

TABLE 28. - Weight of sand and coarse aggregate, in tons per cubic yard[1]

Kind of aggregate	Compacted	Loose
Sand, dry	1.40 to 1.55	1.30 to 1.45
Sand, moist	1.20 to 1.45	1.05 to 1.35
Coarse aggregate (separated):		
3/16 to 3/4 inch	1.35 to 1.45	1.25 to 1.35
3/4 to 1-1/2 inches	1.30 to 1.40	1.25 to 1.35
1-1/2 to 3 inches	1.25 to 1.40	1.20 to 1.35
3 to 6 inches	1.20 to 1.35	1.15 to 1.30
Coarse aggregate (combined):		
3/16 to 1-1/2 inches	1.35 to 1.55	1.30 to 1.45
3/16 to 3 inches	1.40 to 1.60	1.30 to 1.55
3/16 to 6 inches	1.45 to 1.70	1.35 to 1.60
Sand and gravel combined, dry	1.60 to 1.85	1.50 to 1.75

[1] Ruettgers, Arthur, Blanks, R. F., and others, The Concrete Manual: Bureau of Reclamation, A Reclamation Manual, Specialist Supplement, 5th ed., September 1941, p. 117.

In table 28, the weight, in tons per cubic yard, of combined sand and gravel, as shown, ranges from 1.50 to 1.75, or 110 to 129 pounds per cubic foot. A good lightweight aggregate should not weigh over 50 pounds per cubic foot.

Many materials have been used for lightweight aggregate. Their properties and uses are almost as varied as their sources. All of the materials must be lightweight, but some have proved best in one or more of the following properties: Strength, heat insulation, sound insulation, fireproofing, nailability and sawability of the fabricated building units, and economy.

On the basis of source, the lightweight aggregates may be divided into three classes: (1) Naturally occurring substances; (2) byproducts of industry; and (3) products manufactured for use as lightweight aggregate. The materials that occur naturally and have been used as aggregate are volcanic cinder, tuff, pumice, scoria, diatomite, and coal. Industrial byproducts in use include cinders and sawdust. Manufactured products employed as lightweight aggregates are expanded slag (Pottsco), expanded shale and clay (Haydite), expanded perlite, and expanded vermiculite.

Concrete is formed by mixing the aggregate with cement and water. A list of the unit weight in pounds per cubic foot for concrete of various mixes, used with ordinary sand and gravel aggregates of several specific gravities is given in table 29.[27]

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[27] Ruettgers, Arthur, Blanks, R. F., and others, The Concrete Manual: Bureau of Reclamation, A Reclamation Manual, Specialist Supplement, 5th ed., September 1941, p. 117.

TABLE 29. - Observed average weight of fresh concrete

Maximum size of aggregate, inches	Average values			Unit weight, lb. per cu. ft.				
	Sand, percent	Cement, bbl. per cu. yd.	Water, lb. per cu. yd.	Specific gravity of aggregates[1]				
				2.55	2.60	2.65	2.70	2.75
3/4	42	1.60	323	145	147	149	151	153
1-1/2	39	1.40	297	146	148	150	153	155
3	34	1.20	268	147	149	152	154	157
6	26	1.00	222	149	151	154	156	159

[1] On saturated surface-dry basis.

Concretes made with sand and gravel aggregates therefore weigh 145 to 159 pounds per cubic foot. For comparison of relative weight, the weights of concrete produced with lightweight aggregates are given below:

Lightweight aggregate	Lb. per.cu. ft.
Pumice, scoria, or volcanic cinders.	65 to 100
Industrial cinders..................	85
Industrial cinders with natural sand	110 to 115
Expanded shale and clay (Haydite)...	80 to 110
Expanded slag (Pottsco)............	75 to 110
Expanded perlite....................	50 to 80
Expanded vermiculite...............	35 to 75

Another industrial byproduct, slag, has been used successfully in production of building blocks. However, while lighter in weight than concrete made with normal aggregate, the concrete weighs 130 to 140 pounds per cubic foot; consequently the slag should not be considered in the same class with the lightweight aggregates.

The lighter-weight concretes made with lightweight aggregate have numerous advantageous over normal concrete. In structural concrete, the reduction of dead load by use of a lightweight aggregate allows an increase in the number of stories of a building and also in the size of floor panels. The lighter load also allows a decrease in the cost of supporting trusses, columns, and footings for the same size of building. It has been found in numerous cases that there is a considerable saving in total cost of construction through the use of lightweight concrete. An added incentive for use of the lightweight concretes is their lower thermal conductivity, giving enhanced insulation properties. Nearly all of the advantages named above are of particular importance to the Alaskan building industry because of the savings in freight costs on imported structural materials.

Building blocks of lightweight concrete have the added advantage of ease of handling, transportation, and laying over the conventional heavier-concrete building units. Larger building blocks and units also may be fabricated and used, resulting in lower laying costs.

Strengths of the concretes produced with the lightweight aggregates differ. The expanded shale and clay (Haydite) produce concrete whose strength compares favorably with the strength of ordinary concrete. Pumice, scoria, volcanic cinders, industrial cinders, expanded slag, and anthracite produce concrete of less strength but still acceptable for most uses. Diatomite, expanded perlite, and expanded vermiculite produce low-strength concretes.

The insulation properties of the lightweight concretes are almost inversely related to their strength. Concrete made with expanded vermiculite, which has the lowest strength of the lightweight concretes, exhibits the highest insulating value, but the insulating value of concrete made with the heaviest of the lightweight aggregates, Haydite, is still three to four times that of ordinary concrete. Haydite structural concrete has a K factor of 3.00 to 3.98, depending on the density of the concrete, whereas that of ordinary concrete is 12.0. By definition, the K factor is the B.t.u. per square foot per hour per degree Fahrenheit difference per inch thickness.

The lighter-weight concretes also have better nailing and sawing properties than the heavier normal concretes. One of the best concretes for nailability is made with sawdust, but almost all of the lightweight concretes are nailable. Tests have shown that 6-penny nails driven through a 1-1/4-inch board into Haydite precast wall units require a pull of 100 to 165 pounds to extract the nails.

In the past, industrial cinders and pumice have been used in Alaska for lightweight aggregates. The supply of industrial cinders is small, but pumice is abundant, consequently most of the lightweight aggregate used has been pumice. The pumice was secured from Augustine Island in lower Cook Inlet and from within the boundaries of Katmai National Monument on the south side of the Alaska Peninsula. The pumice produces a satisfactory building unit, but its remote location and the necessary transportation charges make it a high-cost aggregate compared with the local-occurring sand and gravel. For this reason, there has been considerable interest in the possible production of Haydite. Deposits of shale and clay amenable for the production of Haydite were investigated during the Bureau of Mines program.

Expanded perlite has favorable heat and sound insulating properties. It now is being used in the United States in increasing amounts, especially as aggregate for plaster and stucco. One small occurrence in the Alaska Railroad belt has been recorded.

Haydite

Haydite is manufactured by burning a clay or shale, which bloats on rapid heating, to produce a lightweight, semivitrified clinker of vesicular nature. Haydite was produced first in 1913 by Stephen J. Hayde and patented by him in 1918.[28]

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[28] Hayde, S. J., Process of making Brick and Similar Articles: U.S. Patent 1,255,878, February 1918.

Numerous investigations have been made to determine the constituents in the clay or shale necessary to produce bloating. It is thought[29] that the gasses from sulfur, carbon, and water remaining in the clays at the vitrification temperature cause bloating. According to Austin, Nunes, and Sullivan[30], the following conditions must exist for bloating to occur:

a. There must be a relatively large amount of glass phase formed. b. A gas must be liberated within the mass while it is in a pyroplastic condition. Thermal expansion of entrapped gas would not be enough to produce the vesicular structure often obtained. c. The glass phase must be viscous enough to maintain the vesicular structure.

Haydite aggregate, of all the lightweight aggregates, is desired for structural concrete where strength and weight are important factors. Although concrete made with Haydite weighs 28 to 47 percent less than concrete made with sand and gravel, comparative strengths are obtained for equal contents of cement. Tests by the Federal Works Agency, Public Roads Administration, on 3- by 6-inch cylinders of Haydite concrete, using 9.4 sacks of cement per cubic yard and weighing 103.5 pounds per cubic foot of wet concrete, gave a compressive strength of 3,360 pounds per square inch, age 7 days, and 4,810 pounds per square inch, age 14 days.

Another advantage of structural concrete made with Haydite is that it is more fire-resistant than normal concrete. To have a fire-endurance period of 3 hours a floor slab should be 6.5 inches thick if the aggregate is highly siliceous sand and gravel, 5.7 inches for calcareous sand and gravel aggregate, but only 4.4 inches using fine and coarse Haydite.[31]

The largest use of Haydite, where it has been produced, is in the manufacture of lightweight-concrete building blocks. Standard 8- by 8- x 16-inch concrete blocks made with Haydite weigh from 25 to 28 pounds. Normal concrete blocks of the same size average 45 pounds. This reduction in weight results in an appreciable saving in transportation, labor, and handling costs.

Haydite, although composed of minute air cells, is not porous because the air cells are not connected. Building blocks of Haydite, therefore, are not as absorbent as those made with other more porous aggregates, consequently, they have more resistance to freezing and thawing.

The insulating value of straight Haydite concrete is three to four times that of ordinary concrete. By combining expanded vermiculite with Haydite, concrete with a K factor of 2.50 can be made. The insulating value of this special concrete is 4.8 times that of ordinary concrete.

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[29] Austin, C. R., Nunes, J. L., and Sullivan, J. D., Basic Factors involved in Bloating of Clays: Am. Inst. Min. and Met. Eng. Trans., vol. 148, 1942, pp. 149-160.

[30] Work cited in footnote 28, p. 159.

[31] Menzel, Carl A., American Society for Testing Materials, vol. 43, 1943, pp. 1099-1153.

A refractory concrete has been made by using Haydite and Lumnite cement, a calcium aluminate cement. Tests by the Carter-Waters Corp., Kansas City, Mo.,[32] have shown that a Haydite-Lumnite concrete is suitable for sustained temperatures up to 1,800°-2,000° F. The resulting concrete also is corrosion-resistant and has good insulating qualities.

Carter-Waters Corp. has produced an insulating Haydite fire brick that has been used as back-up for the carbon blocks in small aluminum converting furnaces. The temperature limit of this brick is 2,000° F. It has a low coefficient of expansion, is extremely resistant to temperature changes, and weighs only 3 pounds, compared to 7 pounds for the ordinary fire brick it replaced.

Plain Haydite blocks are very good for sound absorption because of their cellular structure. Another property, and one of the most important, is their chemical inertness; furthermore, the particles are usually of the rounded shape preferred for easily worked concrete.

During the Bureau of Mines program, all clay and shale samples were submitted for preliminary bloating tests. Samples showing promise were then tested on a larger scale in a continuous rotary kiln, which duplicated commercial practice. The aggregate produced was made into concrete units for physical tests.

The procedure used by the Bureau of Mines Electrotechnical Laboratory at Norris, Tenn., for stationary-kiln bloating tests is as follows: The material to be tested is crushed to pass an 8-mesh sieve. Small briquets, approximately 1/2 by 1 by 2 inches, are formed by hand-tamping dampened particles into a mold. The briquets are artificially dried for about 12 hours at 110° C. or air-dried for several days before firing.

In firing, a laboratory kiln is heated to 1,150° C., and a series of samples is inserted on a silicon carbide slab. Time is allowed after loading for the kiln to come to equilibrium. The samples then are held at the maximum temperature for 15 minutes before removal for visual inspection. The kiln temperature is then adjusted upward or downward, in steps of 50° C., as indicated by the condition of the specimens. Enough heats are run to indicate the range and optimum bloating temperature of the material.

Rotary-kiln tests were made in a No. 4 rotary calcining furnace[33] manufactured by the U. S. Smelting Furnace Co., Belleville, Ill. The kiln is lined with fire-clay shapes and has an inside diameter of 32 inches and a length of approximately 50 inches, exclusive of the conical ends. The rotary unit has a fixed speed of 0.2 r.p.m. Temperatures to 1,400° C. may be attained.

Each of the deposits tested for the production of lightweight aggregate is described as follows:

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[32] Huntly, Phil C., Armour Inst. Technol., Chicago, Ill.

[33] Conley, John E., Wilson, Hewitt, Klinefelter, T. A., and others, Production of Lightweight Concrete Aggregates from Clays, Shales, Slates, and other Materials: Bureau of Mines Rept. of Investigations 4401, 1948, 121 pp.

Clay Products, Inc.

Introduction, Location, and Accessibility

During sampling of the clay on the property of Clay Products, Inc., a composite sample was kept for testing for the production of Haydite.

The Clay Products, Inc., clay pit and brick plant are on the south shore of Knik Arm 4.2 miles by road from the Alaska Railroad terminal in Anchorage. A detailed description of this deposit is given in this report in the section on brick and clay products.

Lighweight-Aggregate Tests

The results of stationary-kiln bloating tests on clay from Clay Products, Inc., are given in table 30.

TABLE 30. - Results of stationary-kiln bloating tests on samples from Clay Products, Inc. deposit

Sample No.	Temperature, C.	Bloating results			Remarks
		Poor	Fair	Good	
28	1,100		x		
28	1,150	x			Too high-glazed.
28	1,200	x			Slumped.

Although the above results indicated the clay was not suitable for Haydite production, two rotary-kiln tests were made because of the large size of the deposit and its accessibility to Anchorage. Data on the rotary-kiln tests are given in the following table.

TABLE 31. - Results of rotary kiln-tests on samples from Clay Products, Inc., deposit

Test No.	Time, min. p.m.	Temperature, °C.	Remarks
1	1:10		Start fire.
	1:40		Off to load.
	1:50		135 lb. loaded and fired.
	2:15	1,050	Off.
			Did not bloat at 1,050° C.
2	2:55		Start fire.
	3:10		Off to load.
	3:20		135 lb. loaded and fired.
	3:45	1,100	Off.
			Aggregate rolled up into a log in rear of kiln.

Note: In test 2, the aggregate in middle of kiln bloated while aggregate in front did not bloat.

Conclusions

The results of the tests indicate that the clay from Clay Products, Inc., has too short a bloating range to be considered for firing in a commercial rotary kiln. The material did not bloat when fired to 1,050° C. After being fired to 1,100° C., the material in the back of the kiln was overfired; that in the middle partly bloated to overfired; and that in front barely bloated or not bloated at all.

Chickaloon Formation Shale

Introduction

Shale from the Chickaloon formation of Tertiary age exposed in the Matanuska Valley is represented by sample 13. This sample was taken adjacent to the Evan Jones road 1-1/2 miles north of the paved Glenn Highway. The general location of the area is shown on figure 3.

Description of Deposit

The black shale sampled is exposed on the left limit of Eska Creek in a bare cliff face east of the road bridge across the creek. The 10-foot shale bed is one in a series of sandstones with minor interbedded conglomerate, clay, coal, and shale. At this location, the formation dips gently southeast.

Lightweight Aggregate Tests

Sample 13 was subjected only to stationary-kiln bloating tests; the results of which are given below:

Results of stationary-kiln tests

Sample No.	Temperature, °C.	Bloating results			Remarks
		Poor	Fair	Good	
13	1,100		x		
13	1,150	x			Too highly glazed.
13	1,200	x			Glazed, slumped.

Test results on sample 13 were unsatisfactory, evidently the shale represented by this sample is not suitable for the production of Haydite.

Anchorage Sand & Gravel Co. (Mile 67 Deposit)

Introduction

The Anchorage Sand & Gravel Co. has produced conventional aggregate in the Anchorage area since 1938. A. F. Waldron, president, erected the first commercial ready-mix concrete plant in Alaska at Anchorage in 1942. Early in 1950, the company became interested in the possibility of producing Haydite from clay or shale in the Anchorage area. Research indicated that there was

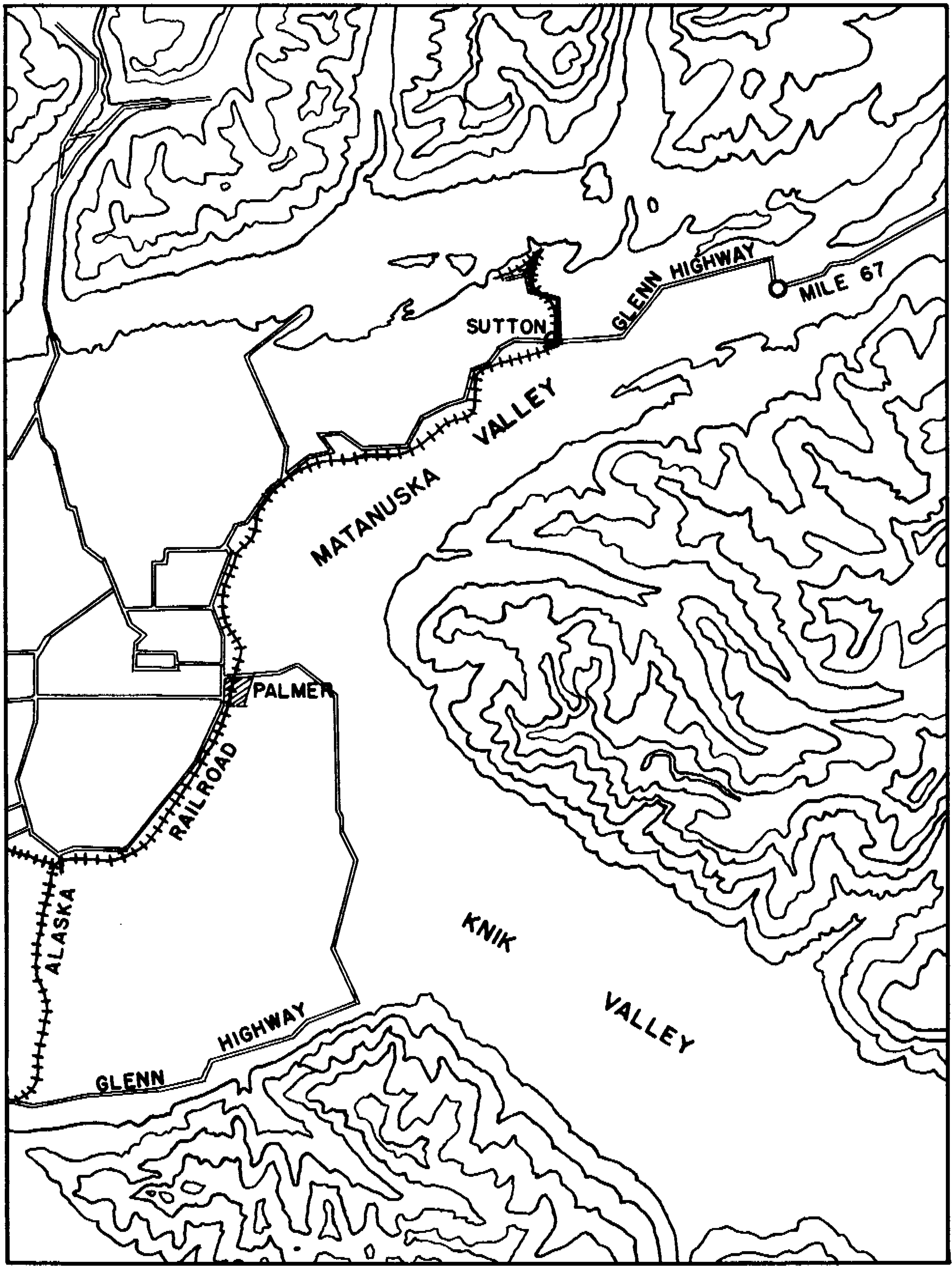

Figure 20. - Map of Matanuska Valley, showing location of mile 67.

Figure 21. - Shale outcrop along King's River, mile 67 shale deposit.

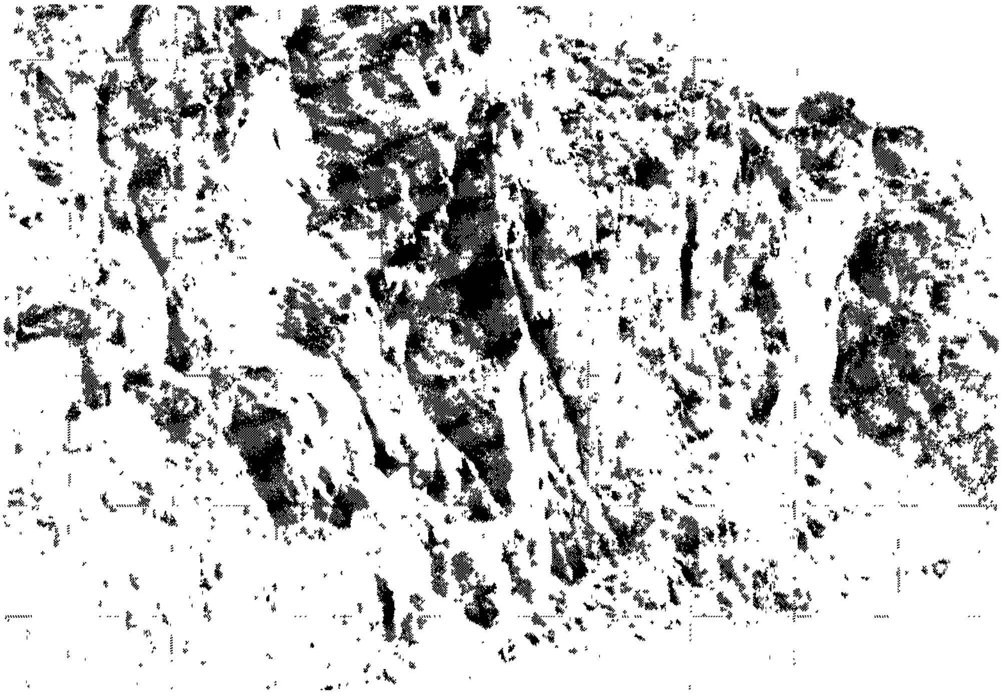

Figure 23. - Road cut at mile 67, showing boundary fault.

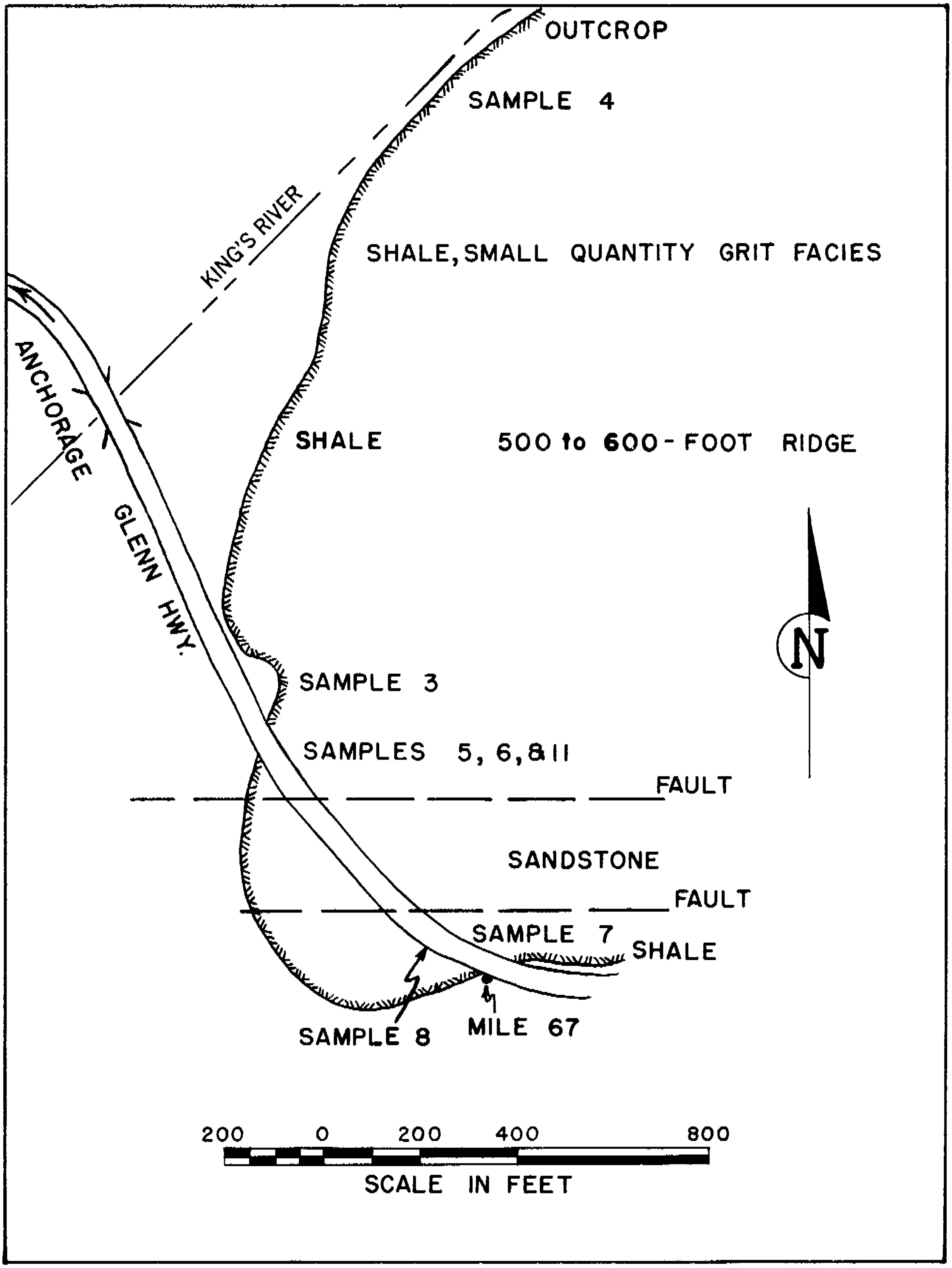

Figure 22. - Sketch map of mile 67 shale deposit.

Figure 24. - Close-up view of boundary fault, mile 67.

a local demand for lightweight aggregate for the building-block industry and that Haydite could capture this market if it could be produced at a price competetive with that of the pumice being used.

Shale and clay samples were submitted by the Anchorage Sand & Gravel Co. to Wolf G. Bauer, consulting engineer, Seattle, Wash. for tests of their suitability for Haydite production. The results of Bauer's tests indicated that several of the samples submitted were amenable for Haydite production, and that the most favorable was a shale from mile 67 on the Glenn Highway.

Location and Accessibility

The shale at mile 67 on the Glenn Highway is very favorably situated for truck haulage. The Glenn Highway is a paved all-season road. The deposit is only 6 miles east of Sutton, the probable site of the Anchorage Sand & Gravel Co.'s proposed expanding plant (fig. 20). A river terrace along the left limit of King's River provides enough space between the river and proposed quarry face for the necessary plant installation and storage facilities.

At Sutton, either rail transportation by the Alaska Railroad or transportation by truck on the Glenn Highway to Anchorage and the Matanuska Valley is available.

Physical Features

The shale deposit, at the confluence of the King's and Matanuska Rivers, is about midway up the valley of the Matanuska River, a tributary of Knik Arm. The Matanuska River flows westward between the Chugach and Talkeetna Mountains. King's River heads in the Talkeetna Mountains on the north side of the Matanuska Valley.

In the immediate area under consideration, the shale outcrops in a series of steep cliffs along the left limit of King's River, where it rises to a 500- to 600-foot northeasterly trending ridge. Figure 21 pictures the outcrop along King's River. Slopes are steep and covered with a dense growth of grasses, devil's club, and alder, with a thin stand of spruce, cottonwood, and birch.

Description of Deposit

The shale at mile 67 is part of the Matanuska formation of Upper Cretaceous age. The base of this formation is represented, in part, by a series of black shale relatively free of sandstone and grit. The material sampled is from this section. Figure 22 is a sketch map of the shale deposit at mile 67.

No bedding in the shale could be determined. The outcrops examined contained only a few, small, scattered grit facies. A zone of medium-grained, dark-gray, dirty sandstone[34] bounded by two vertical faults occupies most of the road cut and terminates the shale on the south. The beds of sandstone strike N. 21° E. and dip 19° to the north. Two views of the outcrop and fault terminating the shale in the roadcut are shown on figures 23 and 24.

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[34] Communication from George O. Gates, geologist, Geological Survey.

Preliminary samples were taken along the outcrop at the locations of samples 3, 4, 5, 7, and 8, as shown on figure 22. The test results were good; consequently, a 300-pound sample 6 was taken later for rotary kiln testing. In order to make physical tests on concrete made with the lightweight aggregate produced from this shale, more material was needed. Therefore sample 32 (600 pounds) was taken later at the same location as sample 6.

Lightweight-Aggregate Tests

Samples 3 through 8, inclusive, from mile 67 were tested for bloating characteristics in a stationary kiln. Results of the tests are given in table 32.

TABLE 32. - Results of stationary-kiln bloating tests on samples 3-8, mile 67

Sample No.	Temperature °C.	Bloating results			Remarks
		Poor	Fair	Good	
3	1,100		x		Temperature too low.
3	1,150			x	
3	1,200		x		Temperature too high.
4	1,000		x		Temperature too low.
4	1,150			x	
4	1,200		x		Temperature too high.
5	1,100		x		Temperature too low.
5	1,150			x	
5	1,200		x		Temperature too high.
6	1,100		x		Temperature too low.
6	1,150			x	
6	1,200		x		Temperature too high.
7	1,100	x			
7	1,150	x			
7	1,200	x			
8	1,100	x			
8	1,150	x			
8	1,200	x			

The results from the stationary-kiln tests showed samples 3 through 6, inclusive, to be very similar as to bloating characteristics and temperature requirements. The samples were combined and a rotary-kiln test made. See table 33 for results of the rotary-kiln test.

TABLE 33. - Results of rotary-kiln bloating tests on samples 3, 4, 5, and 6, mile 67

Particle size...........	1 inch to 4-mesh
Total weight of feed...........	280 lb.
Weight, cu. ft.	94-1/2 lb.
Product, total weight...........	215 lb.
Wt. cu. ft. minus-3/8 inch part...	43 lb.

	Fine	Coarse
Bulk specific gr.	0.89	0.84
Bulk sp. gr. sat. surface, dry basis.......	1.29	1.12
Apparent Sp. gr.	1.66	1.16
Absorption.............	33.2	44.5

Kiln Operating Conditions

Time, minutes	Temperature, °C	Kiln operating conditions, Remakrs
a.m.		
10;10	-	Start fire.
10;40	1,190	Off to load.
10;45	-	Loaded and fired.
11;20	1,200	Off.

Note; Product rolled up in log (expansion 100 percent). Temperature slightly high for best results. However, it is difficult to control or read temperatures closer than 50° C. on this kiln.

Screen analysis of product -- crushed to minus-3/8 inch particle size

Mesh....	-2+4	-4+6	-6+8	-8+18	-18+30	-30+70	-70+100	-100
Percent.	19.0	15.5	11.1	23.4	5.0	9.0	3.0	14.0

A product with excellent vesicular structure and fine but uniformly spaced pores was produced. Volume increase was approximately 100 percent.

The shale showed some tendency to clinker and form logs in the kiln. This could cause some difficulty in continuous rotary-kiln processing. However, it is believed that the sticking tendency is not serious enough to exclude the shale as a possible raw material for lightweight-aggregate production.

In producing enough aggregate to make concrete units for physical tests, sample 32 was split and two separate rotary-kiln runs were made. Though the material was similar to that represented by samples 3, 4, 5, and 6, for which the optimum firing temperature (1,150° C.) had already been determined, the first run was ended at 1,100° C. The resulting volume increase was only 30 percent. The product weighed 70.6 pounds per cubic foot. The second batch was expanded at 1,135° C. with a volume increase of 80 percent. This produced an acceptable lightweight aggregate weighing 47.5 pounds per cubic foot.

Accelerated Weathering Tests

Alternate freezing and thawing tests to measure the weather resistance of concrete block containing this lightweight aggregate have been completed. The block tested were made at the Electrotechnical Laboratory, Region VII, Bureau of Mines, Norris, Tenn. Three groups, each of four blocks, were submitted to the Northwest Experiment Station, Region II, Bureau of Mines, Seattle, Wash., for testing. The block were designated on the basis of the cement - aggregate ratio. Group 1-8, for example, contained 1 part, by volume, of cement to 8 parts of aggregate. Other ratios were 1-10 and 1-12.

Two individuals in group 1-12 reacted with the aluminum pallets during forming and could not be removed except by cutting, hence these block were approximately 8 by 8 by 4 inches. All other block were 8-inch cubes. Three hours after forming, the blocks were steam-cured at 170° F. for 3-1/2 hours. The steam was then turned off, and the block remained in the curing chamber for an additional 24 hours.

The testing was according to A.S.T.M. Specification C 67-44, Method B[35], as no standard weathering test for lightweight-concrete block has been established. Absorption determinations were made by soaking 24-hours in cold water.

The average weight losses for each group appear to be roughly proportional to the cement-to-aggregate ratio with a probable minimum ratio between 1-10 and 1-12. Highest losses were shown by the 1-12 group; lowest, the 1-8. The intermediate group, 1-10, however, showed only slightly higher average weight loss than did the 1-8 group, and two individuals of the former group showed losses lower than any of the 1-8 group.

All block tested, except the half-block of group 1-12 showed satisfactory resistance to freezing and thawing. The two whole block of group 1-12, however, approached the maximum allowable loss of 3 percent. The percent weight losses for all block tested for each five cycles of freezing and thawing are shown in table 34.

Weight losses of the two half-block of group 1-12 were over the allowable 3 percent after 25 cycles but were tested to completion. Due to reaction of these block with the pallet during manufacture, some structural defects were suspected, but none were revealed in testing. Weight losses occurred by displacement of aggregate particles by freezing. No major structural failures occurred in any of the block tested. These block, as well as the other two of group 1-12, appeared to be weakly bonded and small aggregate particles spalled. Losses on the edges of the block were high, especially on the half-block, owing to highly irregular edges formed when the block were cut.

Block of the 1-8 and 1-10 group lost weight in the same manner as group 1-12 but to less extent. The former groups were more securely bonded, owing to higher cement content and showed less general and less severe spalling than group 1-12.

Some weight was lost by handling, which, of course, would not take place if the block were in the wall. These handling losses were largely confined to the inside of the tapered end where a relatively thin edge is formed.

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[35] Work cited in footnote 20.

TABLE 34. - Percent weight loss lightweight aggregate concrete blocks in freezing and thawing test

Identi-fication	Dry weight, grams		Absorp-tion, percent	Weight loss after cycles, percent										
	Original	Final		5	10	15	20	25	30	35	40	45	50	Average
1-8 A	5,020	4,970	21.7	0.60	0.60	0.60	0.60	0.90	0.90	1.00	1.00	1.00	1.00	
B	5,145	5,080	20.8	.58	.58	.87	.87	.97	1.17	1.26	1.26	1.26	1.26	
C	5,220	5,160	21.0	.29	.57	.67	.77	1.05	1.05	1.05	1.15	1.15	1.15	
D	5,190	5,140	21.2	.29	.48	.58	.67	.87	.87	.96	.96	.96	.96	1.09
1-10 A	4,825	4,760	24.4	.31	.52	.83	.83	1.24	1.35	1.35	1.35	1.35	1.35	
B	5,095	5,010	23.9	.59	.69	.88	.98	1.08	1.57	1.57	1.57	1.67	1.67	
C	4,950	4,905	24.4	.30	.30	.51	.51	.71	.81	.81	.81	.91	.91	
D	5,075	5,040	23.1	.00	.30	.30	.30	.49	.59	.59	.59	.69	.69	1.15
1-12 A	4,625	4,515	26.7	.76	.76	1.19	1.51	1.62	1.73	1.73	1.94	2.16	2.38	
B	4,620	4,520	26.8	.22	.43	.65	.97	1.19	1.41	1.41	1.62	1.95	2.16	2.27
C	3,120	2,965	26.5	.48	.96	1.76	2.24	3.04	3.36	3.69	4.17	4.49	4.97	
D	2,475	2,315	26.7	.61	1.01	1.82	2.42	3.23	3.43	3.84	4.85	5.45	6.46	5.71

Conclusions

An excellent-appearing, lightweight aggregate may be produced from the shale deposit at mile 67. The expanded shale has a fine vesicular structure with uniformly spaced pores.

Based on tests, concrete block containing lightweight aggregate, formed similarly to the block of 1 to 8 or 1 to 10 cement-to-aggregate ratio should be sufficiently weather resistant. Additional resistance to spalling probably can be gained by using preparations to fill the surface pores and prevent excessive moisture absorption.

Inasmuch as no definite conclusions regarding the crushing strength of concrete made with this aggregate may be made without actual tests, production of comparative concrete building units and physical tsts were recommended; they were made in May 1951.

Matanuska River Shale (Mile 16 Matanuska Branch Railroad

Introduction

Although preliminary tests of the shale at mile 67 on the Glenn Highway proved that this deposit is suitable for the production of Haydite, a deposit nearer to the railroad and to a source of fuel would have the added advantage of lower production costs. The same Matanuska formation that is exposed at mile 67 crops out along the Matanuska branch of the Alaska Railroad between Moose Creek and Sutten (fig. 25). After a reconnaissance examination in July 1950, one bed of black shale similar in appearance to that at mile 67 was recommended by George O. Gates, geologist, Geological Survey, to the Bureau of Mines for sampling and investigation of its potentialities as a raw material for the production of Haydite.

Location and Accessibility

The shale bed represented by samples 53 and 54 is at mile 16 on the Matanuska Branch of the Alaska Railroad. Here the shale is exposed in a railroad cut at the base of the bluff along the right limit of the Matanuska River. The shale is readily accessible by rail to either Sutton or Palmer and Anchorage. A road less than 3/4 mile long would connect the deposit with the paved Glenn Highway.

Description of Deposit

The geology of the immediate area has been described by Gates[36] as follows:

> *** part of the Matanuska formation is exposed in bluffs along the northwest side of the Matanuska River between Moose Creek and Sutton stations on the railroad. The exposures are between "a" and "b" on the enclosed sketch.***

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[36] Personal communication from George O. Gates, geologist, Geological Survey.

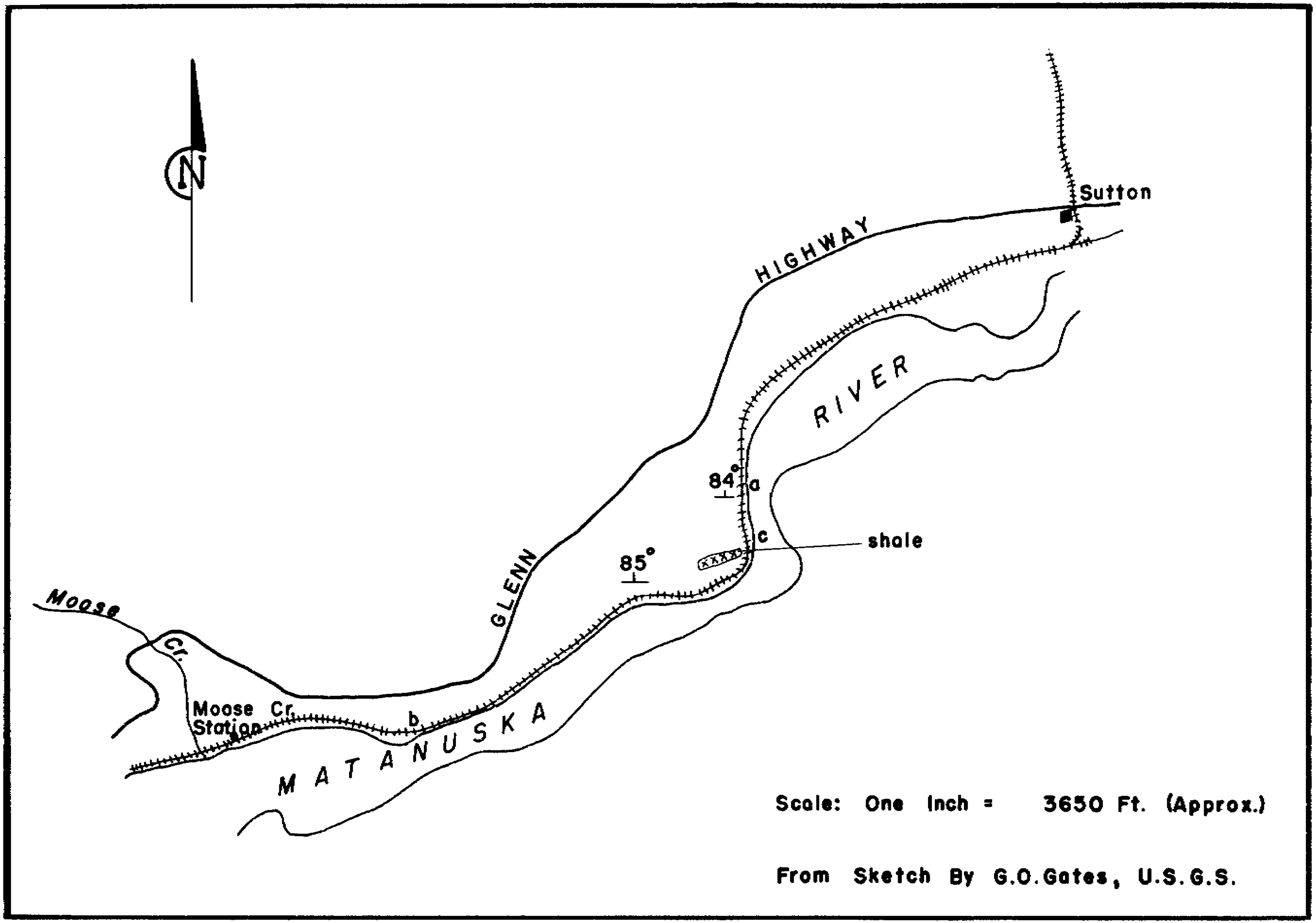

Figure 25. - Shale locality between Moose Creek and Sutton, Alaska.

The Matanuska formation between Moose Creek and Sutton consists of well consolidated gray sandstone and siltstone and dark gray to black shale. Bedding is well defined and the beds generally strike north 70 to 80 degrees east and dip about 85 degrees north. Black shale is present at several different places in the sequence in thicknesses of 50 feet or more. The most favorable occurrence is shown on the map***. It is exposed on a steep forested slope that rises about 180 feet above a terrace several hundred feet wide. As shown on the sketch, the railroad crosses the Terrace. The shale is exposed in almost continuous outcrops in the upper 1/3 of the slope and for several hundred feet along the slope. No siltstone or sandstone interbeds were seen. Thin layers of ironstone concretions are fairly common.

Two samples were taken by the Bureau of Mines 400 feet apart along the strike of the shale deposit shown in figure 25. The bed of black shale is 200 feet south of mile 16 on the railroad. It is at least 80 feet thick. The strike of the formation averages N. 75° E; the dip is nearly vertical to the north. The hanging wall is sandstone.

Sample 53 was 80 feet long. It was cut normal to the strike and dip of the shale exposure in the railroad cut. The second sample, 54, was 50 feet long. It represents the normal width of an outcrop near the sandstone hanging wall of the shale zone.

Lightweight-Aggregate Tests

Table 35 gives the results of stationary kiln tests on the bloating characteristics of samples 53 and 54.

TABLE 35. - Results of stationary-kiln bloating tests on samples 53 and 54, mile 16

Sample No.	Temperature, °C.	Bloating results			Remarks
		Poor	Fair	Good	
53	1,100	x			
53	1,150			x	
53	1,200	x			Bloated.[1]
54	1,100	x			
54	1,150			x	
54	1,200	x			Bloated.[1]

[1] Large, cellular, structural bubbles 1/8 to 1/4 inch in diameter.

Conclusions

The results of preliminary tests indicate that the Matanuska River shale (mile 16 Matanuska Branch Railroad) should be suitable for lightweight-aggregate production.

It is recommended that larger-scale samples be procured and submitted for rotary-kiln tests. Physical tests of the aggregate should then be made, if warranted.

Other Matanuska-Formation Shales

Samples were taken of three other shale beds in the Matanuska formation and preliminary tests made.

Sample 9 was taken across a 200-foot shale bed near mile 68.1 on the Glenn Highway. This shale bed is in the upper part of the Matanuska formation, where it is interbedded with sandstone and conglomerate.

Sample 12, mile 71.5, is very similar to the material from mile 67. It represents a section across a 270-foot bed.

One other sample, 10, was taken from a shale member in the lower part of the Matanuska formation. This sample was taken near the north abutment of the highway bridge across the Matanuska River.

The results of preliminary stationary-kiln tests on samples 9, 10, and 12 are given in table 36.

TABLE 36. - Results of stationary-kiln bloating tests on samples 9, 10, and 12, Matanuska formation shale

Sample No.	Temperature °C.	Bloating results			Remarks
		Poor	Fair	Good	
9	1,100	x			
9	1,150		x		
9	1,200		x		
10	1,100		x		
10	1,150		x		
10	1,200	x			Slumped.
12	1,100		x		Temperature too low.
12	1,150			x	
12	1,200		x		Too high-glazed.

Preliminary tests indicate that the material represented by samples 9 and 10 is not suitable for the production of lightweight aggregate. Sample 12 gave results somewhat similar to that of the Anchorage Sand & Gravel Co. shale at mile 67. It may be suitable for the production of Haydite.

Cantwell Shale

During the building-materials investigation, samples of shale members in the Cantwell-Windy area were taken for testing for ceramic uses and for chemical analyses to determine their possible use in the production of cement or mineral wool. Samples also were submitted for lightweight-aggregate tests. (See fig. 3.)

Sample 51 was taken along the railroad cut at mile 321.1 on the Alaska Railroad 1.4 miles north of Cantwell, Alaska. The formation at this location consists mainly of beds of shale with narrow bands of included igneous material. Sample 51 represents a 250-foot shale bed at mile 321.1.

The second sample, 52, was from a 200-foot shale bed, which forms a cliff on the right limit of Little Windy River 1 mile upstream from the crossing of the Alaska Railroad.

Results of the stationary-kiln tests are given below:

Test results

Sample No.	Temperature, °C.	Bloating results			Remarks
		Poor	Fair	Good	
51	1,100	x			Temperature too low.
51	1,150	x			Slight indication of bloating.
51	1,200	x			Large bubble with glazed outer surface.
52	1,100	x			Temperature too low.
52	1,150	x			Slight indication of bloating.
52	1,200	x			Large bubble with glazed outer surface.

The results obtained indicate that the material represented by samples 51 and 52 is not suitable for production of lightweight aggregate.

Healy Shale

The Tertiary coal-bearing formation in the Healy River Valley (fig. 14) consists of a series of sandstones, grits, shales, claystones, fine conglomerates, and coal beds. Two of the most prominent and persistant shale beds were tested for ceramic uses. Good results were obtained.37/ Duplicate samples also were tested for the production of Haydite.

Samples 45 and 46 were taken across the shale bed near the top of the upper member of the Tertiary formation at stratigraphic section B (fig. 15). Sample 49, at section A, represents the same shale bed 1-1/2 miles west of the first location.

The other shale bed sampled (sample 47) lies on coal bed F approximately 1,300 feet below the first bed sampled. Only the lower 40 feet of this shale bed was sampled because the upper 45 feet was very silty.

The results of stationary-kiln bloating tests for lightweight aggregate on the shale samples from Healy are given in table 37.

37/ See section Brick and Clay Products in this report.

TABLE 37. - Results of stationary-kiln bloating tests for lightweight aggregation Healy shale samples

Sample No.	Temperature °C.	Bloating results Poor	Fair	Good	Remarks
45	1,100	x			Too low.
45	1,150	x			Slight expansion.
45	1,200	x			Large volume increase, fragile honeycomb structure.
46	1,100	x			Slightly bloated core surrounded by unbloated material.
46	1,150		x		Fragile.
46	1,200	x			Over bloated.
47	1,100	x			Temperature too low.
47	1,150	x			Slight core bloat.
47	1,200		x		Short temperature range.
49	1,100	x			Temperature too low.
49	1,150		x		Too fragile.
49	1,200	x			Over bloated-very fragile.

The results of the tests on Healy shale represented by samples 45, 46, 47, and 49 indicate that the shale has no merit as a raw material for the production of lightweight aggregate.

Fairbanks Area Loess

Overlying the gold-bearing gravels in the Fairbanks district is up to 200 feet of partly decayed vegetation and finely divided silt of loam locally called "muck". It is the opinion of Capps[38] that much of this fine material is loess - wind-blown dust from the broad flats of the glacial streams - that was deposited over the hills and valleys in the unglaciated area of interior Alaska. This loess was recommended to the Bureau of Mines for investigation by George O. Gates geologist, Geological Survey, because of its similarity to the loess of Kansas, which may be used to produce an acceptable lightweight aggregate.

Two samples of the muck in the Fairbanks area were taken. The first, sample 42, was taken on Eva Creek in the Ester Creek district, 8 miles west of Fairbanks, Alaska. Here the thickness of the muck averages 60 feet.

Sample 44 was taken upstream from Fox, Alaska, on Goldstream Creek where the muck is at least 100 feet thick. This location is 8 miles northeast of Fairbanks, Alaska.

Samples 42 and 44 were submitted to the Electrotechnical Laboratory of the Bureau of Mines at Norris, Tenn., for testing of bloating characteristics. The results are given in the following table.

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[38] Work cited in footnote 2, pp. 164-165.

TABLE 38. - Results of Fairbanks loess-bloating tests

Sample No.	Temperature °C.	Bloating results			Remarks
		Poor	Fair	Good	
42	1,100	x			No indication of bloating.
42	1,150	x			Do.
42	1,200	x			Shrinkage, outer surface glazed.
44	1,100	x			No indication of bloating.
44	1,150	x			Do.
44	1,200		x		Some expansion.

The results of the stationary-kiln tests given in table 37 indicate that the loess from the Fairbanks area is not suitable for the production of Haydite.

Matanuska Valley Loess

Deposits of loess were reported[39] also in the Matanuska Valley. Several of these dune deposits along the west bank of the Matanuska River north of Palmer were investigated by the Bureau of Mines during the course of the nonmetallic-building-materials program.

The deposits consist of finely divided material that has probably been windblown from the braided stream bed of the glacial silt-laden Matanuska River. The deposits are small and underlain by sand and gravel. Sample 55 was taken from a loess dune exposed in a gravel pit adjacent to the old road 3.1 miles north of Palmer, Alaska.

The deposit sampled is dog-legged in shape. It is about 200 yards long by 250 feet wide. The dune averages 10 feet in thickness throughout the central 100 feet of width but diminishes to approximately 3 feet in thickness near the edges.

Results of stationary-kiln bloating tests on sample 55 follow:

Test Results

Sample No.	Temperature °C.	Bloating results			Remarks
		Poor	Fair	Good	
55	1,100	x			
55	1,150	x			
55	1,200		x		
55	1,250				Slumped - not bloated.

Note: Very little indication of bloating through 1,100° - 1,200° C.

The loess deposits in the Matanuska Valley represented by sample 55 are not amenable for the production of lightweight aggregate.

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[39] Work cited in footnote 36.

West Fork of Chulitna River Area Argillites

Introduction

Many argillaceous materials have been investigated as raw materials for the production of lightweight aggregates. Among those that have been tested[40] are clays, shales, and slates. During this investigation, several argillite beds in the West Fork of the Chulitna River area were sampled.

Location and Accessibility

The West Fork of the Chulitna River area is in the Broad Pass region of the Talkeetna mining district on the south slope of the Alaska Range. It is situated within the Third Judicial Division, headquarters of which is Anchorage, Alaska. The area is approximately at latitude 63° 15' N. and longitude 149° 30' W.

Access to the area from Colorado Station on the Alaska Railroad is by gravel roads maintained by the Alaska Road Commission. The roads connect the Alaska Railroad with the Golden Zone gold mine on the West Fork of the Chulitna River and with the W. E. Dunkle coal mine on Camp Creek in the Costello Creek Basin.

The location of the sample area is shown on figure 26.

Description of Deposits

Permian and Triassic argillites of various compositions are in the West Fork of the Chulitna River area. Argillites of Permian age have been classified by Ross[41] into four units: B, C, D, and E.

Unit D is composed of chert, cherty limestone, and chloritic argillite with minor amounts of andesitic lava, tuff, and fine conglomerate. Three samples were taken from an outcrop of unit D argillite exposed in the ditch near the Golden Zone power house on the West Fork of the Chulitna River (fig. 27). Here the formation is gray to black argillite interbedded with minor amounts of chert and limestone. At the location sampled, the formation strikes N-S, and the dip is vertical. Sample numbers 196, 197, and 198 represent a true thickness of 333 feet.

One sample, 199, was taken from an argillite bed in unit E exposed in the Colorado Creek gorge where the power line from the Golden Zone power house to the W. E. Dunkle coal mine crosses Colorado Creek. Unit E resembles unit D but contains more tuff and less argillite. The unit E argillite bed strikes N. 30° E. and dips 60° southeast. Gray to black, the argillite is much folded and faulted and has a steel-gray luster. True thickness of the argillite represented by sample 199 is 75 feet. Figure 28 shows the location of the sample.

By far the most extensive and homogenous argillite was found in the Triassic argillite unit shown by Ross[42] as a wide belt west of the Golden Zone mine.

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[40] Work cited in footnote 35.

[41] Work cited in footnote 13, p. 297.

[42] Work cited in footnote 13, plate 25.

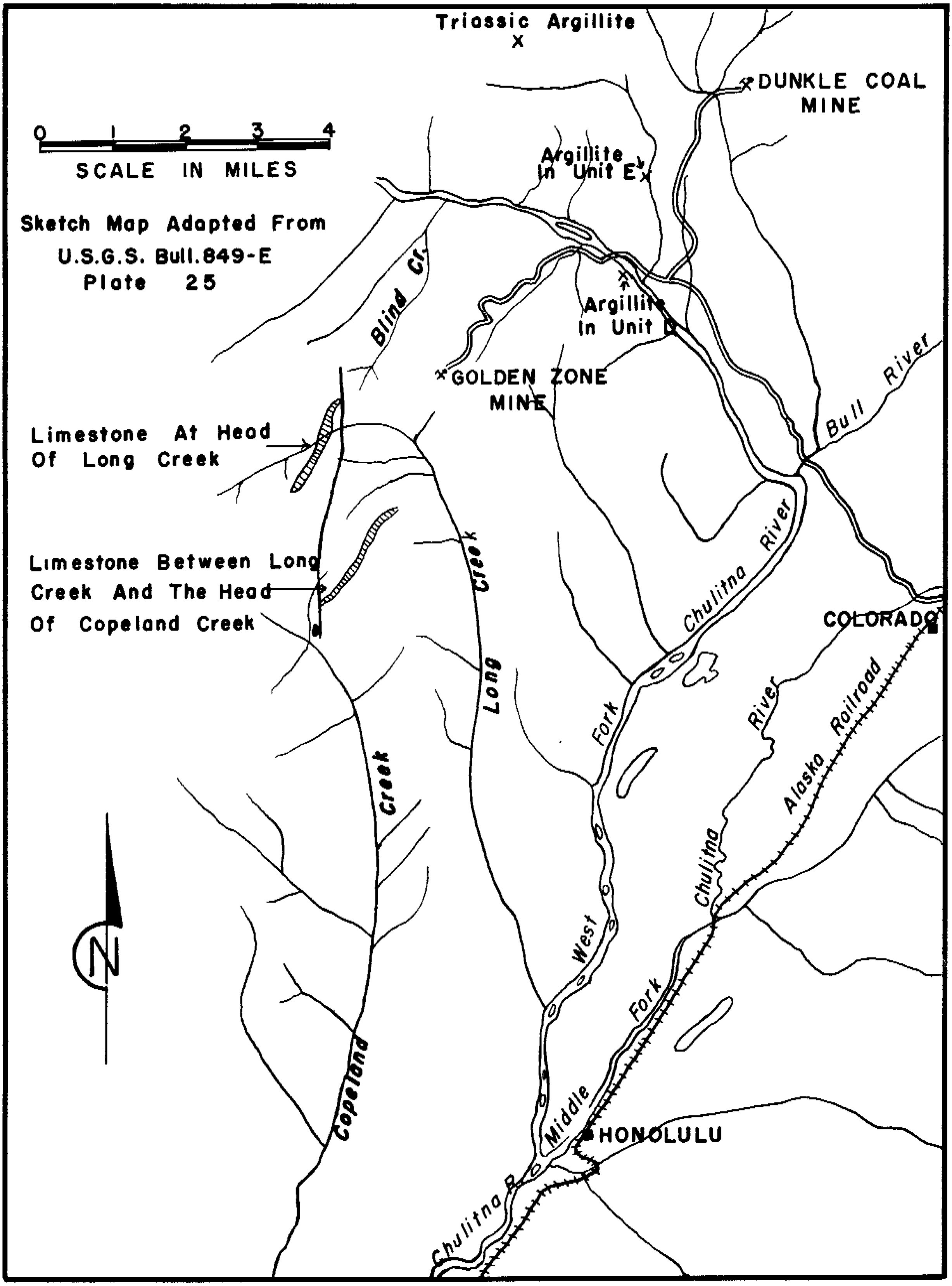

Figure 26. - Location of samples of limestone and argillite taken along West Fork of Chulitna River.

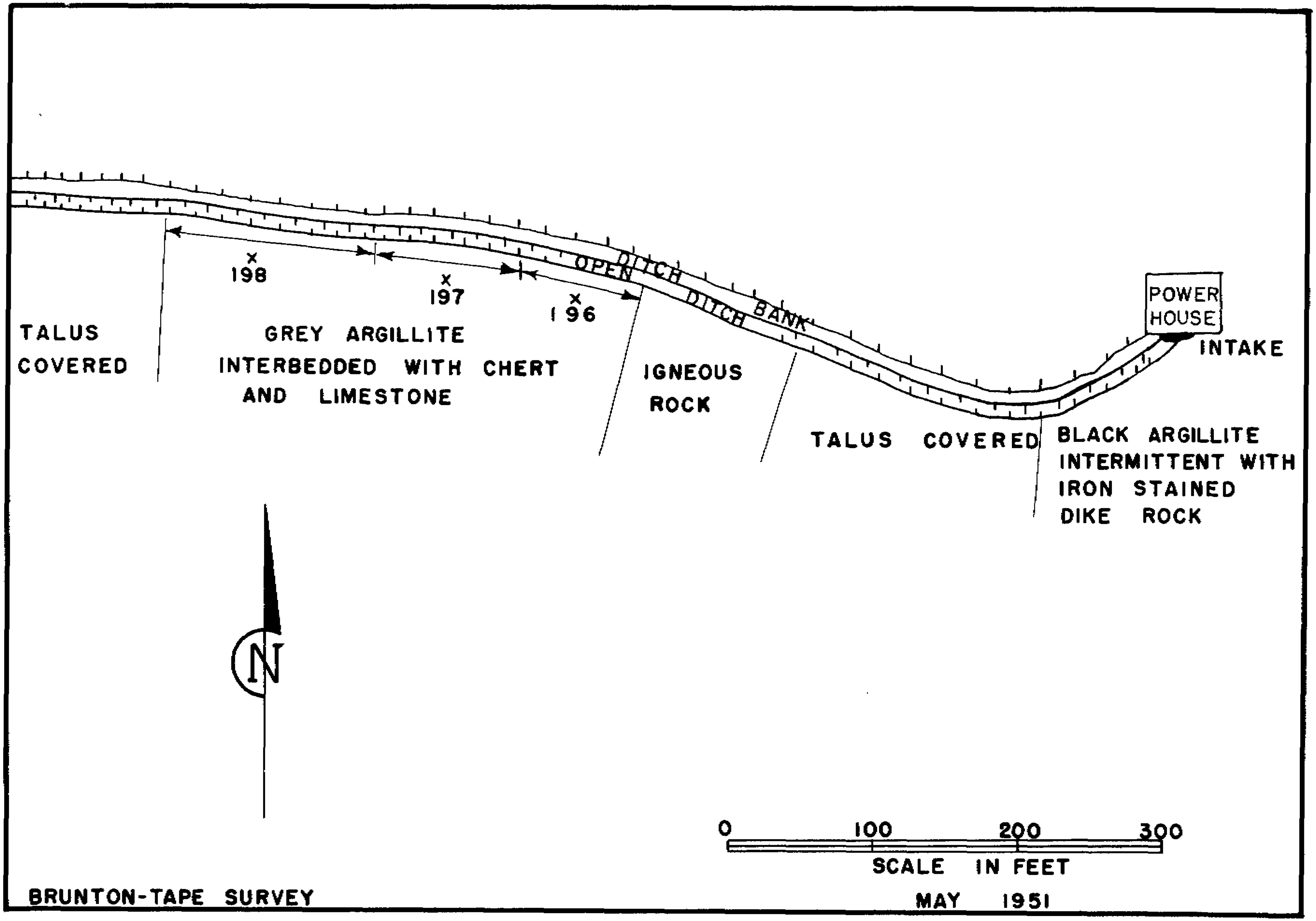

Figure 27. - Outcrop of unit D argillite sampled, West Fork of Chulitna River area.

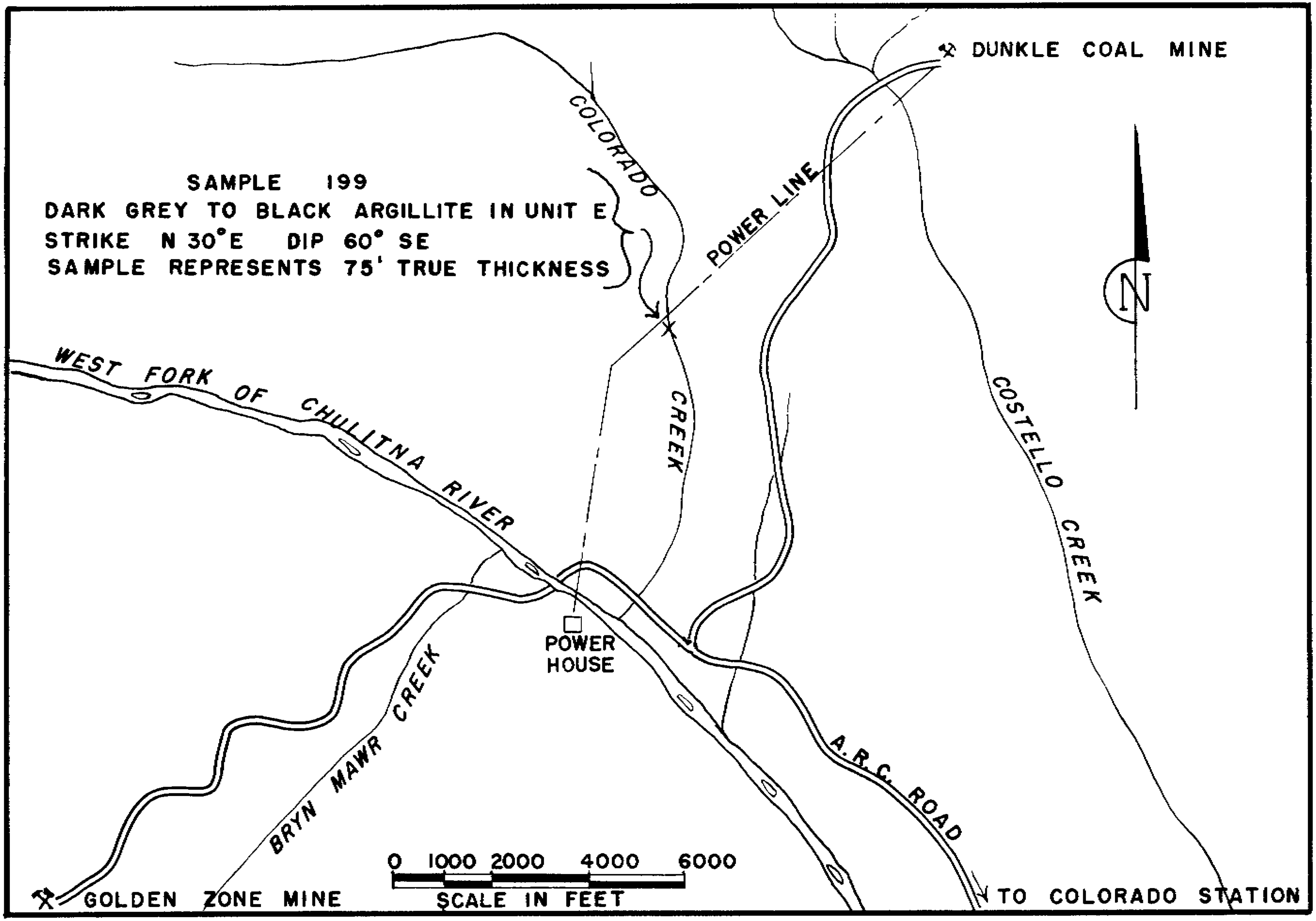

Figure 28. - Location of unit E argillite sampled, West Fork of Chulitna River area.

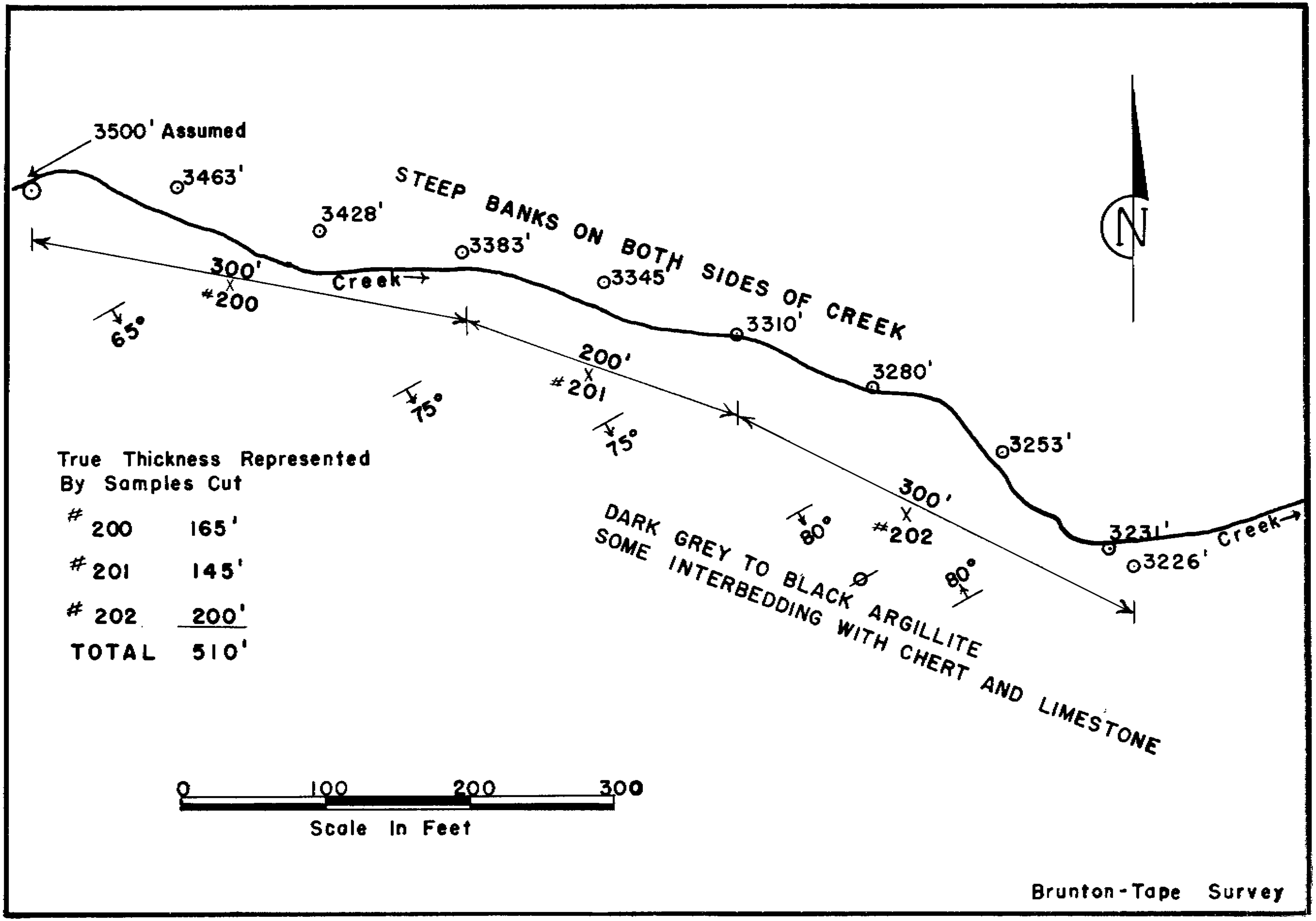

Figure 29. - Deposit of Triassic argillite sampled, West Fork of Chulitna River area.

The argillite beds strike northward across the West Fork of the Chulitna River. Figure 29 indicates the three samples, 200, 201, and 202, taken from this formation. The area sampled is approximately 3 miles west (fig. 26) of the W. E. Dunkle coal mine on the east slope of the ridge, between Colorado and Costello Creeks. Here a tributary of Costello Creek has cut through part of the formation and exposed the argillite in high steep banks.

The argillite, where sampled, is gray to black. It contains only minor amounts of interbedded arenaceous and calcareous material. The strike of the formation is N. 60° - 65° E. The true thickness of 510 feet is represented by the samples taken.

Lightweight-Aggregate Tests

The results of stationary-kiln bloating tests by the Bureau of Mines on the above samples are given in table 39.

TABLE 39. - Bloating tests on argillite from West Fork of Chulitna River

Sample No.	Temperature, °C.	Bloating results			Remarks
		Poor	Fair	Good	
196	1,100	x			
196	1,150	x			
196	1,200	x			
196	1,300	x			No indication of bloating.
197	1,100	x			
197	1,150	x			
197	1,200	x			
197	1,300	x			No indication of bloating.
198	1,100	x			
198	1,150	x			
198	1,200	x			
198	1,300	x			No indication of bloating.
199	1,100		x		
199	1,150			x	
199	1,200		x		Slightly overbloated.
199	1,250	x			Slumped.
200	1,100	x			
200	1,150		x		Possibly good depending on range.
200	1,200		x		Overbloated.
200	1,250	x			Slumped.
201	1,100	x			
201	1,150		x		Possibly good depending on range.
201	1,200		x		Overbloated.
201	1,250	x			Slumped.

TABLE 39 - Bloating tests on argillite from West Fork of Chulitna River (Cont.)

Sample No.	Temperature °C.	Bloating results			Remarks
		Poor	Fair	Good	
202	1,100	x			
202	1,150		x		Possibly good depending on range.
202	1,200		x		Overbloated.
202	1,250	x			Slumped.

Conclusions

The results of the stationary-kiln tests indicate that the material from unit D of the argillite in the West Fork of Chulitna River area, represented by samples 196, 197, and 198, does not bloat throughout a 1,100° - 1,300° C. temperature range; therefore, it is not a raw material suitable for lightweight-aggregate production.

Sample 199, representing an argillite bed in unit E, had the best bloating range of all the materials sampled in this area. This material gave a fair volume increase at 1,100° C., was well-bloated at 1,150° C., and was only slightly overbloated at 1,200° C. Although the above test results indicate that the material sampled has very good bloating characteristics, its remote location and its distance from the Alaska Railroad prohibit further consideration of this deposit as a source of raw material for the production of lightweight aggregate in competition with deposits more favorably situated with respect to the probable markets.

The three samples - 200, 201, and 202 - representing the Triassic argillite gave similar results - the argillite bloated satisfactorily at 1,150° C., but the bloating range is very short. During the tests, no volume increase was noticeable at 1,100° C. The samples were seriously overbloated at 1,200° C.

Indian River Argillite

Introduction, Location, and Accessibility.

Argillites exposed in the cut of the Alaska Railroad along Indian River 4 miles south of Chulitna Station were among the materials tested for the production of lightweight aggregate. The area is 166 miles by rail north of Anchorage, Alaska, and 200 miles south of Fairbanks. Rail transportation on the Alaska Railroad is available throughout the year.

Description of Deposits

The location of the Indian River argillite samples is shown in figure 30. These argillites belong to a group of shales, limestones, argillites, and graywackes that have been mapped by the Geological Survey[43] as undifferentiated Mesozoic rocks. The formation is exposed along the canyon of Indian River for

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[43] Work cited in footnote 2, pl. 2.

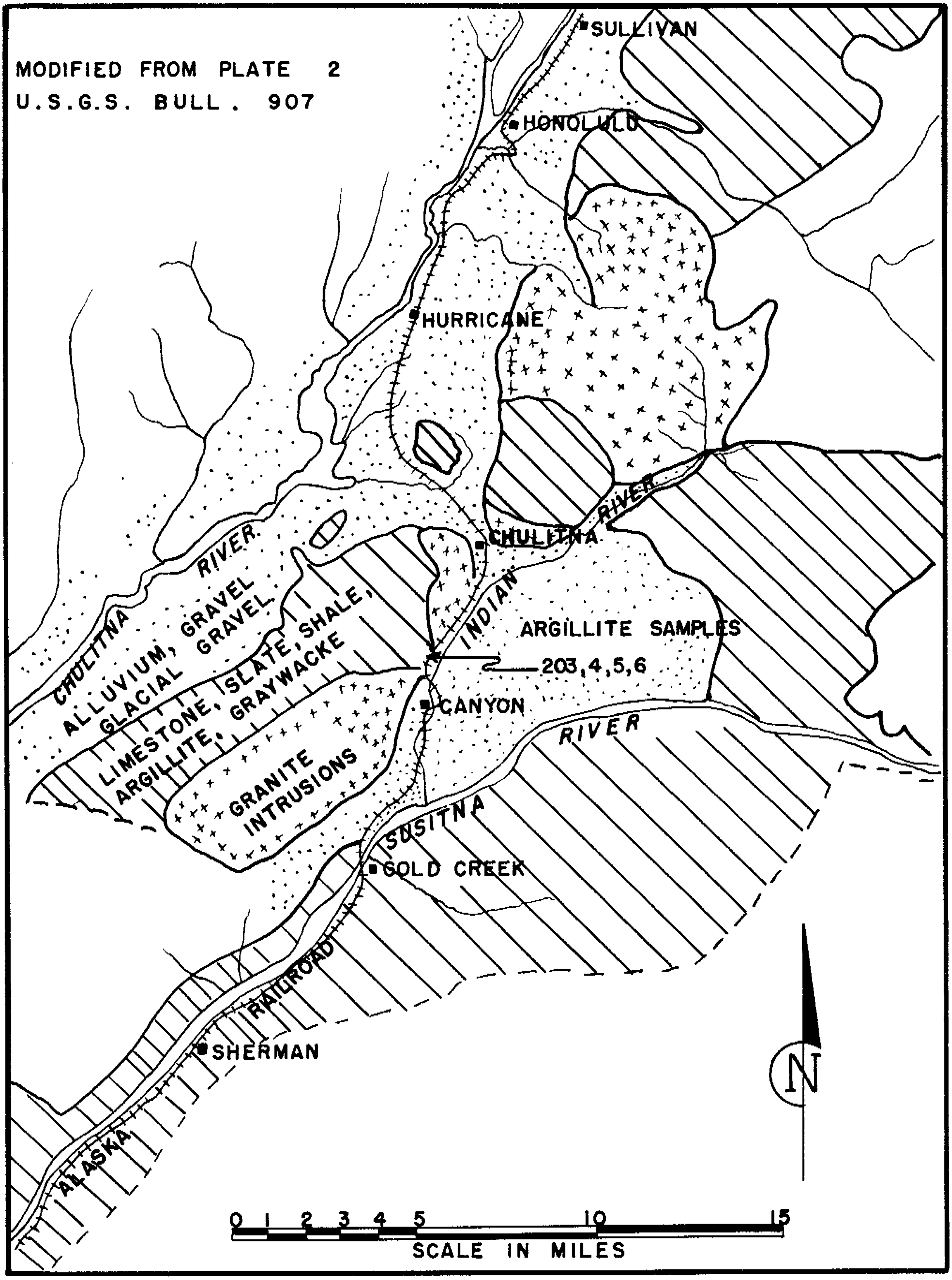

Figure 30. - Location map, Indian River argillite.

approximately 1 mile. The strike of the sediments is east-west, and the dip is 20°- 30° S. The formation sampled contains interbedded layers of shale and calcareous material.

Sample 203 was taken on the west side of the Alaska Railroad at mile 270.7. It consists of argillite with minor amounts of interbedded graywacke. The true width sampled is 216 feet. The strike of the formation at this location is N. 20° W.; the dip is 20° SW.

At mile 269.9, 50 feet south of the Indian River bridge, sample 204 was along the west side of the railroad cut where it traverses a small knoll west of Indian River. Strike of this formation is east-west and the dip 30° S. Where sampled, the argillite is relatively free of impurities and 40 feet wide.

Fifty feet north of the same bridge on the east side of Indian River, sample 205 was taken across 90 feet of interbedded argillite. The strike of the formation is N. 75° W.; the dip is 25° S.

Sample 206 is very similar to 205 in appearance and has the same strike and dip. This sample was taken on the east side of the track, just south of the bridge at mile 270.0.

Lightweight-Aggregate Tests

The results of tests in a stationary kiln on the bloating characteristics of argillite samples from Indian River are given in table 40.

TABLE 40. - Results of stationary-kiln bloating tests on argillite samples from Indian River

Sample No.	Temperature, °C.	Bloating results			Remarks
		Poor	Fair	Good	
203	1,100	x			
203	1,150	x			
203	1,200	x			
203	1,250		x		Possible sticking.
203	1,300	x			Slumped.
204	1,100	x			
204	1,150		x		
204	1,200			x	
204	1,250			x	Possible sticking.
204	1,300	x			Slumped.
205	1,100	x			
205	1,150		x		
205	1,200			x	
205	1,250			x	Possible sticking.
205	1,300	x			Slumped.
206	1,100	x			
206	1,150		x		
206	1,200			x	
206	1,250		x		Starting to slump; possible sticking.
206	1,300	x			Slumped.

Conclusions

The results obtained in the preliminary tests on samples 203 through 206 indicated that further investigations of the material represented by samples 204 and 205 is justified. The location of these deposits along the right-of-way of the Alaska Railroad also favors their exploitation. Larger samples will be submitted for rotary-kiln tests during the 1951 field season.

Miller's Landing Clay

Introduction, Location, and Accessibility

The clay bed near Miller's Landing in the Homer area was the only deposit examined for clay products and for the production of lightweight aggregate that was not directly within the Railroad-belt area. This deposit was sampled because of its location adjacent to Homer and its accessibility, by barge on Cook Inlet to Anchorage or by the new Sterling Highway to both Anchorage and Seward. Homer is on the north shore of Kachemak Bay near the tip of the Kenai Peninsula.

The location of the clay outcrop near Miller's Landing is shown in figure 18.

Physical Features and Climate

Homer is at the southern end of the Kenai lowland, which is on the Kenai Peninsula north of Kachemak Bay along the west flank of the Kenai Mountains.

In the Homer area, the sea cliffs along the north shore of Kachemak Bay are 50 to 200 feet high. A bench 1 to 2 miles wide parallels Kachemak Bay and slopes gently northward from the bluffs. This bench is traversed by several small, parallel streams that drain the uplands to the north.

The climate of the area is that characteristic of coastal Alaska. Summers are cool and winters mild. The mean annual temperature is 37.7° F. The average total precipitation is 25.4 inches. Freezing temperatures may be expected from early September until the middle of June.

Description of Deposit

A 30-foot bed of blue clay outcrops 0.8 mile south of Miller's Landing in the bluff along Kachemak Bay east of Homer, Alaska. The clay lies between two coal beds near the top of the stratigraphic section shown in figure 19. At this locality, the formation dips gently to the north.

Lightweight-Aggregate Tests

Preliminary kiln-bloating test results are given in table 41.

TABLE 41. - Results of stationary-kiln bloating tests on samples Miller's Landing clay

Sample No.	Temperature °C.	Bloating results			Remarks
		Poor	Fair	Good	
77	1,050	x			
77	1,070		x		
77	1,090		x	?	Bloating fairly good.
77	1,100			x	Do.
77	1,125			x	
77	1,150			x	Bloated to extreme.

Note: At 1,100° C., 25-percent volume increase;
at 1,125° C., 75-percent volume increase;
at 1,150° C., 200-percent volume increase.

The preliminary tests indicate that, at temperatures between 1,070° and 1,125° C., a good lightweight aggregate may be produced from this material but that bloating is only fair at the lower temperatures. Bloating is internal, with no apparent sticking on the surface of sample tested. At 1,150° C. the test piece was overbloated.

Sample 77 is one of the borderline cases that are very difficult to evaluate from small-scale tests alone. This clay bloats at a comparatively low temperature, below, 1,100° C., and gives an excellent volume increase. There was some indication that it might be one of the rare materials that will bloat before the outer surface reaches a pyroplastic condition. This would permit production of aggregate in a gradation of sizes that does not require crushing after processing. On the other hand, the tests indicate a very short bloating range; consequently, it would be difficult to prevent overbloating in a rotary kiln. Overbloating would result in a very light but fragile product. The clay breaks down into fine particles rather than into lumps when crushed; therefore, it probably would be necessary to pelletize the clay before processing.

Conclusions

Preliminary stationary-kiln tests indicate that an acceptable lightweight aggregate may be produced from the Miller's Landing clay. Larger-scale samples with rotary-kiln tests are warrented because of the favorable bloating characteristics of this clay. Additional samples were to be procured during the 1951 field season.

Pumice

Pumice is a volcanic glass with a highly cellular structure that has been formed by rapid cooling and rapid pressure change of an acid-type lava, such as rhyolite. The degree of expansion of the original siliceous lava and the size of the vesicle in the pumice are determined by the rate of cooling and by the amounts of gas and water vapor in the lava. Pumice ranges in size from grains a few millimeters in diameter to lumps of several cubic feet displacement.

Large amounts of water vapor and gas may produce a finer fragmentary product called volcanic ash or pumicite.

Pumice and pumicite were first used as aggregate in the days of the Romans. Some of their monolithic concrete structures, such as the Colosseum and the aqueducts, which were made with volcanic ash, are still standing. In the United States, the largest use is as aggregate for lightweight building blocks and units, and for monolithic concrete structures where light weight is desirable.

Deposits of pumice and pumicite occur in Alaska in several localities. Areas that are known to contain deposits of this type and are accessible to Anchorage and to the rail belt region are on Augustine Island in Cook inlet and along the Alaska Peninsula, especially within the Katmai National Monument. Pumice and pumicite have been mined in both localities and shipped by barge to Anchorage for the building-block industry.

In the Department of the Interior program, the Geological Survey was designated as the agency to make all preliminary explorations of deposits containing nonmetalliferous minerals for use as building materials in the Alaska Railroad region. The Geological Survey was unable to investigate these deposits during 1950, but plans called for examination of the pumice deposits by this agency during the 1951 field season.

The Bureau of Mines is indebted to the Territorial Department of Mines for much of the data on pumice and pumicite deposits included in this report.

Augustine Island Pumice

Introduction, Location, and Accessibility

The pumice deposits on Augustine Island in Cook Inlet were examined by L. A. Dahmers[44] of the Territorial Department of Mines during October 1947. The examination was made at the request of the Alaska Katmalite Corp., Anchorage, Alaska, who were producing lightweight building blocks from pumice they were mining on Augustine Island.

Augustine Island is in lower Cook Inlet near 59° 20' north latitude and 153° 20' west longitude (fig. 31). There is no good harbor on the island, and all shipments must be made by barge or small boat.

Physical Features and Climate

Augustine Island is a smooth volcanic cone rising from Cook Inlet to 3,973 feet. Mount Augustine is still considered active,[45] though its last violent eruption was in October 1883.[46]

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[44] Dahmers, L. A., Preliminary Report on Some Pumice Deposits, Augustine Island, Alaska: Alaska Territorial Dept. of Mines, unpub. rept., 1947, 10 pp.

[45] Martin, G. D., and Katz, F. J., A Geological Reconnaissance of the Iliamna Region, Alaska: Geol. Survey Bull. 485, 1912, p. 94.

[46] Davidson, George, Notes on the Volcanic Eruption of Mount St. Augustine, Alaska, Oct. 6, 1883: Science, vol. 3, 1884, pp. 186-189.

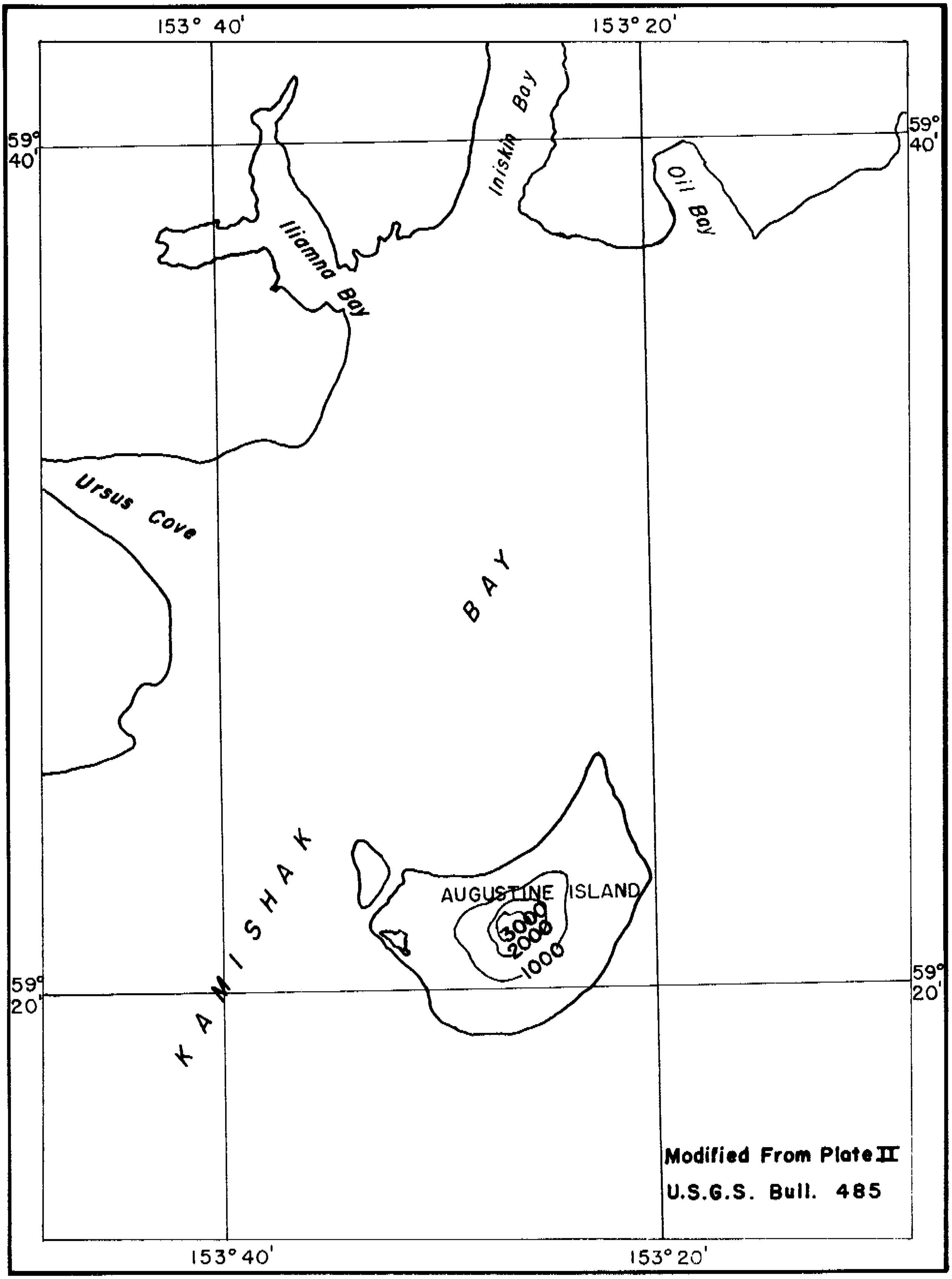

Figure 31. - Augustine Island, Alaska.

The slopes of the cone are steep and covered with a dense growth of alder. Mosses and grass form a carpet under the alders and cover the more open slopes between the alder thickets. There are no trees on the island. Numerous streams, which flow radially down the island's slopes, have formed steep-walled gullies.

The climate of the region is moderate, being that typical of coastal Alaska. Summers are cool, and the winters, although long, are mild.

Description of Deposits

The volcanic material forming Mount Augustine and covering the island has been determined by Becker[47] to be andesitic. The individual deposits examined by Dahners, except one, were thin (2 to 3 feet maximum thickness). Pumice deposits are in shallow depressions along the slopes. The inclination of the slope at the deposits has been estimated to be 10° or less.

The best deposit, 5, has been described by Dahners as follows:

> The exceptional deposit noted above is at an elevation of 1,240 feet and is represented by sample number 5. This deposit is more than 10 feet thick and the face that was visited is in one of the numerous canyons on the island. The deposit shows bedding (thought to be cross-bedding) and most of the individual particles of pumice are rounded pebbles. The deposit is much cleaner than the others, being nearly pure pumice and containing little or no non-vesicular volcanic glass. Although it has been thought by some that the canyon has been cut through a pumice deposit of large areal extent, it is more likely that this deposit has been washed from above by freshet action, which would carry the pumice as long as the volume of water was large and as long as it was possible to keep the load in motion. However, as soon as a deposit started to form, succeeding freshets would drop their load in the same place because the water would tend to drain away through the earlier deposit. Even though the margins of the deposit are not visible, it is estimated on the above premise that the dimensions of this deposit will not exceed 300 feet in length in the valley and 50 feet in width, and that the average thickness will be approximately 10 feet even though the visible face is much thicker than that. Further, it may be deduced, if the above premise is correct, that the supply of pumice that could be washed into this canyon and accumulated in this deposit is now depleted; or, less reasonable, that the freshet or flood action is not active now because at present the canyon is being reopened through the pumice deposit.

A screen analyses of sample 5 by Dahners is given below:

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[47] Becker, G. F., Reconnaissance of the Gold Fields of Southern Alaska, with some Notes on the General Geology: Geol. Survey, 18th Ann. Rept.; 1898, pp. 28-30, 52-54.

Fraction	Plus-4-m.	4/10-m.	10/28-m.	28/60-m.	60/100-m.	100/150-m.	Minus-150-m
Wt., gms...	481.9	311.9	453.6	396.9	113.3	23.8	31.8
Wt. percent	27	17	25	22	6	1	2
Sp. gr. ...	.9	1.0	1.5	2.1	2.5	2.5	2.6

The average specific gravity of the sample was 1.3. The material was nearly all pumice that was less granular and contained less glassy particles than the other samples taken.

The pumice from Augustine Island has been used in Anchorage to produce acceptable lightweight building blocks. The deposits, however, are small, mining costs have been high, and transportation from the harborless island is difficult.

Katmai National Monument Pumice

Introduction

Volcanism is still active within the Katmai National Monument. Five active and one extinct volcano have been identified[48] in this area. They are the source of the pumice and other extrusive rocks. Two of the volcanoes, Mageik Mountain and Mount Katmai, have had major explosive eruptions since 1900.[49] Majeik Mountain erupted on July 4-5, 1936, and again in 1946 (?). Mount Katmai erupted June 6-9, 1912. Majeik Mountain had a minor explosive eruption in August 1927, and Mount Katmai has had minor eruptions October 1912, March 9, 1920, and November 27, 1921.

The pumice and pumicite deposits of the Katmai district have been known since 1915, when the National Geographic Society sent an expedition into the region to investigate the effect of the 1912 eruption of Mount Katmai.[50] On the basis of the data gathered by this expedition, and by later expeditions, Griggs[51] calculated that a total mass of 6.25 cubic miles of volcanic material was thrown out during the eruption.

In 1923, the northwest half of the monument was included in a survey of the Gold Bay-Katmai district by the Federal Geological Survey,[52] and a geologic map of the area was prepared. The pumice deposits in the Valley of Ten Thousand Smokes have been described in more detail by C. N. Fenner,[53] one of the members of the National Geographic Society expeditions.

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[48] Smith, W. R., The Cold Bay-Katmai District: Geol. Survey Bull. 773-d, 1925, p. 186.

[49] Coats, Robert R., Volcanic Activity in the Aleution Arc: Geol. Survey Bull. 974-b, 1950, table 2.

[50] Griggs, R. F., The Valley of Ten Thousand Smokes: Nat. Geographic Soc., 1922, 341 pp.

[51] Work cited in footnote 50, p. 31.

[52] Work cited in footnote 48.

[53] Fenner, C. N., The Origin and Mode of Emplacement of the Great Tuff Deposit in the Valley of Ten Thousand Smokes: Katmai Series No. 1, Nat. Geographic Soc., 1923.

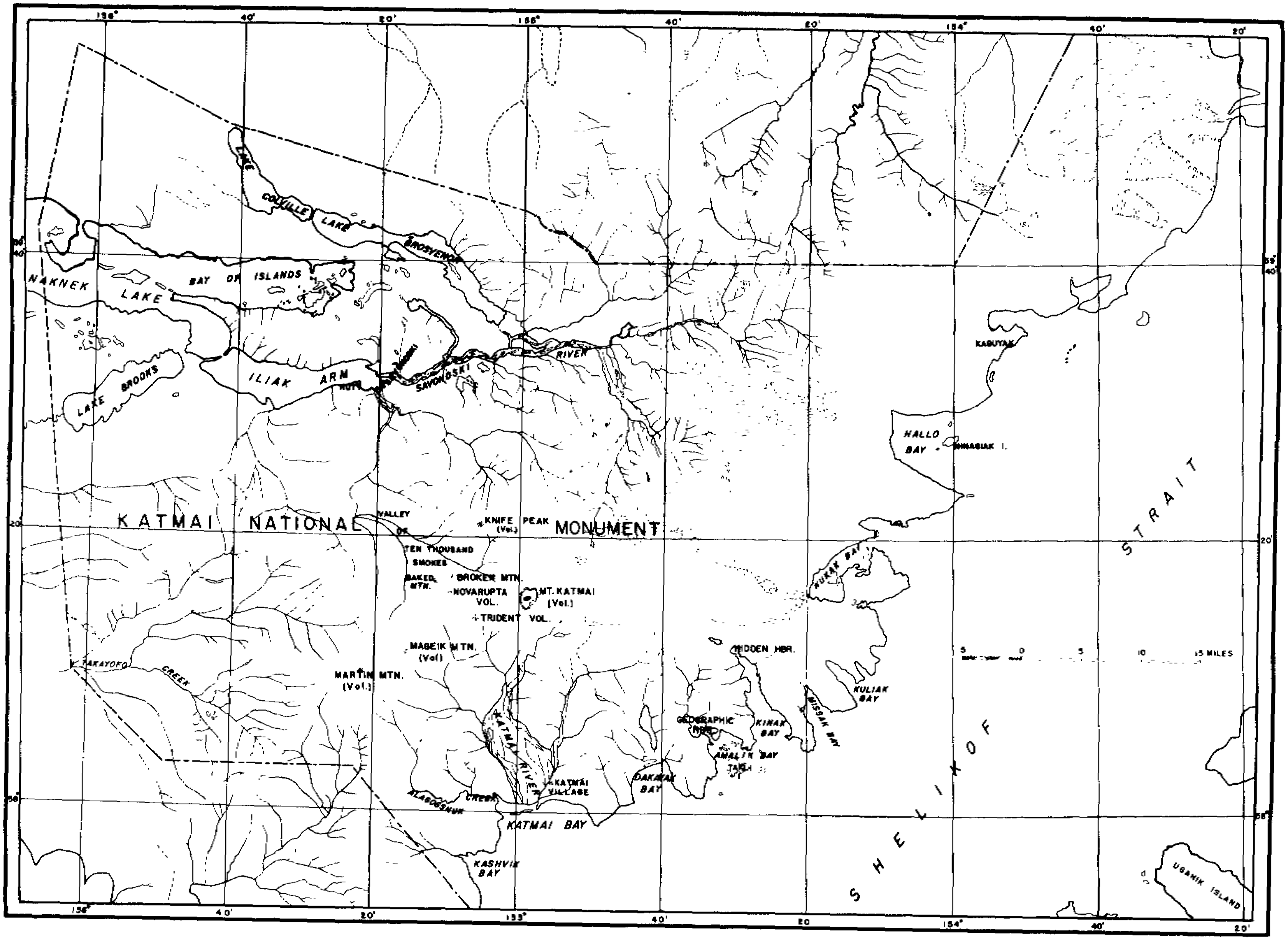

Figure 32. - Map of Katmai National Monument.

The search for lightweight aggregate for the concrete-block industry of Anchorage, Alaska, led to an investigation by the Alaska Territorial Department of Mines[54] in 1947 of the pumicite deposits in the Katmai National Monument that are accessible to the Pacific Ocean. In 1941, Roehm[55] had examined the pumice deposits in the Valley of Ten Thousand Smokes on the north slope of the Aleutian Range. At that time, he reported that all of the fumaroles for which the valley was named, except eight active vents on the west and north flank of Baked Mountain and Novarupta Volcano, had ceased to give off steam. In all the tests on the pumicite from Katmai National Monument, most of the impurities, sand, and ash were minus-28-mesh.

Location and Accessibility

The Katmai National Monument embraces an area on the south side of the Alaska Peninsula from latitude 57° 52' to 59° 01' N. and longitude 153° 16' to 156 08' W. The area examined by Roehm in 1947 is approximately 280 miles south of Anchorage, Alaska, by water by Cook Inlet and Shelikof Strait (see fig. 32).

Description of Deposits

During and after the eruptions of Mount Katmai and Novarupta Volcano, the pumicite was deposited over the surface of both the land and sea. Figure 33 shows approximate depth contours for the blanket of pumicite as originally laid down. Wind, wave, and stream action has since removed much of this material, leaving accumulations along the stream valleys and the beaches. One of the largest deposits, but one not easily accessible, is that formed by the incandescent sand flow from Novarupta Volcano and other minor vents that flowed down the Valley of Ten Thousand Smokes.

An abstract of Roehm's data for each of the six areas examined during 1947[56] follows;

Area 1, Hidden Harbon, Kinack Bay

Hidden Harbor is a small embayment at the head of Kinack Bay. The harbor is shallow and is connected with Kinack Bay by a narrow, rocky passage 3 to 4 fathoms deep.

Two areas of pumicite are easily accessible to this harbor. One lies to the northeast in a low pass of benches and small rolling hills. The benches, hills, and intervening gulches are mantled with light-gray pumicite. The other area lies to the northwest of the harbor. It consists of accumulations of pumicite extending from the toe up the slopes of the mountains for 400 to 500 feet

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[54] Roehm, J. C., Preliminary Report on Some Pumicite Deposits, Katmai National Monument, Alaska; Territorial Dept. of Mines unpub. rept., 1947, 14 pp.

[55] Roehm, J. C., Summary Report of Mining Investigations in the Kvichak Precinct, Alaska; Territorial Dept. of Mines unpub. rept., 1941, 3 pp.

[56] Work cited in footnote 52.

The bench and hill deposits are sparesely covered with grass and alders. Slope deposits begin within 300 feet of the beach. Bench deposits begin immediately behind the beach.

The pumicite of slope deposits and of bench deposits appears to be similar. The average size of the larger pumicite pieces is 3/8 inch in diameter. Bench deposits range from 4 to 6 feet in thickness, while the slope deposits are over 10 feet at the bottom and gradually thin out up the slopes. The lowest foot of material in the bench deposits is a pumicite mud grading into black, carbonaceous material.

One sample was taken from near the bottom of one of the slope deposits. Depth sampled was 10 feet, which was not the total depth. A screen analysis of the sample is given below.

Screen analysis of Hidden Harbor pumicite, in percent

Plus-4-mesh	Minus-4-mesh Plus-10-mesh	Minus-10-mesh Plus-28-mesh	Minus-28-mesh Plus-60-mesh	Minus-60-mesh Plus-100-mesh
4	15	46.2	33.2	0.33

Area 2, Head of Kinack Bay, East Shore

The northeast head of Kinack Bay is a wide, low valley with rolling hills and numerous draws mantled with pumicite. The pumicite on the hills range from 3 to 4 feet in thickness. Erosion by wind and stream action has concentrated a greater thickness of pumicite in the valleys and draws. Many thin, black, cinder seams less than 1/4 inch in thickness were noted in the pumicite. As many as eight cinder seams were noted in the 4-foot thickness of the pumicite deposit trenched. The top 3 feet consisted of unsorted pumicite particles ranging from 1/2 inch in diameter down to fine dust. Below the 3 feet of coarse pumicite was a layer of fine altered pumicite mud.

Because of the abundance of impurities, no screen tests of this sample were made.

Area 3, Southwest Corner of Geographic Harbor

Geographic Harbon is situated west of the entrance of Kinack Bay in the south-central part of Katmai Monument. Area 3 consists of long slopes, with intervening draws leading to the mountains inland from the southwest portion of the harbor. Geographic Harbor is ideal for medium-size vessels. Charts show 60 fathoms of water 200 feet offshore.

In 1947, the Pumice Building Block Co. of Anchorage was mining pumice from below tide level on the shores of this harbor.

The pumicite-covered benches, which rise abruptly from the shore lines, are 30 to 50 feet high. The surface slopes at about a 30° angle from the benches westward 1/2 mile to the mountains. The average thickness of the pumicite on the slopes is 3 feet, but the thickness increases gradually along the side slopes and in the draws. The pumicite is underlain by 6 to 12 inches of black, carbonaceous material on hard, sedimentary bedrock.

A sample taken from the top of one of the long slopes represents a depth of 3 feet. A screen analysis of this pumicite follows:

Screen analysis of area 3 pumicite, in percent

Plus- 4-mesh	Minus-4-mesh Plus-10-mesh	Minus-10-mesh Plus-28-mesh	Minus-28-mesh Plus-60-mesh	Minus-60-mesh Plus-100-mesh
4	28	50	17	1

The minus-4-mesh to plus-28-mesh material, which represents 82 percent of the total, appears to be suitable for pumicite blocks.

Area 4, Northwest Corner of Geographic Harbor

Pumicite covers the floor of the long, low, glacial valley in the northwest part of Geographic Harbor. The hills range from 30 to 100 feet in height. The depressions between the hills contain glacial gravels. Because of the considerable wind action in this area, the largest accumulations of pumicite are in the depressions and on the southeast or lee side of the hills. The thickness of pumicite ranges from 2-1/2 feet on the tops of the hills to over 10 feet on the slopes and in the depressions. A 30-foot bench at the beach also is covered with pumicite.

The pumicite in this area contains more sand than the pumicite in area 3; futhermore, it contains a small amount of cinder. The pumicite is light gray. The fragments are more rounded than the fragments from the other deposits sampled.

Screen analysis of area 4 pumicite, in percent

Plus-4-mesh	Minus-4-mesh Plus-10-mesh	Minus-10-mesh Plus-28-mesh	Minus-28-mesh Plus-60-mesh	Minus-60-mesh Plus-100-mesh
4	15	46	32	3

Area 5, Takli Island

Takli Island is 2 miles off-shore from the entrance of Geographic Harbor in Amalik Bay. The island is low relief, generally less than 50 feet. The only notable topographic feature is a hill in the northwest corner of the island which rises abruptly from the beach to an altitude of over 300 feet.

Wind action has removed the pumicite from the low hills and concentrated it in the north-south valleys and in other depressions. The area examined by Roehm is inland from a small bay at the George Hadden cabin on the center of the north shore of Takli Island. One deposit, situated near the Hadden cabin, occupies a depression more than 300 feet wide; its larger axis bears south-southwest. Mixed with the pumicite are fine, black glass particles from the weathered lava bedrock. No sample was taken from this deposit, because samples from it have been tested extensively by Northwest Laboratories for the Pumice Building Block Co. of Anchorage.

A sample was taken from the slope deposit east of the Hadden cabin. The slope deposits have been formed in the lee of the hills; their thickness ranges from 6 feet at the toe of the slope to nothing near the top. The screen analysis of this pumicite is given below.

Screen analysis of Takli Island pumicite, in percent

Plus-4-mesh	Minus-4-mesh Plus-10-mesh	Minus-10-mesh Plus-28-mesh	Minus-28-mesh Plus-60-mesh	Minus-60-mesh
0.8	14	59	24	4.1

Area 6, Kukak Bay

Kukak Bay is a long, southwest-trending indentation from Shelikof Strait behind Cape Ugyak. Two large streams, which head in the direction of Mount Katmai 22 miles to the west, enter at the head of the bay and have deposited a large quantity of pumicite there, making it very shallow. Kukak Bay is navigable by large vessels to within a mile of the head where the depth changes rapidly from 60 fathoms to a few feet. The location of Kukak Bay is shown on figure 31.

High mountains are on both sides of the river valley, which has a width of over a mile. The valley is of glacial origin. For several miles westward from the head of the bay, it is only a few feet above sea level. Numerous small streams, which flow from hanging valleys, drain the mountain slopes. Between the valley floor and the mountains on each side, the rolling topography is mantled heavily with pumicite. Slope deposits of pumicite cover the toes of the mountains on the north side of the valley. These deposits, as seen from a distance, appeared to be whiter than the deposits noted in Kinack Bay and along the south shores of the monument. The major proportion of pumicite particles are larger than were those noted elsewhere in the monument. Pieces up to 3/4 inch were observed.

The fresh-water streams that enter at the head of the bay are largely responsible for the great accumulation of pumicite found below tide level and on the beaches. Because of this abundance of fresh water at the head of the bay, it is very probable that the pumicite beneath tide level is not contaminated with salt.

A high-grade deposit of pumicite was found at driftwood level on the beach. This deposit extends for over 1/2 mile along the beach and ranges in width from 60 to 70 feet. The pumicite is gray; its average particle size is about 1/4 inch. The thickness sampled was 3 feet. A screen analysis of the sample follows:

Screen analysis of Kukak Beach pumicite deposit, in percent

Plus-4-mesh	Minus-4-mesh Plus-10-mesh	Minus-10-mesh Plus-28-mesh	Minus-28-mesh Plus-60-mesh	Minus-60-mesh Plus-100-mesh
3	40	55	2	None.

The above test shows the absence of fines. Impurities also are absent. The pumicite deposit is chiefly a concentration by strong waves and tidal action, of strong durable pieces of pumicite of approximately uniform size.

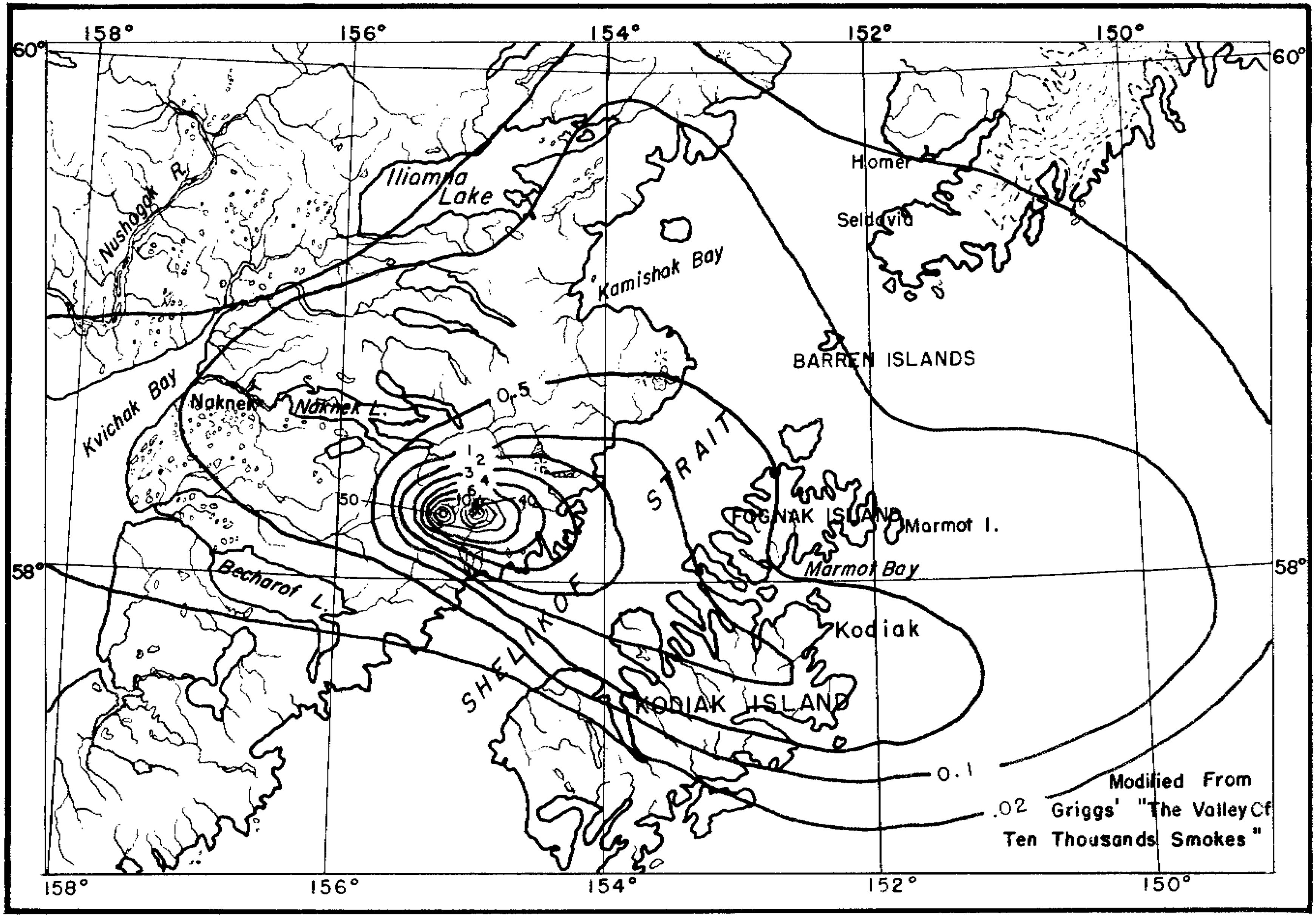

Figure 33. - Map showing depth contours of ash fall during 1912 eruption of Mount Katmai.

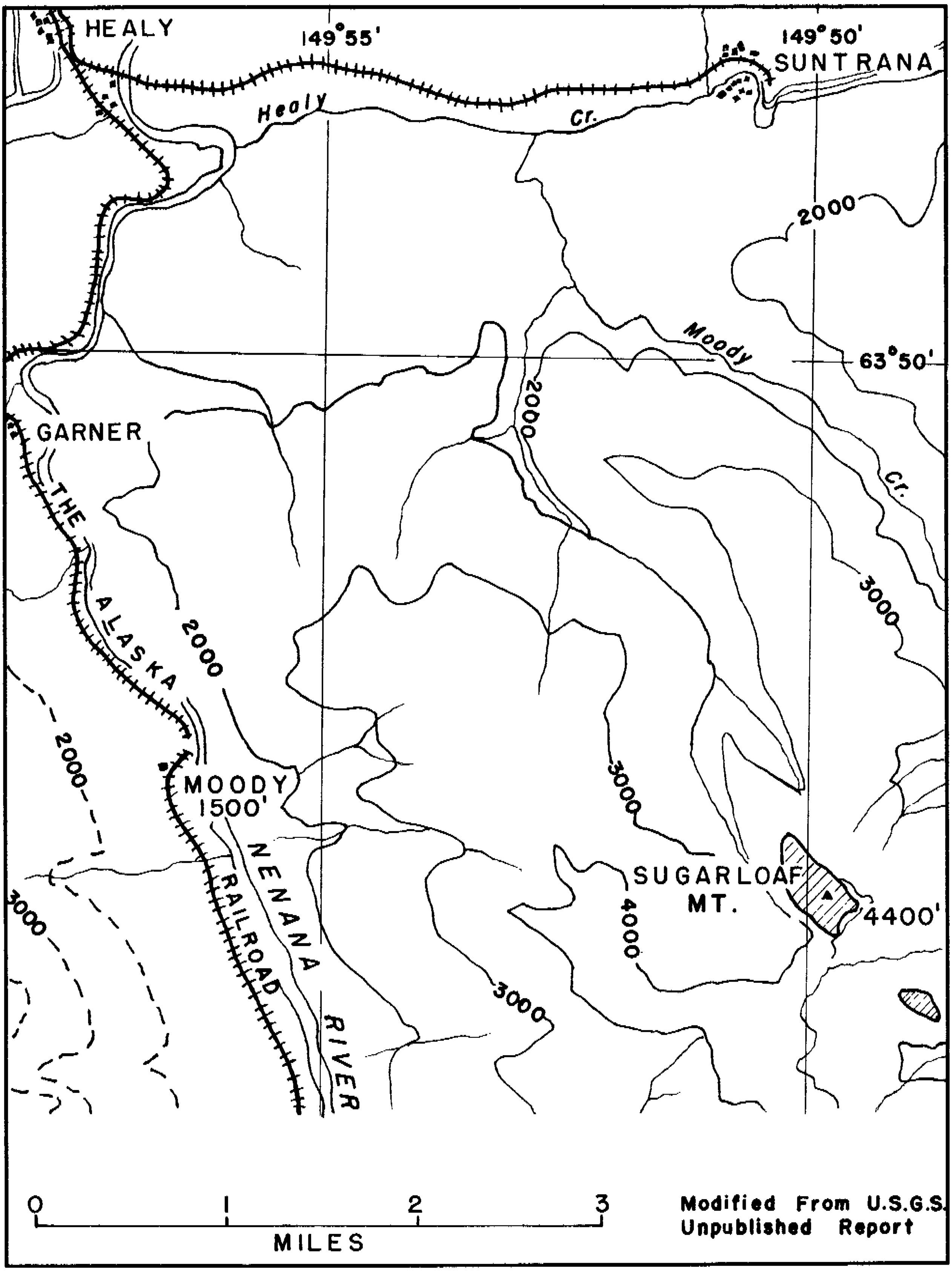

Figure 34. - Location map, Healy perlite.

Perlite

Introduction

Perlite is a pearly volcanic glass with a concentric lamellar structure that contains 3 to 4 percent combined water.[57] Upon rapid heating, this combined water expands the volume of the perlite several times to produce a lightweight aggregate. Expansion takes place at the softening point, which ranges from 800° to 2,200° F. depending upon the chemical composition of the crushed perlite.[58]

Although perlite does not have the strength of some of the other lightweight aggregates, its heat and sound insulating properties are very good. The largest use for expanded perlite is as aggregate for plaster in the building industry.

Only one deposit of perlite is known to occur in the Alaska Railroad belt. This deposit, near Healy, Alaska, was investigated by Wahrhaftig and Eckhart[59] of the Geological Survey in 1950. The following data have been abstracted from their report.

Location and Accessibility

The Healy perlite deposit is associated with the igneous complex, including rhyolite, forming Sugarloaf Mountain, 8 miles southeast of Healy, Alaska. Sugarloaf Mountain is at the head of the left fork of Moody Creek; it is approximately 4 miles south of the railroad spur up Healy Creek to the Suntrana coal mine (fig. 34).

Description of Deposit

The outcrop of perlite is on the southeast side of the mountain, near the base of the rhyolite body. The base of the perlite outcrop is hidden by talus, but a thickness of about 2 feet is exposed. When examined on May 29, 1950, a snowbank covered the outcrop to the southwest leaving only a 6-foot segment exposed between the snowbank and the talus-blanketed slope to the northeast. Scattered perlite float was observed in this talus for about 50 feet. Wahrhaftig estimated the perlite could not be more than 10-15 feet thick. Probably much of its thickness is less.

In addition to the perlite at this outcrop, perlite float was found at three other places on the southeast and northeast sides of Sugarloaf Mountain; however, only a few pieces of perlite were observed at each locality. It is very unlikely that a large body of perlite exists beneath the rhyolite talus at these locations.

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[57] Johannsen, A., A Descriptive Petrography of the Igneous Rocks: University of Chicago Press, vol. 2, 1932, pp. 284-285.

[58] Dolbear, S. H., Bowles, Oliver, and others, Industrial Minerals and Rocks: Am. Inst. Min. and Met. Engr., 2d ed., 1949, p. 749.

[59] Wahrhaftig, Clyde, and Eckhart, R. A., Perlite Deposit, near Healy: Geol. Survey memo. rept., unpublished, 1949, 3 pp.

The perlite is black, glassy obsidian with numerous phenocrysts of quartz or glassy feldspar; it shows distinct, fine, conchoidal fracturing.

Expanding Tests

Two specimens of the perlite were obtained from Wahrhaftig and submitted to the Southwest Experiment Station of the Bureau of Mines at Tucson, Ariz., for testing. The samples were rolls - crushed through 10-mesh. Because the perlite is an exploding variety, preheating was required to minimize the decrepitation during expansion. The minus-10-mesh feed and a 10 to 20-mesh fraction of the material were preheated at 500° C. for 1 minute, then they were expanded in a vibrator-actuated tube furnace at 1,100° C. The bulk weight of the expanded minus-10-mesh and 10 to 20-mesh fractions were 12.0 and 9.6 pounds per cubic foot, respectively. The expanded minus-10-mesh material was fractionated by sink-float to determine the gangue content. About 2.7 percent composed principally of quartz fragments, was reported as sink. The expanded particles were white and appeared quite strong.

The Healy perlite compares favorably with Arizona and New Mexico perlites, which are being processed for plaster and concrete aggregates.

Conclusions

The specimens tested produced good expanded perlite. The area was to be investigated by the Bureau of Mines during the 1951 field season to delimit the known occurrance and, if possible, discover others.

Summary and Comparison of Lightweight-Aggregate Tests

Shales and other argillaceous rocks amenable to the production of the lightweight aggregate Haydite occur in several localities within the Railroad belt. One of the best of those tested is at mile 67 on the Glenn Highway, where it is readily accessible to the Matanuska Valley and to the Anchorage area. Preliminary tests indicate that the lightweight aggregate produced has a fine, vesicular structure, with uniformly spaced pores. Physical tests are in progress on commercial-size concrete building units made with aggregate produced from the mile 67 shale.

A shale from mile 16 on the Matanuska branch of the Alaska Railroad is of similar age and composition to the mile 67 shale; it gave similar results in preliminary bloating tests. Additional samples will be taken for large-scale-kiln tests.

Of the other formations tested for their bloating characteristics and possible use as lightweight aggregate, two samples of argillite near Indian River 4 miles south of Chulitna Station gave the best results. Preliminary tests indicate good bloating at 1,200° C. Larger samples will be submitted for continuous kiln tests.

One deposit that was not directly within the Railroad belt was sampled. This was a blue clay bed near Miller's Landing at Homer, Alaska. Preliminary tests indicate that the clay bloats at a comparatively low temperature, below 1,100° C., and gives an excellent volume increase. There was some indication that this material may bloat before the outer surface reaches a pyroplastic condition, permitting the production of aggregate in a gradation of sizes that does not require crushing after processing.

Pumice, a natural lightweight aggregate, occurs within the Katmai National Monument on the Alaska Peninsula and also on Augustine Island in Cook Inlet. Although no samples have been taken by the Bureau of Mines, building units of excellent strength and appearance have been produced from this material.

One occurrence of perlite in the Healy area was investigated during 1950 by the Geological Survey. Two specimens procured from the Geological Survey by the Bureau of Mines compare favorably with Arizona and New Mexico perlites, which are being processed for plaster and concrete aggregates. The known deposit is extremely small, but the area was to be investigated further by the Bureau of Mines during the 1951 field season.

POZZOLAN

Pozzolans are siliceous and aluminous materials, natural or artificial, processed or unprocessed, which, though not cementitious in themselves, contain constituents that will, at ordinary temperatures, combine with lime in the presence of water to form compounds that have a low solubility and possess cementing properties.60/ The pozzolanic material may be added to concrete as it is being mixed, or it may be ground with cement clinker to produce a portland-pozzolan cement.

The addition of pozzolan to concrete or use of a portland-pozzolan cement in making concrete gives several desirable characteristics to the concrete. This is especially true where the concrete is to be used in large, massive structures made with aggregate containing reactive substances or to be placed in contact with alkali or sulfate waters.

Because the Bureau of Reclamation is the primary designer and builder of large dams and other structures of massive concrete in the United States, it has taken the lead in investigating pozzolans and their effect on concrete. Several publications and papers on different phases of this study of pozzolans have been prepared by members of the Bureau of Reclamation.

The following data have been taken from a report by R. C. Mielenz.61/

> The mechanism by which the pozzolan accomplishes these changes in the properties of concrete is not fully known. However, the pozzolanic action generally is believed to be in part physical and in part chemical. The physical effects relate particularly to the low specific gravity of most pozzolans (ranging generally from 2.3 to 2.8, in contrast to about 3.1 for portland cement), as a result of which the pozzolan occupies a greater volume than the weight-equivalent of portland cement. Thus, if the cement-to-aggregate ratio by weight is

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60/ Work cited in footnote to Table 28, p. 53.

61/ Mielenz, R. C., Materials for Pozzolan - A report for the Engineering Geologist: Bureau of Reclamation, Research and Geology Div., Petrographic Laboratory Rept. Pet-90A, Apr. 4, 1949, pp. 2-3.

held constant, use of a portland-pozzolan cement effectively increases the volume of cement in the concrete, with resulting tendency to increased workability, plasticity, and water requirement.

Chemically, pozzolans decrease susceptibility of the hydrated portland cement to dissolution or deterioration by reaction with the calcium hydroxide released by hydration of the portland cement. Reactive substances of pozzolan, such as amorphous silica, volcanic glass, or aluminous and siliceous compounds produced by calcination of clays, are converted by this reaction with calcium hydroxide into comparatively stable substances, many of which are cementitious. Other constituents of pozzolans, particularly zeolites, may play a secondary role in the reaction with hydrating portland cement. Through destruction of the readily dissolved and decomposed calcium hydroxide, the concrete is rendered less susceptible to leaching or to decomposition by aggressive waters. Also, because the pozzolanic reactions proceed slowly, portland-pozzolan cement concretes harden slowly, and usually, but not always, increase progressively in strength and durability for long periods of time. Those pozzolans which inhibit or prevent cement-aggregate reaction in concrete do so by combination with the alkalies (Na_2O and K_2O) released by the hydrating portland cement. The alkalies thus retained by the pozzolan are unable to attack the aggregate.

As a result of investigations of portland-pozzolan cements at the Bureau of Reclamation Materials Laboratory in Denver, Colo., the following conclusions have been made:62/

1. When made with excellent pozzolanic materials, the portland-pozzolan cements, although their early strengths are less, are found to produce strengths equal to those of straight portland cement at the later ages, exhibiting more substantial gain with age.

2. No material differences in water requirement or concrete workability are observed as a general rule for the portland-pozzolan cements although some slight improvement in water gain or bleeding is noted.

3. Portland-pozzolan cements show greater tensile strength than the straight portland cement, with no tendency to show retrogression in the test for tensile strength as is often exhibited by the portland cements.

4. A greater resistance to aggressive alkaline waters is observed for the portland-pozzolan cements over the portland cements, except that the resistance of the former approaches that of special sulphate resisting portland cement.

5. Portland-pozzolan cements have lower heats of hydration than straight portland cements.

62/ Savage, J. L., Special Cements for Mass Concrete: Bureau of Reclamation, Denver, Colo., 1936, pp. 89-91.

6. A greater plastic flow is observed for portland-pozzolan cements than for portland cement.

7. Portland-pozzolan cements do not exhibit volume change characteristics materially different from those of portland cements, on wetting or drying. Under adiabatic curing they are observed to show shrinkage while the portland cements are found to expand.

8. Portland-pozzolan cements show relatively greater strength development in lean concrete mixes than in rich ones.

9. The thermal coefficient of expansion is slightly greater for concrete containing portland-pozzolan cements than for concrete containing straight portland cement.

10. Of 19 groups of materials tested, pumices and diatomites were found to be the most active classes of pozzolanic materials.

11. Calcination quite generally improves pozzolanic activity, the average optimum temperature appearing to be 1,450° F.

12. Using modified portland cement, an optimum blend of 30 percent by absolute volume was indicated for a typical pumicite.

The advantages, therefore, in the use of pozzolan in concrete are enhanced properties over the properties of straight portland concrete as follows: (1) greater resistance to aggressive alkaline waters and soils; (2) better workability; (3) less water gain and segregation; (4) lower permeability, (5) reduced expansion owing to reactive aggregate; and (6) less heat generation. A saving in cost results also from substitution of pozzolanic material for part of the portland cement.

Materials that have been used as pozzolans may be divided into the following classifications:

1. Volcanic tuffs and pumicites.
2. Siliceous sedimentary rocks;
   a. Diatomaceous earth,
   b. Opaline cherts and shales.
3. Calcined clays and shales.
4. Industrial byproducts;
   a. Blast-furnace slag,
   b. Fly ash.

The first two classifications may or may not require calcination for activation or to enhance their pozzolanic properties.

At the beginning of the Bureau of Mines investigation of nonmetallic materials of construction in the Alaska Railroad belt, the Bureau of Reclamation requested that deposits of pozzolanic materials be included in the Bureau of Mines program. The pozzolan was for use in proposed massive concrete dams for power development by the Bureau of Reclamation.

The pumicite deposits in the Katmai National Monument offered the best chance for developing a source of pozzolan in Alaska that is accessible to the Railroad belt. Because the Bureau of Mines program did not include an investigation of these deposits until 1952, or until after they had been explored by the Federal Geological Survey, a sample of mine-run pumicite was secured from the Anchorage Sand & Gravel Co. for submission to the Denver Materials Laboratory of the Bureau of Reclamation for testing. Test procedures and results follow:[63]

> The sample as received consisted of lumps of rhyolite pumice of an index of refraction of about 1.485. The sample was contaminated with one fragment of impure metasandstone. The glass contained crystals of quartz, feldspar, epidote, etc.
>
> The sample was split into two portions, one part of which was calcined at 1,400° F., the other portion of the sample was not heated. The raw sample required grinding for 1 hour and 10 minutes in a small laboratory ball mill to get 91.7 percent passing the No. 325 sieve. The raw ground sample consisted of 75- to 80-percent glass. The balance of the sample was inert minerals, chiefly quartz, feldspar, and epidote.
>
> The calcined sample required 1 hour and 45 minutes grinding to get 92.4 percent passing the No. 325 sieve. The air permeability surface on the raw material was 5,224 square centimeters per gram, and was 4,810 square centimeters per gram for the calcined sample.
>
> Time of set tests was made using a 1 to 4 mix with hydrated lime. Water necessary to get normal consistency with the raw sample was 38.8 percent and 36.0 percent for the calcined material. Initial set was obtained in 96 hours for the raw sample and in 36 hours for the calcined one. Final sets took 120 hours and 84 hours, respectively.
>
> Specific gravity of the raw sample was 2.52 and 2.54 for the calcined material. Strength specimens were made using 2- by 2-inch cubes. Cubes were made using a 1 to 2.75 mix with graded Ottawa sand, but 35 percent of the cement by volume was replaced with pumice. Two types of curing were used; (1) standard curing, which was water curing at 73° F., (2) mass curing, which was sealed storage at 100° F. for 28 days and the balance of the time at 73° F. Strengths obtained are shown in the following table, and the control concrete is shown for comparative purposes.

Compressive strength 2 by 2 inch (p.s.i.)

	Standard curing						Mass curing					
	7 days	%	28 days	%	90 days	%	7 days	%	28 days	%	90 days	%
Raw.....	1,240	43	2,490	50	3,940	69	2,380	58	4,130	74	4,460	73
Calcined	1,430	49	3,160	63	4,520	79	2,750	67	4,840	87	4,980	82
Control.	2,900		500		5,740		4,080		5,580		6,080	

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[63] Bureau of Reclamation, Denver Matwax Laboratory report to Juneau field office, March 13, 1951.

Pyrex glass bars were made to determine if the material would be effective in the reduction of expansion which is caused by alkali-aggregate reaction. Bars were made using three replacements of 15, 25, 40 percents by volume. The results obtained follow:

Pyrex-glass-bar data
(Percent reduction)

Days.........	14	14	14	28	28	28
Replacement..	15	25	40	15	25	40
Raw sample...	-8	32	53	9	44	69
Calcined.....	-7	22	64	10	36	76

The water requirement was 94 percent for the raw sample and 95 percent on the calcined sample. Shrinkage bars were made using a 1 to 2.75 mortar mix. The raw material had a shrinkage of .069 percent, and the calcined had a shrinkage of 0.067 percent.

Results of preliminary tests indicate that the pumice would be satisfactory in strength development but that it is not outstanding. The activity as shown by the time of set tests is satisfactory and is improved greatly by calcination at 1,400° F. Water-requirement tests indicate that a mixture of cement and pumice would require less water than an equal amount of cement, a desirable characteristic. The shrinkage also is satisfactory, but the material is ineffective in reducing expansion caused by alkali-aggregate reaction. If reactive aggregate is used to make concrete, this pumice would not provide insurance against excessive expansions.

MINERAL WOOL

Introduction

Mineral wool is a processed fibrous material resembling loose wool, which is composed of silicates in the form of fine, glassy fibers. These fine, interlaced fibers are made by subjecting a melt of blast-furnace slag (or a similar melt composed of the necessary mineral constituents) while still molten to a strong blast of air or steam. Mineral wool produced from blast-furnace slag is called slag wool. Slag from iron blast furnaces is the material most commonly used, although copper and lead blast-furnace slag also has been used. Rock wool is made from naturally occurring rocks, either alone or in the proper combination.

Mineral wool is used principally as an insulating agent. In the industrial field, it is used as a protective layer to inhibit radiation losses from heated surfaces; and, in the building industry, it is used to block the transfer of heat through the walls and roof of the building unit.

Insulation in Alaska's building-construction program is virtually a must because of the high thermal differential through a unit's roof and exterior walls that is produced by the rigorous climate throughout long periods. Because of its low heat conductivity, the insulation reduces the transfer of heat units from one side to the other of the insulating medium. This results in a saving in the amount of fuel necessary to heat the building unit.

Mineral wool is fireproof, giving it an added advantage as an insulating material. Because mineral wool is inert and incombustible, its use between the joists and wall studs of a building unit acts as a barrier to the spread of fire; consequently, an insulated frame building may be classified as slow-burning.

Mineral wool is marketed in a variety of forms. It may be used as loose wool; it may be rolled into small pellets and used as granulated wool; or it may be fabricated into bats and blankets. In new construction, it is most commonly used in the form of bats and blankets but loose wool also may be used. To insulate old structures, granulated wool is blown into the space between wall studding and floor joists.

Mineral wool exhibits the lowest heat conductivity of any material except still air.[64] In measuring the quantity of heat transferred, the British thermal unit (B.t.u.) is used. One B.t.u. is the amount of heat necessary to raise 1 pound of water from 63° to 64° F. The thermal conductivity of a material is the number of B.t.u. per hour per square foot of material 1 inch thick that is transferred as a result of temperature gradient of 1° F. The lower the value of this thermal conductivity of K factor, the better are the insulating properties of the material. For comparative purposes, the K factors of a variety of building materials are given in table 42.

TABLE 42. - Thermal conductivity of building materials[1]

Material tested	Density, lb. per cu. ft.	Conductivity, K
Still air	0.08	0.16
Cork	8.1	.31
Corkboard	5.4	.25
Do.	14.0	.34
Insulite (wood pulp)	16.2	.34
Celotex (sugar-cane fiber)	13.2	.34
Expanded vermiculite	7.0	.38
Do.	10.0	.48
Flaked gypsum	24.0	.48
Rock wool	6.0	.26
Do.	10.0	.27
Do.	14.0	.28
Do.	18.0	.29
Bricks, common	125	5.0
Bricks, face	150	9.2
Concrete	150	12.0
Haydite concrete	80	3.0
Do.	110	4.0

[1] Chemical Rubber Publishing Co. Handbook of Chemistry and Physics; 18th ed., 1933, pp. 1194-1195.
Kidder-Parker, Architects' and Builders' Handbook; John Wiley & Sons, Inc., 18th. ed., 1949, p. 1574a.

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[64] Bateman, Alan M., Economic Mineral Deposits: John Wiley & Sons, Inc., New York, N. Y., 2d ed., 1950, p. 729

Mineral Composition Necessary to Produce Mineral Wool

Four major components are required to produce a melt from which rock wool may be blown. These components are silica, alumina, lime, and magnesia. Variation in the percentages of these components is great, but in practice they are usually within the following limits: Silica, 35 to 50 percent; alumina (R_2O_3), 5 to 20 percent; lime, 20 to 40 percent; and magnesia, 5 to 20 percent. Miscellaneous oxides that may be present as impurities are Fe_2O_3, MnO, BaO, TiO_2, Na_2O, K_2O, and S compounds.

In practice, virtually all of the rock wool is made from naturally occurring rocks of the proper consistency. The Illinois State Geological Survey has published the results of an intensive investigation of the mineral-wool resources of Illinois.[65] This report[66] includes the laboratory results of experimental production of rock wool from naturally occurring wool rocks and also from combinations of other rock formations. As a result of the experimental work, Dr. Dryling found that determination of the carbon dioxide content of rocks afforded a simple and satisfactory means of obtaining a preliminary evaluation of the rock-wool possibilities of a given rock sample. All rock samples containing 20 to 30 percent CO_2 yielded rock wool in the experimental blowing tests.

A rapid method for determining the CO_2 content within allowable limits was devised by Fryling as follows: A 1-gram sample of dried, pulverized rock is weighed into a porcelain crucible and heated at 400° C. for 1 hour to remove moisture. After being cooled in a desiccator, the sample is weighed. The sample is then heated for 1 hour at 1,000° C., cooled in a desiccator, and again weighed. The difference in weight closely approximates the CO_2 content.

Work by Bureau of Mines

All samples taken by the Bureau of Mines during the investigation of nonmetallic sources of building materials in the rail belt were submitted for chemical analyses. Though no naturally occurring wool rock (rock of the proper composition for the production of rock wool) was revealed by the analyses, rocks containing the necessary components were located in three areas. These areas and rock components are as follows:

Area	Rock
Anchorage	Potter limestone, graywacke, or argillite.
Cantwell-Windy	Windy limestone, shale.
West Fork of the Chulitna River	Limestone, argillite.
Homer-Seldovia	Seldovia limestone, Homer clay.

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[65] Lamar, J. E., Willman, H. B., Fryling, C. F., and Voskuil, W. H., Rock Wool from Illinois Mineral Resources: Illinois State Geol. Survey Bull. 61, 1934, 262 pp.

[66] Work cited in footnote 62, pp. 159-204.

Bulk samples of these formations were to be taken and submitted for testing for production of mineral wool during the 1951 field season.

CEMENT

Cement is the principal ingredient of concrete, one of the most commonly used construction materials of modern civilization. A cement plant located within the Alaska Railroad belt is desirable for several reasons. One of these is the possibility of lowering construction costs by using locally manufactured cement. Local manufacture would reduce transportation charges and thereby reduce costs to the consumer unless offset by higher manufacturing costs. A local cement industry, with its permanent installation and employment, would assist in stablizing the economy of the Railroad belt area. Another consideration is the assurance of a local supply of cement for national-defense projects, if imports are interrupted during any future emergency.

Cement has been known since the days of the Romans, who used pozzolan cement in building large structures, many of which are still standing. This cement was a mixture of quicklime and a volcanic ash from Puzzuoli, Italy--the first known use of a pozzolanic material in concrete.

Natural hydraulic cement, a cement that sets under water, was first made in England in 1756 by John Smeaton. Natural cement is produced by calcination of argillaceous limestone to drive off the carbon dioxide at a temperature below the fusion point. Most of the early cements made in America were natural cements. Raw material for natural cement usually consists of an impure high-magnesium limestone.

The variable composition of the raw material for natural cement resulted in cements of different physical characteristics. This variability has led to replacement of natural cements by the more-uniform and stronger Portland cements. No chemical specifications, except a maximum allowable ignition loss of 12 percent and a minimum insoluble residue of 2 percent,67/ have been established for natural cement. The burned material should be ground so that 90 percent will pass through a 100-mesh screen.

Natural cements, which are employed extensively in brick-laying mortars, are not desirable for concrete.68/

Portland cement was invented by Joseph Aspdin of England in 1824; it was so named because of the close resemblance of the set cement to the Portland limestone. It is made by burning to a clinker a finely ground, intimately mixed, feed composed of calcareous and argillaceous materials in the proper proportion to have the following approximate composition: 70-75 percent $CaCO_3$; 15-25 percent combined SiO_2, Al_2O_3, and Fe_2O_3; and 5 percent combined MgO, alkalies, and other impurities. After cooling, the clinker is ground to a fineness of at least 78-percent minus-200-mesh.

67/ Work cited in footnote 19, p. 14.

68/ Kidder, F. E., and Parker, Harry, Kidder-Parker Architects' and Builders' Handbook: John Wiley & Sons, Inc., New York, N. Y., 1931, p. 1109.

Finished portland cement of good quality is usually within the following chemical limits.[69]

Range of composition of portland cement

Component	Limits, percent	Average percent	Component	Limits, percent	Average percent
SiO_2	20-24	22.0	CaO	60-64.5	62.0
Fe_2O_3	2-4	2.5	MgO	1-5	2.5
Al_2O_3	5-9	7.5	SO_3	1-2	1.75

The American Society of Testing Materials has set specifications[70] for the five types of Portland cement (A.S.T.M. C 150-49) as follows:

Type I. For use in general concrete construction when the special properties specified for types II, III, IV, and V are not required.

Type II. For use in general concrete construction exposed to moderate sulfate action, or where moderate heat of hydration is required.

Type III. For use when high early strength is required.

Type IV. For use when a low heat of hydration is required.

Type V. For use when high sulfate resistance is required.

The A.S.T.M. specifications for chemical composition of each of the above five types of portland cement are given in table 43.

TABLE 43. - A.S.T.M. Chemical requirements for portland cement, in percent

Constituent	Type I	Type II	Type III	Type IV	Type V
Silicon dioxide (SiO_2), minimum.............	-	21.0	-	-	-
Aluminum oxide (Al_2O_3), maximum.............	-	6.0	-	-	(1)
Ferric oxide (Fe_2O_3), maximum...............	-	6.0	-	6.5	(1)
Magnesium oxide (MgO), maximum..............	5.0	5.0	5.0	5.0	4.0
Sulfur trioxide (SO_3), maximum..............	[2] 2.0	2.0	[3] 2.5	2.0	2.0
Loss on ignition, maximum..................	3.0	3.0	3.0	2.3	3.0
Insoluble residue, maximum.................	.75	.75	.75	.75	.75
Tricalcium silicate ($3CaO \cdot SiO_2$), maximum....	-	50	-	35	50
Dicalcium silicate ($2CaO \cdot SiO_2$), minimum.....	-	-	-	40	-
Tricalcium aluminate ($3CaO \cdot Al_2O_3$), maximum..	-	8	15	7	5

[1] The tricalcium aluminate shall not exceed 5 percent, and the tetracalcium aluminoferrite ($4CaO.Al_2O_3.Fe_2O_3$) plus twice the amount of tricalcium aluminate shall not exceed 20 percent.

[2] The maximum limit for sulfur trioxide content of type I cement shall be 2.5 percent when the tricalcium aluminate content is over 8 percent.

[3] The maximum limit for sulfur trioxide content of type III cement shall be 3.0 percent when the tricalcium aluminate content is over 8 percent.

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[69] Furnas, C. C., Rogers' Industrial Chemistry: D. Van Nostrand Co., Inc. New York, 6th ed., vol. 1, 1942, p. 856.

[70] Work cited in footnote 19, pp. 1-4.

Federal specifications state, in addition, that when a low-alkali cement is required, the maximum alkali content is 0.6 percent. Total alkali is calculated as the percent Na_2O plus 0.658 percent of the K_2O present.

Portland cements are specified for used in concrete for construction in Alaska by the following agencies:

Federal Housing Administration (FHA form 2383, 405-A-1).
Alaska Public Works.
Alaska Housing Authority (FHA form 2383, 405-A-1).
Alaska Road Commission.
Corps of Engineers, U. S. Army, Alaska District.
Civil Aeronautics Administration.

Magnesia (MgO) is one of the undesirable components of portland cement. The maximum allowable magnesia content in the finished cement is 5.0 percent. Because the magnesia content of the raw materials, limestone and shale, is increased in the cement in proportion to the amount of carbon dioxide and organic matter driven off during calcination, the MgO content of any of the constitutents should not exceed 3.3 percent.[71]

The specifications for raw materials for portland cement are interrelated through calculations from analyses of the materials available; they may be derived through calculation of a theoretical cement having the required specifications minus-1-percent magnesia allowance for fluctuations in mix. In all cement calculations for a plant in the Railroad belt, analyses of ash from the Healy coal and of shale from the area adjacent to the limestone deposits in the Windy-Foggy Pass area were used. Thus, although the allowable magnesia content of the limestone theoretically is 3.3 percent, the presence of magnesia in the shale and coal ash available for use requires reduction of permissible magnesia in the limestone to an average of 2.6 percent, with no individual mix in excess of 3.2 percent.

Investigations of only the two major components of portland cement, limestone and shale, are described in this report.

Limestone

Introduction

The problem of a supply of lower-cost cement has been an integral part of the Bureau of Mines and Geological Survey investigation of construction raw materials in the Railroad belt as a part of the Department of the Interior program of development for Alaska.

The Alaska Railroad also was vitally interested in establishing a cement plant and other local industries within the sphere of its transportation facilities and employed G. Reed Salisbury in 1948 to make an economic survey of potential markets for cement in the Railroad belt.

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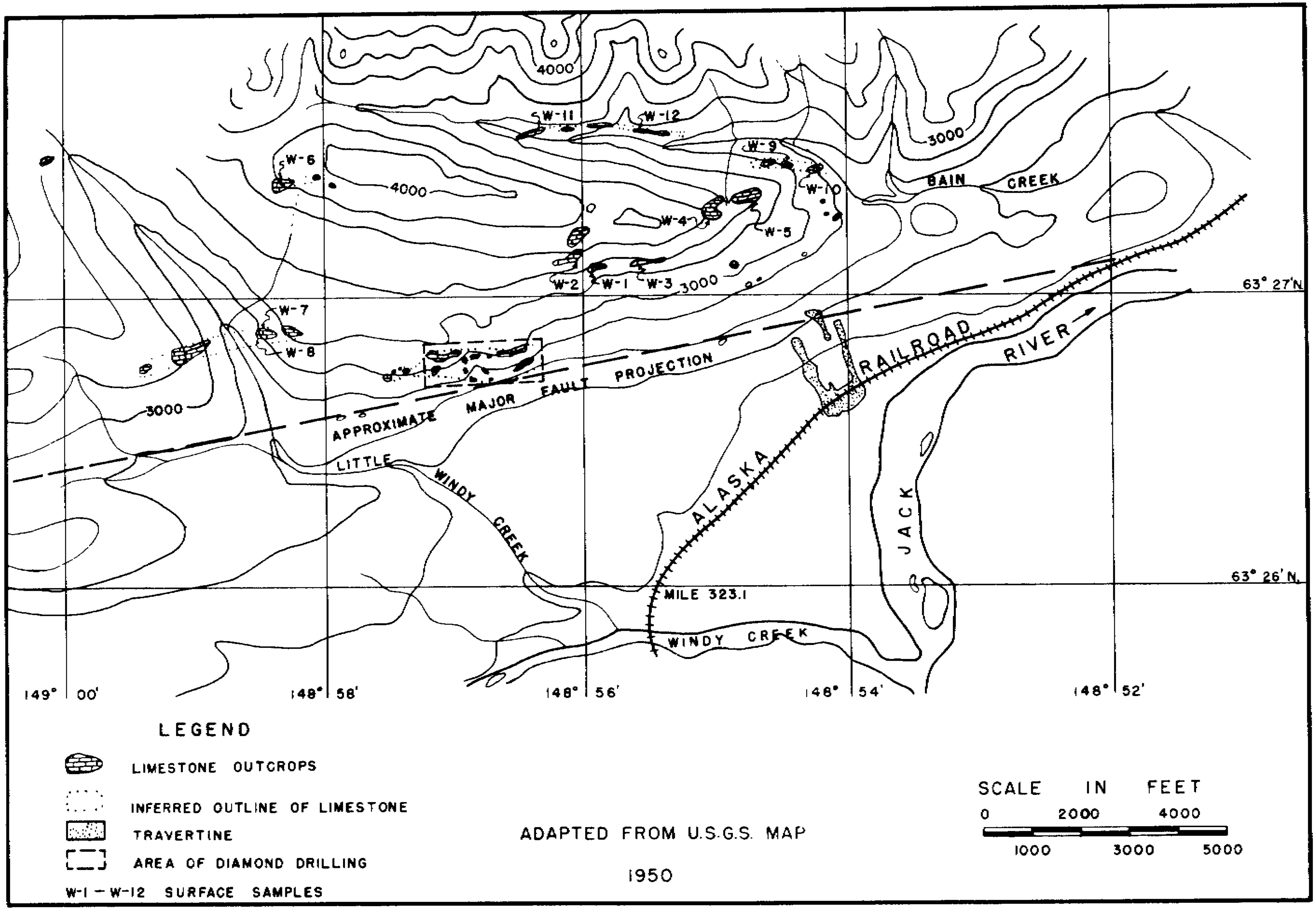
[71] Work cited in footnote 67, p. 857.



ADAPTED FROM U.S.G.S. MAP

1950

Figure 35. - Map of Windy Creek limestone area.

Samples of limestone deposits and other nonmetallic minerals in the Railroad belt were first taken by G. A. Waring of the Geological Survey in 1931.[72] In 1947, a more detailed examination of the Windy limestone deposit was undertaken by E. H. Cobb of the Federal Geological Survey. Information about Cobb's examination was made available to Government agencies in an unpublished report dated August 1948. The Windy limestone occurrence was the deposit recommended by the Geological Survey to the Bureau of Mines for investigation as the best possible source of limestone of the quality required for a cement plant.

Field investigations of limestone deposits in the Railroad belt were begun by the Bureau of Mines in September 1948.

In 1949, the Bureau of Reclamation, acting on instructions from former Assistant Secretary of the Interior Warne, assigned Maj. S. E. Hutton to the Railroad belt to prepare a survey of the cement supply problems and formulate chemical specifications of raw materials required for a cement plant.[73]

Field investigations by the Bureau of Mines have been made of the Windy limestone deposit, adjacent deposits in the Windy area, the Devonian limestone on the West Fork of Windy River near Foggy Pass, limestone deposits in the West Fork of the Chulitna River area, the Fox limestone, the Castle Mountain limestone, and a limestone deposit near Seldovia, Alaska. Additional investigations of the Foggy Pass deposit and of a limestone occurrence near Potter, Alaska, are in progress.

A description of each of the deposits investigated by the Bureau of Mines follows;

Windy Limestone Deposit

Location and Accessibility

The Windy limestone deposit is on the southern slope of the Alaska Range in the southeastern corner of Mount McKinley National Park. It is situated at 63° 26' 45'' north latitude and 148° 57' west longitude, as shown in figure 35. The limestone outcrops between altitudes of 2,600 and 3,200 feet.

The lower outcrops of the Windy limestone deposit are slightly over 1 mile northwest of mile 323.1 on the Alaska Railroad, as shown in figure 35. The track elevation at mile 323.1 is approximately 2,130 feet. If a branch line to the deposit is built, it probably would leave the railroad in the vicinity of mile 322. A spur line leaving the railroad at mile 322 would being above 2,130 feet. The greater altitude, and the greater length required, would permit a better grade for a rail line to the deposit.

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[72] Waring, G. A., Nonmetalliferous Deposits in the Alaska Railroad Belt: Geol. Survey Circ. 18, 1947, 10 pp.

[73] Hutton, S. E., A Report on Investigations and Conclusions with respect to Cement-Supply Problems of Central Alaska: Bureau of Reclamation, 1950, 48 pp.

Mile 323.1 on the Alaska Railroad is 323.1 miles by rail from Seward, Alaska; 208.8 miles from Anchorage, Alaska; and 147.2 miles from Fairbanks, Alaska. It is 37 to 40 miles from the principal coal deposits of the Healy Valley.

A small airplane landing strip is at Cantwell, 4 miles from the limestone deposit. This landing strip, adjacent to and paralleling the Alaska Railroad tracks, is suitable for only small, bush-type airplanes. At Summit, on the Alaska Railroad, the Civil Aeronautic Administration maintains an airfield, which is used by the Alaska Airlines on its route between Fairbanks and Anchorage. Summit is approximately 12 miles by rail from mile 323.

The route of a survey for a proposed road from the vicinity of Paxton, Alaska, on the Richardson Highway, to Mount McKinley National Park, passes within a few miles of the Windy limestone deposit.

Physical Features and Climate

From the Alaska Railroad at mile 323, the ground rises sharply for about 100 feet, then breaks into a gently sloping, brush-covered terrace, which extends for 1 mile toward the Windy limestone deposit. A scrub-spruce-covered slope of increasing gradient rises from the terrace to the base of the deposit.

The limestone outcrops rise abruptly like islands in bare or brush- and moss-covered talus slopes from an altitude of 2,600 feet to an altitude of 3,200 feet. At the crest of the limestone, another gradual, tundra-covered slope intervenes before a final sharp rise to a summit more than 5,000 feet above sea level. Beyond this summit are barren ranges of greater altitude.

At an altitude of 2,500 feet, a short distance below the limestone outcrops, a series of springs discharge a moderate flow of water. Little Windy Creek skirts the edge of the limestone slightly more than 1/4 mile west of the deposit.

Sub-zero temperatures can be expected in this area from November through April. Freezing temperatures sometimes occur in every month of the year; the annual mean temperature is approximately 28° F. The maximum low temperature recorded in the reports available for 1947 was -48° F.; the maximum high temperature was 80° F.

Precipitation during 1947 totaled 14.6 inches. The snowfall was 71 inches.

History, Production, and Ownership

Samples of limestone in the Windy area were first taken in 1931 by G. E. Waring of the Geological Survey, who sampled the limestone outcrops on Bain Creek above Windy Station on the Alaska Railroad. The Windy limestone deposit near mile 323.1 was examined in 1948 by E. H. Cobb, geologist, Geological Survey. Cobb's examination was followed, in September 1948, by a sampling and diamond-drilling program by the Bureau of Mines.

Early in October 1948, Kroenung, as agent for A. E. Beaudin of Anchorage, Alaska, staked five placer claims covering the greater part of the Windy limestone deposit. These claims were surveyed in July 1949.

In July 1949 the Bureau of Mines signed an exploration agreement with the Northern Empire Development Co., the present holders of the above-mentioned claims.

Diamond drilling of the Windy limestone deposit by the Bureau of Mines was completed in September 1950.

No production from this deposit has been made.

General Geology

The following is quoted from an unpublished report.[74] In this quotation, the Windy limestone deposit is referred to as limestone body No. 1.

> The area bounded by the ridge north of Bain Creek, by Little Windy Creek, and by the Alaska Railroad is underlain by clastic sedimentary rocks, chert, limestone, and greenstone. In most places south of Bain Creek bedrock is exposed only on steep slopes and in the sides of the gully of Little Windy Creek. Except for bedrock exposures, the surface is talus, glacial gravels, soil, travertine near the Alaska Railroad at 148° 54' west longitude, and some muskeg at the foot of the slope on which Limestone Body No. 1 is exposed. Clastic sedimentary rocks in the area are conglomerate, argillite of various colors, medium-grained sandstone somewhat limy in places, and some shale and slaty shale.
>
> The limestones of the area are dense gray rocks shot with small calcite veinlets. The bodies north of Bain Creek and at the west and east ends of the ridge south of Bain Creek are somewhat cherty and carry brachiopod fragments. All other bodies appear to be non-cherty and have yielded no recognizable fossils. The limestone is so massive that only rarely can bedding be determined accurately.
>
> The trace of a large fault which has been found at intervals from Muldrow Glacier northeast of Mt. McKinley to Mt. Deborah passes through this area near the base of the slope on which limestone Body No. 1 is exposed, and probably is marked by a muskeg-filled trench and springs depositing travertine near 148° 54' west longitude.
>
> Within the mapped area (fig. 35), the rocks north of the foot of the slope on which Limestone Body No. 1 is exposed are certainly Paleozoic and possibly Devonian in age. The rocks exposed in the lower part of the gully occupied by Little Windy Creek have been assigned to the Mesozoic by Capps.[75]

Description of Deposit

The exposed length of the Windy limestone deposit is approximately 2,400 feet. An apparently narrower tongue of limestone extends throughout an additional strike length of 1,000 feet to the west. A diamond-drill hole begun on the

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[74] Cobb, E. H., Limestone in the Windy Creek Area, Alaska: Geol. Survey. (unpublished).

[75] Work cited in footnote 2.

lowest outcrop at an altitude of 2,665 feet penetrated limestone for 629 feet before entering a quartzite footwall bed at an altitude of 2,340 feet. The hanging-wall side of the deposit probably lies under considerable cover near the base of a steep slope. A stratigraphic thickness of 800 feet has been estimated for the deposit by the geologist.[76] A major fault with an assumed trend of N. 79° E. and a southerly dip is inferred, from geologic interpretation, to be the hanging wall of the limestone beds.

The quartzite-limestone contact along the footwall strikes N. 67° E. and dips 60° to 70° southward. The altitude was determined by two diamond-drill holes and by contact points on the surface. The quartzite bed was assumed, because of gradational changes indicated by analyses and microscopic study, to be conformable with the limestone bed.

Study of the drill core and drill records substantiates the geological interpretation of faulting in and adjacent to the limestone. In places calcite which evidently recements openings made by fracturing, comprises 5 to 25 percent of the rock. Much of the limestone drilled contains fractures that have not been recemented.

The surface contact along the footwall (see fig. 36), together with the strike of the beds as determined by the contact intercepted in diamond-drill holes 4 and 8, indicates two probable lines of step faulting. Neither the amount of throw in the step faulting nor the exact position of the faults is known, but the complex geologic conditions largely eliminate, as a source of limestone, the area from the gully through to the section cut by hole 7.

The diamond-drill holes were directed at an angle approximately normal to the footwall strike and dip. Samples representing each 5-foot interval of the core were taken where possible. A study of the analyses of these core samples by graphic and tabular methods appeared to indicate parallelism of beds from drill section 8 to drill section 4.

A fairly low magnesia limestone with a thickness of approximately 100 feet was encountered deep in holes 4 and 8, which were drilled during 1949. This limestone was separated from the quartzite footwall by a 30-foot thickness of highly siliceous limestone. Diamond-drill holes 9, 10, 11, and 12 were drilled during the 1950 field season to delimit in more detail this bed of low-magnesia limestone. The results of the analyses from these holes prove that the bed is continuous but is not as uniform or regular as had been indicated. Changes in the magnesia content of the limestone along both the strike and dip of the bed betwen holes are indicated. Although the average of the analyses of the core samples representing the low magnesia bed is within the limits required for portland cement, sections with higher magnesia content are present; therefore, careful mining, thorough mixing when stockpiling, and close control would be necessary to insure an uniform limestone product.

Hole 6, drilled in the eastern part of the limestone, encountered fairly low magnesia limestone throughout the first 225 feet. The average magnesia content of the core was 2.12 percent, but magnesia analyses considerably above the allowable limits were obtained from two sections of the hole. Nevertheless, the magnesia content was more uniform than in the other holes. However, the

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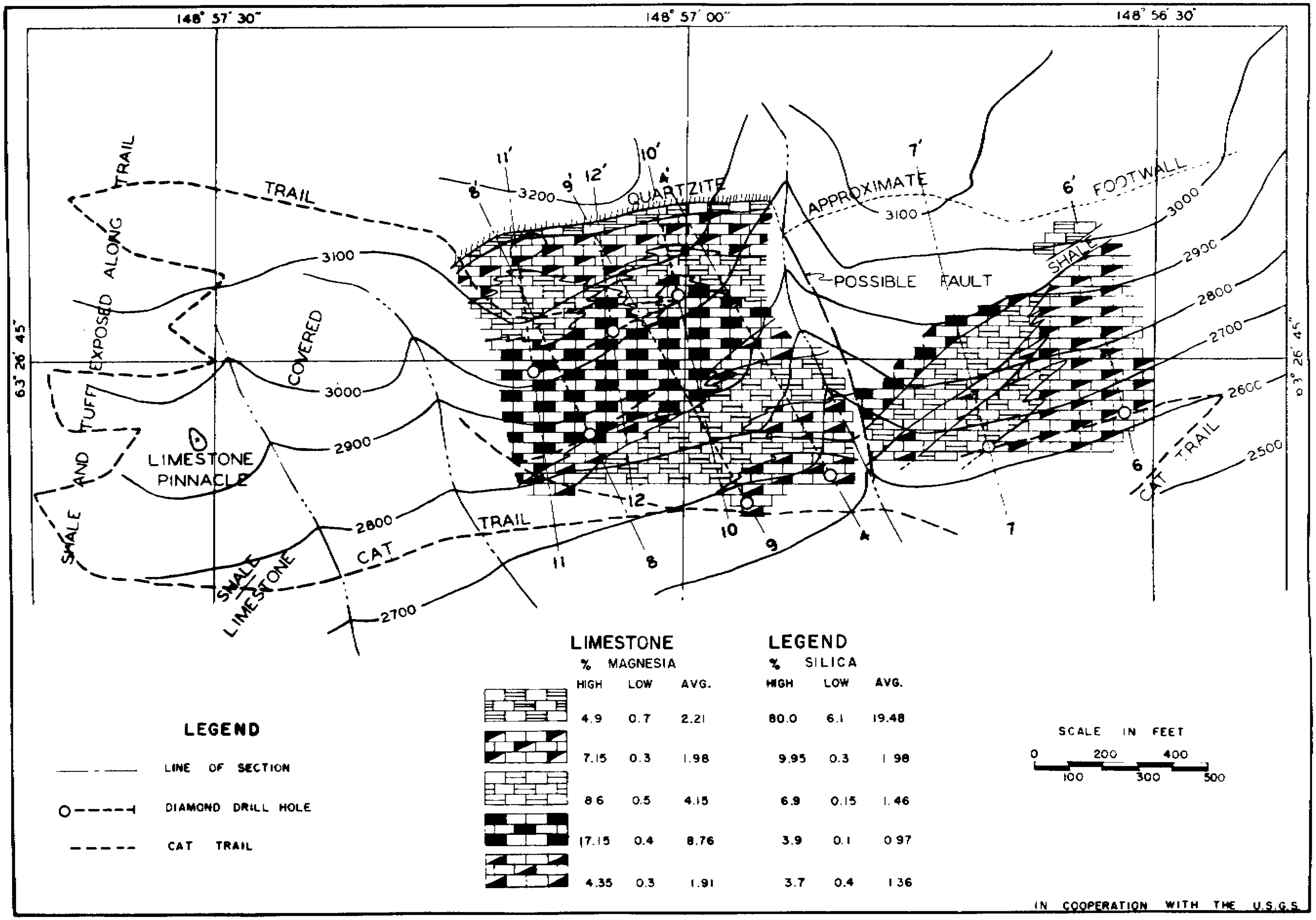
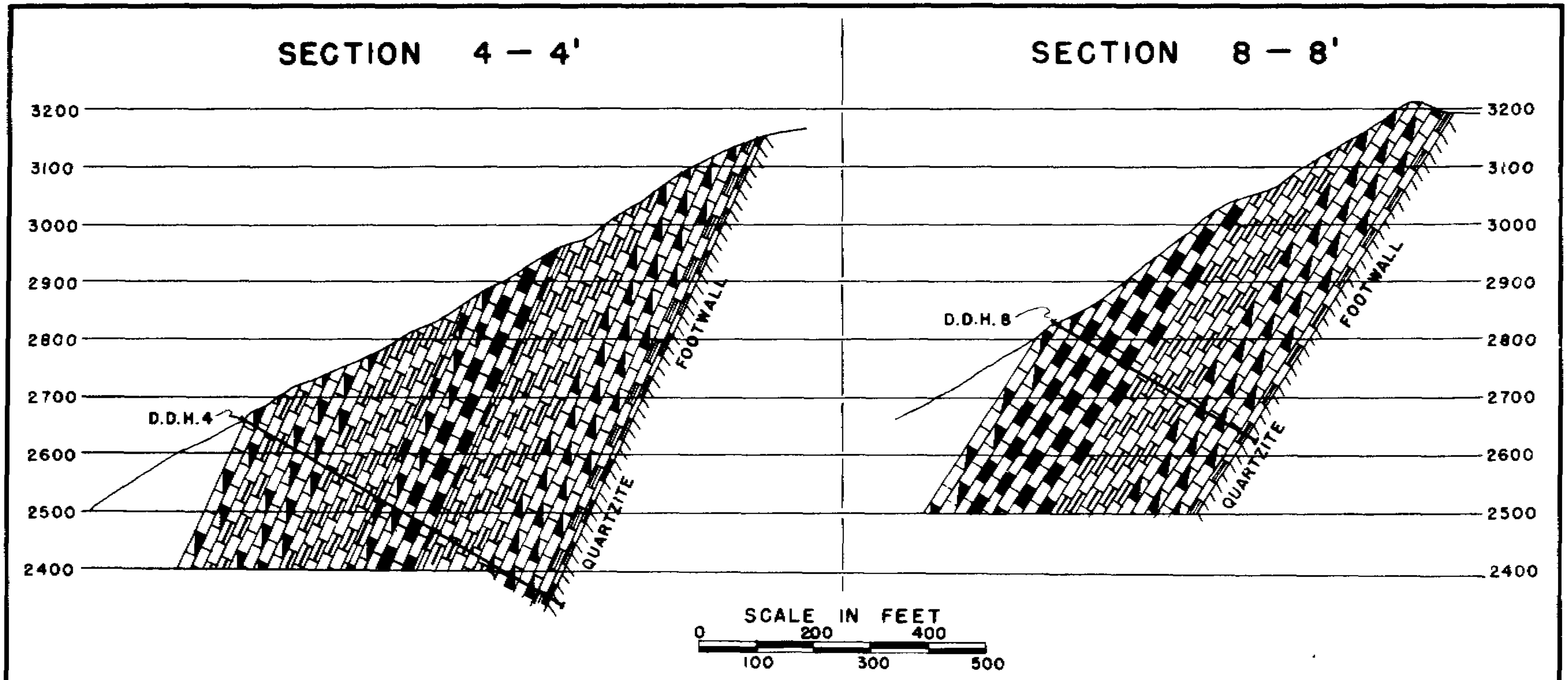
[76] Dr. Robert Fellow, Geological Survey.



LIMESTONE LEGEND

	% MAGNESIA			% SILICA		
	HIGH	LOW	AVG.	HIGH	LOW	AVG.
▤	4.9	0.7	2.21	80.0	6.1	19.48
◩	7.15	0.3	1.98	9.95	0.3	1 98
▦	8 6	0.5	4.15	6.9	0.15	1.46
■	17.15	0.4	8.76	3.9	0.1	0 97
◪	4.35	0.3	1.91	3.7	0.4	1 36

Figure 36. - Geologic map of Windy Creek limestone.

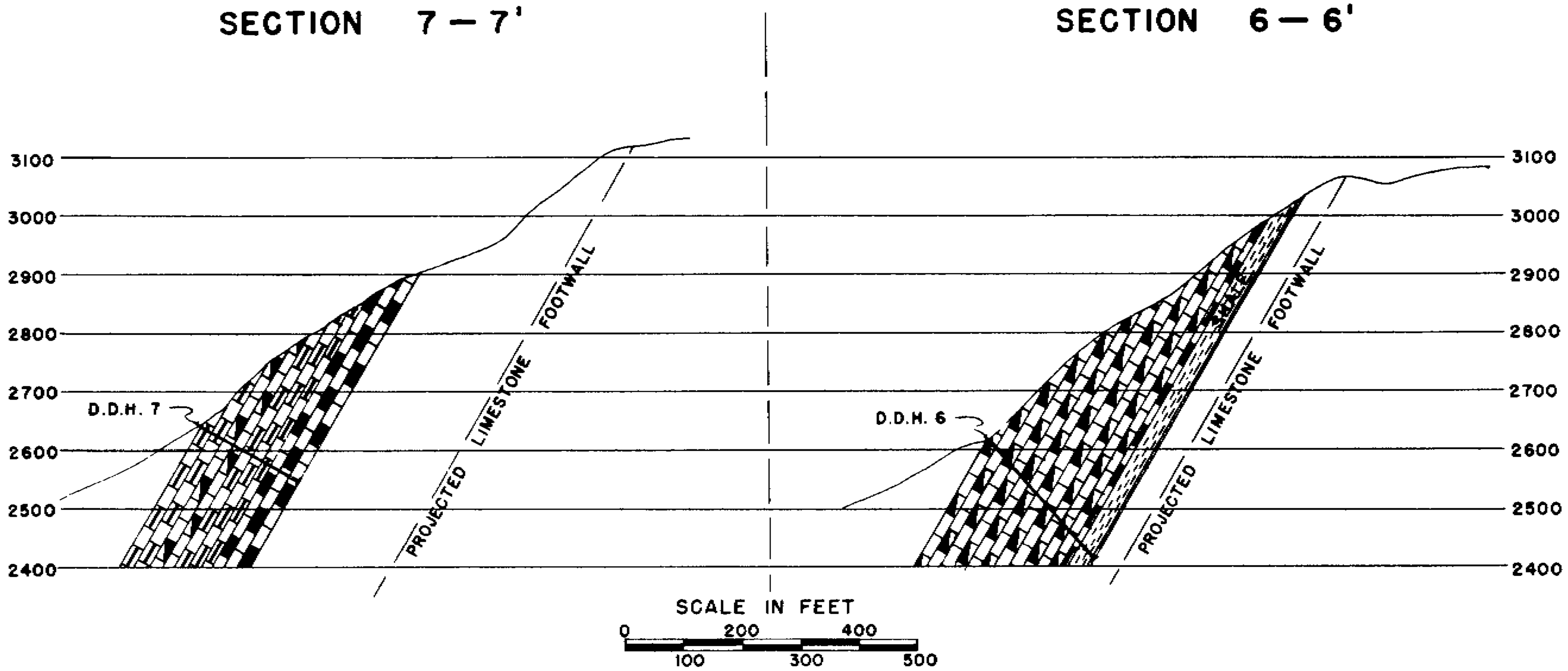


LIMESTONE LEGEND

	% MAGNESIA			% SILICA			% MAGNESIA			% SILICA		
	HIGH	LOW	AVG.	HIGH	LOW	AVG.	HIGH	LOW	AVG.	HIGH	LOW	AVG.
▤	1.9	1.05	1.61	61.3	6.1	16.16	3.1	1.5	2.53	28.7	21.55	24.25
◩	4.25	0.15	2.02	5.2	0.8	2.84	3.8	0.7	2.14	7.5	2.15	3.95
▦	7.95	0.95	4.40	6.9	0.35	1.61	5.7	2.4	4.16	3.25	0.15	1.15
■	16.3	1.6	10.02	1.7	0.15	0.56	17.1	5.6	10.02	0.85	0.1	0.44
◪	4.35	0.3	2.11	2.5	0.4	1.20	3.6	0.4	1.5	2.35	0.45	1.46

MARCH, 1950

Figure 37. - Geologic sections, Windy Creek limestone.

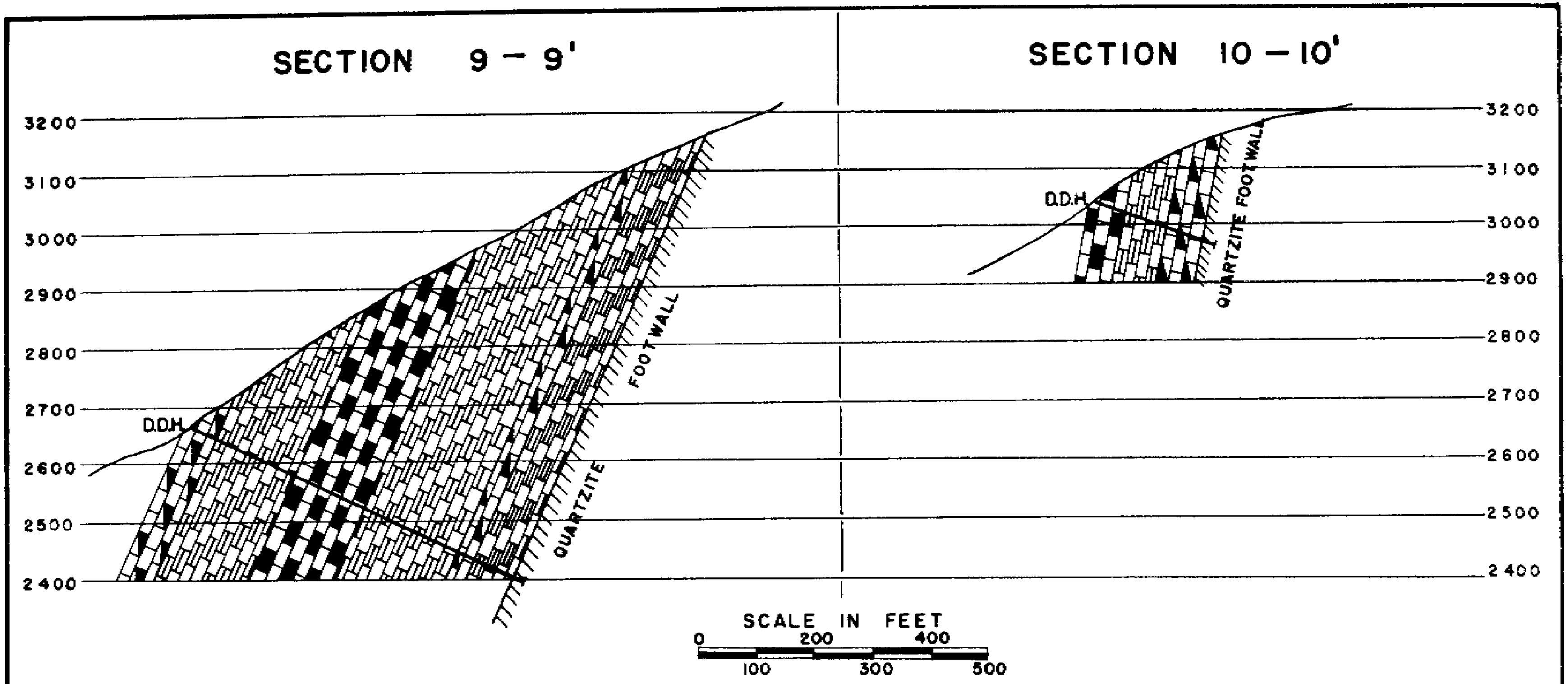


LIMESTONE LEGEND

	% MAGNESIA			% SILICA			% MAGNESIA			% SILICA		
	HIGH	LOW	AVG.	HIGH	LOW	AVG.	HIGH	LOW	AVG.	HIGH	LOW	AVG.
◩							7.15	0.85	2.12	9.95	0.35	3.26
▤	7.85	1.6	4.21	1.5	0.3	1.12						
■	8.45	3.0	5.94	2.0	0.6	1.1						
◪	2.45	0.7	1.56	3.2	1.0	1.70						
▦							4.5	1.3	2.9	13.8	10.4	12.1

MARCH, 1950

Figure 38. - Geologic sections, Windy Creek limestone.



LIMESTONE LEGEND

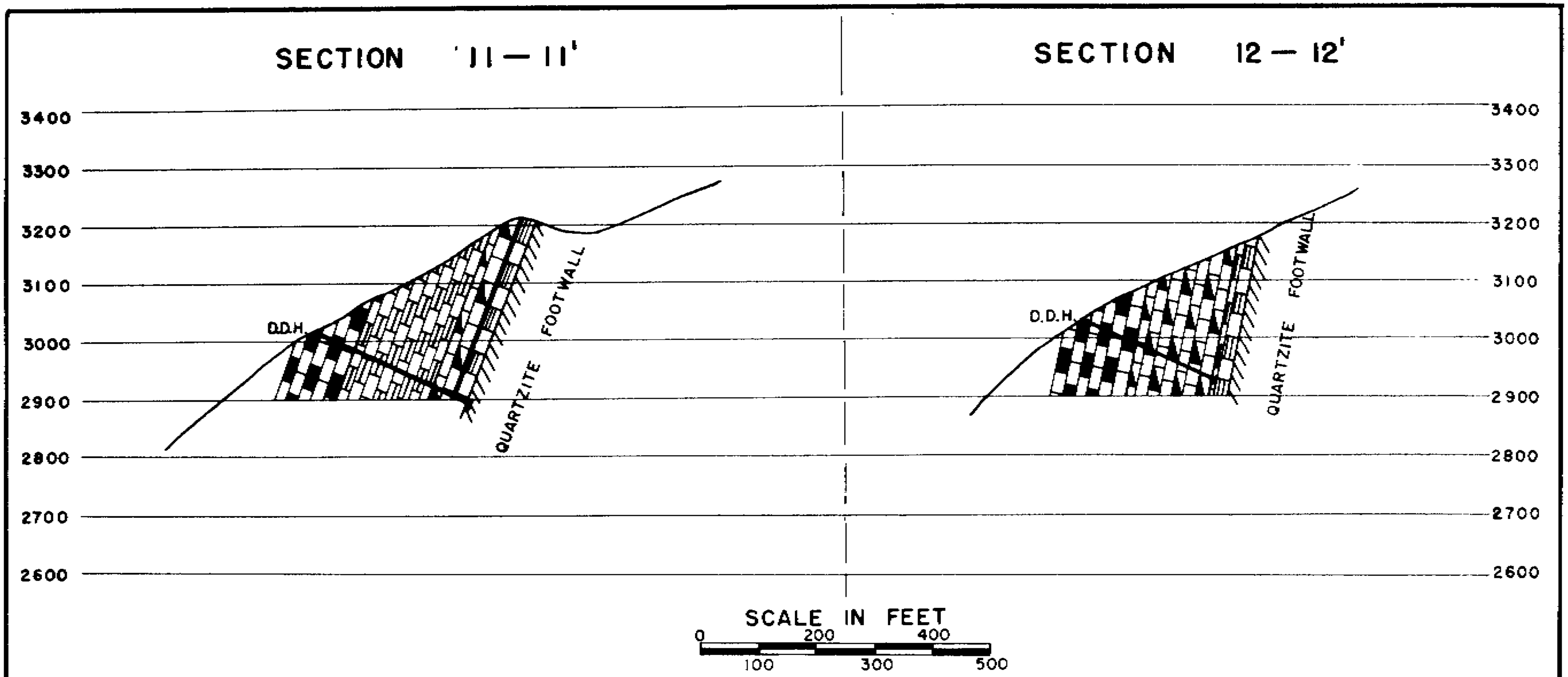
	% MAGNESIA			% SILICA		
	HIGH	LOW	AVG.	HIGH	LOW	AVG.
▤	4.9	0. 7	2.27	80.0	6.2	45.17
◩	5.3	0. 7	2.06	9.5	3.2	4.49
▦	7.0	0.5	3.68	5.5	0.5	1.74
■	13.9	0.4	6.73	3.0	0.4	1.07
◪	3.2	0.3	1.91	3.7	0.6	1.52

LIMESTONE LEGEND

% MAGNESIA			% SILICA		
HIGH	LOW	AVG.	HIGH	LOW	AVG.
3.0	0.7	1.75	6.3	0.3	3.89
5.9	2.8	4.39	6.2	0.4	2.39
9.7	6.2	8.37	2.2	0.6	1.15

MAY 1951

Figure 39. - Geologic sections, Windy Creek limestone.



	LIMESTONE LEGEND						LIMESTONE LEGEND					
	% MAGNESIA			% SILICA			% MAGNESIA			% SILICA		
	HIGH	LOW	AVG.	HIGH	LOW	AVG.	HIGH	LOW	AVG.	HIGH	LOW	AVG.
▤	1.3	0.5	0.90	29.0	13.9	19.30						
◩	4.4	0.3	1.14	5.3	0.6	3.38	5.5	0.3	1.64	5.4	0.6	2.17
▦	8.6	1.8	4.67	5.1	0.4	1.42						
▩	11.2	4.1	8.11	3.9	0.4	1.54	10.4	6.7	8.96	3.1	0.3	0.8
◪												

MAY 1951

Figure 40. - Geologic sections, Windy Creek limestone.

silica content increased and became more erratic than the magnesia content. The position of this hole near the eastern end of the exposed limestone and the fact that a carbonaceous shale was penetrated from a depth of 235 feet to 263 feet suggest that the limestone beds are grading into shale east of this hole.

Figures 37, 38, 39, and 40 are diagrammatical sections through the diamond-drill holes. Surface exposures are too limited to allow correlation of surface samples with those of the drill holes; consequently, the average analyses indicated by the drill-hole samples have been projected to the surface on all drill sections. In preparing the geologic map (fig. 36), the most weight was given to the analyses projected from the upper drill holes.

The limestones shown by symbols in the drill sections (figs. 37, 38, 39, and 40) and on the geologic map (fig. 36) have been classified on the basis of their content of magnesia and silica into the following five general classes:

1. Low magnesia-high silica.
2. Low magnesia-low silica (footwall section).
3. Medium magnesia-low silica.
4. High magnesia-low silica.
5. Low magnesia-low silica.

Geologic logs of all diamond-drill holes are given in table 44. A comparison of the geologic logs and the analyses of core samples, table 45, demonstrates that no visual differentiation can be made between limestones of different magnesia content.

The results of the exploratory drilling to date have shown that the chemical variations in this limestone deposit are very great and that grades change at very short intervals.

TABLE 44. - Geologic logs of diamond-drill holes, Windy limestone deposit

Log of Bureau of Mines diamond-drill holes
(Logged by W. S. Twenhofel, Federal Geological Survey)

Drill hole 1:	Bearing N. 17° W., inclination horizontal, total depth 35 feet. No drill cores available.
Drill hole 2:	Bearing N. 25° W., inclination horizontal, total depth 75 feet. No drill cores available.
Drill hole 3: 0-63 T.D.	Brecciated, fine-grained, black limestone with a few white calcite veinlets. Bearing N. 25° W., inclination -30°.
Drill hole 4:	Bearing N. 30° W., inclination -31°.

Footage		
0 - 55	Black, brecciated, fine-grained, crystalline limestone cut by a network of white, coarsely crystalline, calcite veinlets about 1/8 to 1/4 inch wide. No orientation of veinlets. Some brownish clay-like material that probably represents insoluble residue from leaching of limestone.	
55 - 320	Dense, fine-grained, unbrecciated, black limestone with only a very few calcite veinlets. No calcite veinlets present because limestone is not brecciated. Brown shaly partings from 270 to 277 feet.	
350 - 355	Massive, unbrecciated, gray limestone.	
355 - 408	Brecciated, gray limestone cut by white calcite veinlets. Veinlets comprise 5-10 percent of rock. A few zones with brownish, claylike residue.	
408 - 490	Fine-grained, black limestone with a few gray shale partings. A very few white calcite veinlets and a few zones of brownish, claylike residue in limestone.	
490 - 510	Brecciated, blue-gray limestone cut by white calcite stringers.	
510 - 546	Unbrecciated, black, fine-grained limestone.	
546 - 547	Pure-white, crystalline limestone.	
547 - 605	Unbrecciated, black, fine-grained limestone, with a very few white calcite stringers. Shale partings perpendicular to direction of drill core. These may represent bedding.	
605 - 610	Fine-grained, sandy, gray limestone.	
610 - 615	Fine-grained black limestone.	
615 - 629	Brecciated, fine-grained, black limestone cut by white calcite stringers.	
629 - 640	Schistose green tuff. Schistosity perpendicular to core. Miscroscopic examination of this material by Harold L. Gibbs, Metallurgical Division of the Bureau of Mines at Salt Lake City shows it to be two-thirds quartz and one-third calcite, interspersed with fine sericite mica and a few scattered cubes of pyrite. Part of calcite occurs as bands crossing the sample, and part is intergrown with quartz.	
640 - 645	Schistose purple tuff)	) Cut by seams of calcite and quartz.
645 - 648	Schistose green tuff)	
648 - 650	Schistose purple tuff)	
650 - 658	Schistose green tuff)	

Drill hole 6: Bearing N. 15° W., inclination -48°.

Footage	
0 - 3	Brecciated, fine-grained, blue-gray limestone.
3 - 110	Brecciated, fine-grained, black limestone, cut by white calcite veinlets comprising about 5 percent of the rock. Prominent brownish, claylike residue from 20 to 25 feet.
110 - 139	Same as above, with much brownish, claylike residue.
139 - 140	Black slaty limestone, with cleavage parallel to the drill core.
140 - 165	Brecciated, fine-grained, black limestone.
165 - 168	Unbrecciated, fine-grained, gray limestone.
168 - 235	Brecciated, fine-grained, black limestone, with a crude schistosity parallel to the drill core.
235 - 264	Black shale. Very soft; recovery consists of only fine, black-shale fragments.
264 - 265	Brecciated, black limestone, with shale partings perpendicular to the drill core.

Drill hole 7: Bearing N. 15° W., inclination -30°.

Footage	
0 - 52.5	Brecciated, fine-grained, black limestone cut by white calcite veinlets less than 1/4 inch wide. Calcite veinlets comprise 5-10 percent of core.
52.5- 55	Pure-white, crystalline limestone.
55 - 81	Brecciated, fine-grained, blue-gray limestone, cut by white calcite veinlets.
81 - 100	Unbrecciated, fine-grained, blue-gray limestone.
100 - 110	Brecciated, fine-grained, black limestone, cut by a few veinlets of white calcite.
110 - 115	Brecciated, fine-grained, blue-gray limestone, with a few bands of white limestone.
115 - 140	Unbrecciated, fine-grained, black limestone.
140 - 150	Brecciated, fine-grained, blue-gray limestone, with about 5 percent white calcite veinlets.
150 - 200	Brecciated, fine-grained, black limestone cut by white calcite veinlets.

Drill hole 8: Bearing N. 25° W., inclination -30°.

Footage	
0 - 38	Brecciated, fine-grained, blue-gray limestone cut by irregular white calcite veinlets less than 1/4 inch wide. A few zones of claylike residue in the limestone.
38 - 77	Black, fine-grained, unbrecciated limestone with a very few veinlets of white calcite.
77 - 165	Brecciated, fine-grained, blue-gray limestone with brownish, claylike residue along fractures. White calcite veinlets comprise about 10 percent of core.
165 - 318	Unbrecciated, fine-grained, black limestone, with a very few calcite stringers. A few shale partings perpendicular to the core.
318 - 395	Unbrecciated, fine-grained, very black limestone, with a few white-calcite stringers. Well-developed shale partings perpendicular to the core.
395 - 416	Purple and green schistose chloritic tuff.

(Logged by J. J. Mulligan, Bureau of Mines)

Drill hole 9: Bearing N. 30° W., inclination -25°, total depth 635 feet.

Footage	
0 - 114	Brecciated, fine-grained, dark-gray limestone, with numerous unoriented veinlets filled with coarsely crystaline calcite. Veinlets vary in size from almost invisible up to 1/4 inch across. Entire mass is broken by numerous fractures, with no discoverable orientation. A brownish, claylike material is present along most fracture surfaces. This is probably a product of the decomposition of limestone above.
114 - 188	Brecciated fine-grained black limestone. Calcite veinlets are present but not quite as numerous. Grayish-brown, claylike material is present along fracture surfaces.
188 - 204	Brecciated, dark-gray, fine-grained limestone, with calcite veinlets very numerous. Calcite makes up about 10 percent of total volume. The yellowish-brown, claylike material is present only at irregular intervals.
204 - 211	Dark-gray, brecciated, fine-grained limestone with a few calcite veinlets. A small amount of brownish, claylike material occurs along fracture surfaces.

Footage	
211 - 228	Gray limestone, brecciated and cut by a few calcite veinlets. The limestone shows evidence of weathering and in places is stained yellowish brown. A small amount of gray-brown shale is present also.
228 - 470	Medium- to dark-gray limestone cut by an irregular and unoriented network of calcite veinlets. Calcite makes about 5 percent or less of the total volume. Veinlets range from almost invisible to 1/4 inch across. Some yellowish-brown stain occurs along fracture surfaces.
470 - 493	Dark-gray to black limestone, brecciated but well-cemented with calcite vein fillings. Calcite forms about 20 percent of total volume.
493 - 495	Coarsely granular, white limestone.
495 - 530	Well-consolidated, dark-gray, brecciated limestone. Calcite veinlets are numerous but small. There are a few small partings of limy shale.
530 - 552	Gray brecciated limestone, with some calcite veinlets and some brownish, claylike material along fractures.
552 - 555	Fine-grained, gray sandstone.
555 - 568	Dark-gray limestone, with a moderate number of irregular calcite veinlets.
568 - 570	Fine-grained gray quartzite.
570 - 590	Black silicified limestone.
590 - 603	Black shale interspersed with silicified, black limestone.
603 - 615	Black shale.
615 - 623	Light-gray limestone.
623 - 625	Gray, silicified consolidated tuff.
625 - 628	Green, silicified consolidated tuff.
628 - 630	Purple, silicified consolidated tuff.
630 - 635	Gray-green and purple silicified tuff.

Drill hole 10; Bearing N. 13° W., inclination -20°, total depth 219 feet.

Footage	
0 - 58	Fine-grained, brecciated, black limestone, with numerous unoriented veinlets of coarsely crystaline calcite. Veinlets vary in width from almost invisible to 1/4 inch across. Numerous fractures, also unoriented, occur at irregular intervals. Some yellow-brown, earthy material is found on most fracture surfaces.
58 - 60	Limestone as above but cut by some highly siliceous, irregular bands.
60 - 61	Yellow-brown, plastic, earthy gouge, probably a residue from decomposition of limestone.
61 - 97	Black limestone, brecciated and fractured similar in all respects to that occuring from 0 - 58 feet.
97 - 119	Dark-gray limestone, with a slightly larger number of calcite-filled veinlets.
119 - 196	Brecciated black limestone similar to that found between 0 and 58 feet, but (although calcite veinlets are no more numerous) broken by more numerous fractures along which yellow-brown, earthy material occurs. There are a few scattered narrow shale partings below 180 feet. These are approximately perpendicular to the drill hole.
196 - 199	Black, silicified limestone intermixed with sandstone.
199 - 208	Poorly consolidated shales and sandstones, from which little core can be recovered.
208 - 219	Poorly consolidated shales and sandstone, with nodular quartz inclusions.

Drill hole 11; Bearing N. 8° W., inclination -25°, total depth 295 feet.

Footage	
0 - 228	Black, fine-grained, brecciated limestone, cut by numerous small veinlets of coarsely crystaline calcite. Veinlets show no orientation, are irregular in shape, and vary from hairline to about 1/4 inch across. Entire mass is cut by numerous unoriented and irregular fractures. These fractures usually contain a yellowish-brown, earthy deposit. Near the surface a few fractures show the surfaces encrusted with nodules of calcite.

Footage	
228 - 240	Black limestone as described above, but with more evidences of weathering and with a large amount of yellow-brown, earthy residue deposited in cracks.
240 - 270	Black, fine-grained limestone showing laminations perpendicular to the drill hole. Very little calcite present.
270 - 284	Black, fine-grained limestone, with irregular laminations perpendicular to the drill hole. Little calcite is present, but there is considerable evidence of weathering.
284 - 295	Siliceous, green, consolidated tuff cut by veins and nodules of quartz.

Drill hole 12: Bearing N. 8° W., inclination -25°, total depth 250 feet.

Footage	
0 - 141.5	Dark-gray, fine-grained, brecciated limestone, with numerous small, irregular, unoriented veinlets of coarsely crystaline calcite. Veinlets vary in thickness from hairline to about 1/4 inch across. The mass is broken by numerous unoriented fractures filled with an earthy, yellow-brown deposit.
141.5 - 173.0	Black, fine-grained, brecciated limestone, with a large amount of calcite in unoriented veinlets and numerous fractures filled with a yellow-brown, earthy deposit.
173.0 - 173.5	Large seam, filled with brownish-yellow, plastic, claylike material.
173.5 - 195.0	Dark-gray, brecciated, fine-grained limestone, with fewer calcite veinlets and more-numerous unoriented fractures filled with an earthy, yellow-brown deposit.
195.0 - 245.0	Black, fine-grained limestone, showing less brecciation and little calcite. Between 195.0 and 205.0 the core tends to break into wafers perpendicular to the drill hole. Limestone has a brownish, weathered appearance near the shale contact.
245.0 - 250.0	Black shale.

TABLE 45. - Analysis of diamond-drill cores, Windy limestone deposit

Footage								
From -	To-	Interval	CaO, percent	MgO, percent	SiO_2, percent	Al_2O_3, percent	Fe_2O_3, percent	SO_3, percent
				Drill hole 1				
0	5	5	51.9	2.10	1.9	0.58	0.34	0.01
5	10	5	51.6	2.45	1.5	.49	.21	.01
10	15	5	52.9	1.50	.9	.36	.14	.01
15	20	5	53.9	0.80	1.0	.49	.11	.01
20	25	5	51.2	2.50	1.8	.79	.29	.01
25	30	5	52.0	2.35	1.0	.50	.24	.01
30	35	5	49.7	4.55	.8	.51	.25	.01
				Drill Hole 2				
0	5	5	52.5	1.80	1.3	.63	.21	.01
5	10	5	51.3	3.00	1.2	.65	.19	.01
10	15	5	50.0	3.95	1.1	.67	.29	.01
15	20	5	53.4	1.30	.7	.49	.15	.01
20	25	5	52.0	2.40	1.0	.55	.17	.01
25	30	5	53.3	1.25	.9	.53	.17	.01
30	35	5	51.3	3.10	.7	.56	.20	.01
35	40	5	48.8	4.85	1.1	.78	.30	.01
40	45	5	50.5	3.60	1.1	.53	.23	.01
45	50	5	49.3	4.65	1.3	.57	.29	.01
50	55	5	49.4	4.30	1.6	.93	.23	.01
55	60	5	49.6	4.15	1.1	.96	.20	.01
60	65	5	52.2	2.25	1.1	.28	.16	.01
65	70	5	50.7	3.60	.6	1.01	.19	.01
70	75	5	-	-	-	-	-	-
				Drill hole 3				
0	5	5	50.5	3.15	2.2	.79	.29	.01
5	10	5	53.0	1.00	1.8	.47	.17	.01
10	15	5	52.7	1.60	1.0	.56	.24	.01
15	20	5	52.8	1.75	.9	.51	.21	.01
20	25	5	53.15	2.05	1.1	.9	.24	.02
25	30	5	55.3	.45	.5	.45	.14	.01
30	35	5	54.5	.85	1.1	.65	.21	.01
35	40	5	51.15	3.9	.8	.65	.21	.03
40	50	10	51.35	3.85	.8	.6	.21	.05
50	55	5	46.15	7.5	1.4	.9	.36	.01
55	60	5	50.2	4.5	.9	.8	.34	.01

Drill hole 4

Footage		Inter-val	CaO percent	MgO percent	SiO_2 percent	Al_2O_3 percent	Fe_2O_3 percent	SO_3 percent	Na_2O percent	K_2O percent
From-	To-									
0	5	5	49.6	4.05	2.4	1.35	0.37	0.01	1/0.01	1/0.01
5	10	5	53.3	1.0	2.5	.9	.18	.01	-	-
10	15	5	53.2	.9	1.7	.75	.18	.01	-	-
15	20	5	53.8	1.15	.6	.55	.20	.01	-	-
20	25	5	55.0	.6	1.0	.55	.13	.01	-	-
25	30	5	55.4	.35	.3	.6	.11	.01	-	-
30	35	5	55.4	.45	.7	.55	.11	.01	-	-
35	40	5	54.5	.6	.7	.65	.16	.01	-	-
40	45	5	52.1	3.15	.4	.65	.23	.02	-	-
45	50	5	52.4	3.15	.45	.55	.21	.01	-	-
50	55	5	50.5	4.15	.75	.65	.36	.01	-	-
55	60	5	49.6	5.15	.95	.75	.36	.01	-	-
60	65	5	51.7	3.25	.95	.60	.20	.01	-	-
65	70	5	54.2	.95	.5	.65	.16	.01	-	-
70	75	5	51.5	3.3	.6	.95	.25	.01	-	-
75	80	5	49.1	5.55	.95	1.2	.56	.01	-	-
80	85	5	54.4	.45	.6	.9	.20	.01	-	-
85	90	5	54.6	.55	.45	.75	.16	.01	-	-
90	95	5	53.45	2.0	1.2	.8	.27	.005	-	-
95	100	5	54.6	.85	.8	.7	.11	.005	-	-
100	105	5	51.35	3.65	.85	.85	.32	.005	-	-
105	110	5	53.35	2.0	.65	.75	.23	.005	-	-
110	115	5	53.45	1.75	.8	.85	.21	.005	-	-
115	120	5	51.15	3.6	.6	.85	.28	.005	-	-
120	125	5	53.25	2.2	.65	.65	.27	.005	-	-
125	130	5	49.4	4.35	1.75	1.05	.30	.005	-	-
130	135	5	51.85	2.95	1.2	.95	.25	.005	-	-
135	140	5	50.55	3.25	1.6	1.05	.41	.005	-	-
140	145	5	49.2	4.05	2.2	1.55	.23	.005	-	-
145	150	5	50.95	3.15	1.65	1.25	.35	.005	-	-
150	155	5	50.65	3.5	2.45	.75	.18	.005	-	-
155	160	5	51.95	2.05	2.4	.65	.15	.005	-	-
160	165	5	52.35	2.7	.95	.75	.18	.005	-	-
165	170	5	50.35	4.55	.8	.9	.25	.005	-	-
170	175	5	50.0	4.75	1.0	1.1	.35	.005	-	-
175	180	5	51.95	2.8	.9	.6	.20	.005	-	-
180	185	5	51.45	3.0	1.45	1.05	.30	.005	-	-
185	190	5	49.5	5.0	1.3	1.1	.39	.01	-	-
190	195	5	51.7	3.7	1.1	.65	.33	.01	-	-
195	200	5	48.4	5.55	1.8	1.1	.39	.01	-	-
200	205	5	45.0	7.95	2.25	1.4	.57	.01	-	-
205	210	5	53.3	1.3	2.15	.55	.19	.01	-	-
210	215	5	53.5	1.65	1.45	.7	.20	.01	-	-
215	220	5	51.5	2.7	1.7	1.0	.29	.01	-	-
220	225	5	49.4	3.4	3.85	1.2	.27	.01	-	-
225	230	5	48.4	3.65	4.95	.9	.21	.01	-	-
230	235	5	47.7	5.8	2.00	1.2	.37	.01	-	-

1/ Composite

Drill hole 4 (Cont.)

Footage		Inter-val	CaO percent	MgO percent	SiO_2 percent	Al_2O_3 percent	Fe_2O_3 percent	SO_2 percent	Na_2O percent	K_2O percent
From-	To-									
235	240	5	46.6	6.45	2.3	1.45	0.43	.01	-	-
240	245	5	48.8	4.45	2.7	1.15	.36	.01	-	-
245	250	5	51.5	2.75	2.2	.6	.13	.01	-	-
250	255	5	49.7	4.05	2.25	1.0	.31	.01	-	-
255	260	5	48.9	4.95	1.75	1.35	.21	.01	-	-
260	265	5	50.9	3.65	1.45	.8	.34	.01	-	-
265	270	5	49.3	4.45	1.95	.8	.30	.01	-	-
270	275	5	42.4	5.85	6.9	3.1	1.13	.01	-	-
275	280	5	51.4	1.4	3.7	1.35	.36	.01	-	-
280	285	5	51.3	3.7	.9	.6	.24	.01	-	-
285	290	5	47.1	5.3	3.9	1.05	.37	.01	-	-
290	295	5	48.8	3.55	4.35	.95	.31	.01	-	-
295	300	5	51.1	2.35	3.15	.9	1.33	.01	-	-
300	305	5	53.5	.35	2.95	.9	.20	.01	-	-
305	310	5	53.2	.3	3.25	1.1	.17	.01	-	-
310	315	5	50.9	2.15	2.55	1.15	.49	.01	-	-
315	320	5	53.0	1.7	1.25	1.0	.29	.01	-	-
320	325	5	46.9	7.15	1.7	.75	.37	.01	-	-
325	330	5	55.8	1.6	.6	.55	.20	.01	-	-
330	335	5	42.2	11.75	.6	.5	.36	.01	-	-
335	340	5	39.9	13.35	.4	.65	.40	.01	-	-
340	345	5	41.0	12.65	.5	.95	.36	.01	-	-
345	350	5	43.7	16.3	.45	.8	.34	.01	-	-
350	355	5	42.7	11.2	.3	.5	.37	.01	-	-
355	360	5	47.9	5.85	.15	.65	.31	.01	-	-
360	365	5	45.7	8.05	.6	.95	.37	.01	-	-
365	370	5	48.4	8.2	.35	.6	.34	.01	-	-
370	375	5	44.4	8.1	.3	.5	.29	.01	-	-
375	380	5	44.7	7.4	.3	.65	.36	.01	-	-
380	385	5	43.3	8.6	.5	.7	.56	.01	-	-
385	390	5	47.1	6.8	.75	.95	.49	.01	-	-
390	400	10	49.1	6.25	.35	.65	.29	.01	-	-
400	405	5	48.2	6.1	.5	.85	.40	.01	-	-
405	410	5	48.6	5.7	.6	1.05	.43	.01	-	-
410	415	5	47.3	7.1	.4	.75	.44	.01	-	-
415	420	5	48.5	5.35	1.0	1.35	.43	.01	-	-
420	425	5	47.5	6.35	1.1	.9	.39	.01	-	-
425	430	5	51.3	3.4	1.0	.65	.33	.01	-	-
430	435	5	50.9	3.55	1.55	.45	.26	.01	-	-
435	440	5	50.0	3.9	1.25	.65	.33	.01	-	-
440	445	5	53.9	.6	.8	.65	.31	.01	[1]0.01	[1]0.01
445	450	5	50.9	3.05	1.2	.7	.33	.01	-	-
450	455	5	51.4	3.1	.75	.5	.24	.01	-	-
455	460	5	51.5	2.6	1.8	.75	.24	.01	-	-
460	465	5	49.4	2.55	3.75	1.1	.31	.01	-	-
465	470	5	51.4	2.65	1.6	.75	.27	.01	-	-

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[1] Composite

Drill hole 4 (Cont.)

Footage		Interval	CaO percent	MgO percent	SiO_2 percent	Al_2O_3 percent	Fe_2O_3 percent	SO_3 percent	Na_2O percent	K_2O percent
From-	To-									
470	475	5	51.1	2.4	2.4	0.9	0.29	0.01	-	-
475	480	5	49.6	4.0	1.8	.9	.34	.01	-	-
480	485	5	49.1	4.25	1.85	1.05	.49	.01	-	-
485	490	5	50.2	3.55	1.8	.8	.37	.01	-	-
490	495	5	50.4	2.4	2.7	.8	.31	.01	-	-
495	500	5	46.6	5.05	3.85	1.45	.53	.01	-	-
500	505	5	49.0	.4	4.2	1.30	.53	.01	-	-
505	510	5	48.6	.45	2.6	1.35	.47	.01	-	-
510	515	5	51.5	.15	3.5	1.50	.50	.01	-	-
515	520	5	51.5	1.25	3.9	1.55	.57	.01	-	-
520	525	5	50.9	2.1	3.3	2.20	.43	.01	-	-
525	530	5	53.1	.8	2.3	.85	.36	.01	-	-
530	535	5	51.7	1.1	3.6	1.75	.37	.01	-	-
535	540	5	52.8	1.0	2.3	1.05	.33	.01	-	-
540	545	5	51.2	.9	4.1	1.75	.69	.01	-	-
545	550	5	51.4	1.3	3.7	1.40	.43	.01	-	-
550	555	5	51.6	1.65	3.0	1.10	.37	.01	-	-
555	560	5	50.8	1.5	3.6	1.65	.51	.01	-	-
560	565	5	51.2	2.2	2.9	1.40	.44	.01	-	-
565	570	5	52.1	1.5	2.6	1.25	.40	.01	-	-
570	575	5	51.9	1.35	3.2	1.25	.41	.02	-	-
575	580	5	51.3	1.4	3.3	1.55	.61	.01	-	-
580	585	5	48.3	2.2	5.2	2.65	.77	.01	-	-
585	590	5	50.3	2.45	3.1	1.35	.03	.01	-	-
590	595	5	50.2	2.6	3.3	1.40	.49	.01	-	-
595	600	5	46.5	3.45	6.1	2.65	1.43	.01	-	-
600	605	5	47.8	1.9	6.4	2.65	.86	.01	-	-
605	610	5	15.4	1.05	61.3	4.30	2.10	.01	-	-
610	615	5	44.2	1.5	12.2	3.15	1.75	.01	-	-
615	620	5	49.0	1.05	6.9	2.30	.80	.01	-	-
620	629	9	46.5	1.15	10.1	2.35	1.16	.01	-	-
629	640	11	Footwall, green guartzite							
640	658	18	do.							

Drill hole 6

Footage		Interval	CaO percent	MgO percent	SiO_2 percent	Al_2O_3 percent	Fe_2O_3 percent	SO_3 percent	Na_2O percent	K_2O percent
0	5	5	54.8	1.2	.35	.5	.15	.005	[1] 0.01	[1] 0.01
5	10	5	52.35	3.05	.7	.85	.21	.005	-	-
10	15	5	51.55	3.5	.45	.8	.25	.005	-	-
15	20	5	51.95	3.0	.8	.9	.28	.005	-	-
20	25	5	45.05	7.15	2.7	1.5	.61	.005	-	-
25	30	5	47.1	1.1	9.95	3.15	.61	.005	-	-
30	35	5	51.25	3.4	1.7	1.15	.23	.005	-	-
35	40	5	50.85	2.15	3.45	1.7	.44	.005	-	-
40	45	5	53.15	1.25	1.45	1.7	.35	.005	-	-
45	50	5	52.65	2.0	1.4	1.1	.28	.005	-	-
50	55	5	50.0	2.6	2.8	1.25	.43	.01	-	-

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[1] Composite

Drill hole 6 (Cont.)

Footage		Inter- val	CaO percent	MgO percent	SiO_2 percent	Al_2O_3 percent	Fe_2O_3 percent	SO_3 percent	Na_2O percent	K_2O percent
From-	To-									
55	60	5	52.0	0.95	2.1	0.95	0.36	0.01	-	-
60	65	5	46.9	3.4	5.2	1.1	.31	.01	-	-
65	70	5	50.1	2.0	2.95	1.1	.26	.01	-	-
70	75	5	50.3	3.2	1.15	1.3	.26	.01	-	-
75	80	5	52.0	1.95	1.75	1.05	.20	.01	-	-
80	85	5	49.6	3.1	2.1	1.05	.17	.01	-	-
85	90	5	47.2	4.45	4.1	1.35	.29	.01	-	-
90	95	5	49.2	2.9	3.85	1.0	.24	.01	-	-
95	100	5	49.7	3.45	1.7	1.15	.24	.01	-	-
100	105	5	49.5	2.75	2.8	1.55	.34	.01	-	-
105	110	5	51.3	2.0	1.4	1.25	.33	.01	-	-
110	115	5	48.2	1.65	5.35	2.5	.57	.01	-	-
115	120	5	52.0	1.35	3.75	3.1	.72	.01	-	-
120	125	5	43.3	2.85	7.2	3.3	.80	.01	-	-
125	130	5	47.5	2.1	5.1	3.15	.80	.01	-	-
130	135	5	48.2	2.45	4.0	3.5	.82	.01	-	-
135	140	5	48.6	1.55	5.5	3.10	.89	.01	-	-
140	145	5	51.8	1.3	2.6	1.65	.63	.01	-	-
145	150	5	51.2	1.6	3.5	1.70	.47	.01	-	-
150	155	5	52.0	1.4	2.8	1.15	.46	.01	-	-
155	160	5	51.9	1.45	2.0	1.35	.47	.01	-	-
160	165	5	52.2	1.0	2.2	1.3	-	.01	-	-
165	170	5	50.7	.85	5.4	1.6	-	.01	-	-
170	175	5	52.1	1.1	2.6	1.05	-	.01	-	-
175	180	5	52.9	.45	2.2	1.1	-	.01	-	-
180	185	5	52.5	1.05	2.6	1.0	-	.01	-	-
185	190	5	49.9	1.0	5.6	1.8	1/.20	.01	1/0.007	1/0.01
190	195	5	50.9	0.95	5.0	1.25	-	.01	-	-
195	200	5	47.1	3.5	5.2	2.25	-	.01	-	-
200	205	5	50.7	1.5	3.0	1.55	-	.01	-	-
205	210	5	49.7	1.45	4.8	1.80	-	.01	-	-
210	215	5	51.7	.9	3.2	1.25	-	.01	-	-
215	220	5	50.3	1.8	3.8	1.75	-	.01	-	-
220	225	5	49.3	1.7	4.6	2.10	-	.01	-	-
225	230	5	44.3	1.3	13.8	2.50	.85	.01	-	-
230	235	5	41.4	4.5	10.4	3.10	1.5	.01	-	-
235	250	15	2.1	1.75	74.0	6.60	3.35	.01	-	2.65
250	263	13	1.9	.45	72.0	6.40	3.95	.01	-	3.00
263	265	2	46.1	1.8	9.4	2.2	-	.01	-	-

Drill hole 7

0	5	5	49.1	4.75	2.0	.75	.44	.01	1/0.01	1/0.01
5	10	5	51.7	3.05	1.6	.65	.20	.01	-	-
10	15	5	51.0	3.9	.3	.55	.26	.01	-	-
15	20	5	49.2	5.05	1.3	.65	.21	.01	-	-
20	30	10	52.0	2.9	1.1	.5	.16	.01	-	-
30	35	5	46.2	7.85	1.1	.5	.23	.01	-	-

1/ Composite

Drill hole 7 (Cont.)

Footage From-	Footage To-	Interval	CaO percent	MgO percent	SiO_2 percent	Al_2O_3 percent	Fe_2O_3 percent	SO_3 percent	Na_2O percent	K_2O percent
35	40	5	50.4	4.5	0.4	0.4	0.14	0.01	-	-
40	45	5	47.6	6.05	1.4	.7	.49	0.01	-	-
45	50	5	46.6	6.35	2.1	1.05	.77	.01	-	-
50	55	5	52.2	1.3	2.2	.05	.34	.01	-	-
55	60	5	52.5	.7	3.2	1.25	.39	.01	-	-
60	65	5	52.9	1.1	1.9	.65	.29	.01	-	-
65	70	5	53.0	1.95	1.2	.45	.26	.01	-	-
70	75	5	53.2	1.7	1.0	.45	.21	.01	-	-
75	80	5	53.2	1.75	1.2	.55	.17	.01	-	-
80	85	5	52.0	2.45	1.2	.75	.23	.01	-	-
85	90	5	48.7	5.3	1.5	.85	.26	.01	-	-
90	95	5	50.7	3.95	.9	.7	.20	.01	-	-
95	100	5	47.6	6.25	1.4	.6	.24	.01	-	-
100	105	5	51.0	3.1	1.4	.6	.21	.01	-	-
105	110	5	48.5	5.55	1.1	.7	.34	.01	-	-
110	115	5	50.3	3.9	1.5	.65	.26	.01	-	-
115	120	5	51.2	3.9	.5	.5	.16	.01	-	-
120	125	5	51.0	3.45	1.3	.55	.23	.01	-	-
125	130	5	51.8	3.35	.8	.45	.21	.01	-	-
130	135	5	51.2	3.45	.9	.55	.21	.01	-	-
135	140	5	52.3	3.0	1.0	.6	.19	.01	-	-
140	145	5	51.1	3.75	1.0	.60	-	.01	1/0.013	1/0.01
145	150	5	52.2	2.9	.8	.45	-	.01	-	-
150	155	5	53.9	1.6	.8	.25	-	.01	-	-
155	160	5	52.0	3.3	.6	.40	-	.01	-	-
160	165	5	48.8	6.0	.8	.55	-	.01	-	-
165	170	5	46.6	7.8	.6	.40	1/.55	.01	-	-
170	175	5	48.0	6.55	.6	.35	-	.01	-	-
175	180	5	46.0	8.45	.6	.55	-	.01	-	-
180	185	5	50.7	4.4	.8	.55	-	.01	-	-
185	190	5	46.3	7.3	1.6	.60	-	.01	-	-
190	195	5	50.7	3.0	2.0	1.0	-	.01	-	-
195	200	5	50.2	4.0	1.8	.55	-	.01	-	-

Drill hole 8

Footage From-	Footage To-	Interval	CaO percent	MgO percent	SiO_2 percent	Al_2O_3 percent	Fe_2O_3 percent	SO_3 percent	Na_2O percent	K_2O percent
0	5	5	55.1	.45	.5	.45	.23	.01	1/0.01	1/0.01
5	10	5	54.6	.6	.7	.75	.15	.01	-	-
10	15	5	53.6	1.15	1.3	.55	.20	.01	-	-
15	20	5	53.0	1.4	1.7	.55	.23	.01	-	-
20	25	5	48.4	3.3	3.4	2.35	.83	.01	-	-
25	30	5	52.4	1.1	2.3	1.70	.60	.01	-	-
30	35	5	53.6	.4	1.3	1.30	.37	.01	-	-
35	40	5	51.0	3.6	.5	1.30	.28	.01	-	-
40	45	5	47.3	6.45	.6	.95	.37	.01	-	-
45	50	5	43.2	10.8	.5	.60	.34	.01	-	-
50	55	5	40.1	13.3	.3	.60	.34	.01	-	-

1/ Composite

Drill hole 8 (Cont.)

Footage		Inter-val	CaO percent	MgO percent	SiO_2 percent	Al_2O_3 percent	Fe_2O_3 percent	SO_3 percent	Na_2O percent	K_2O percent
From-	To-									
55	60	5	35.6	17.1	0.6	0.70	0.46	0.01	-	-
60	65	5	44.8	9.2	.6	.70	.34	.01	-	-
65	70	5	42.6	11.1	.5	.50	.26	.01	-	-
70	75	5	43.2	10.5	.5	.60	.31	.01	-	-
75	80	5	42.2	11.6	.1	.45	.23	.01	-	-
80	85	5	43.2	10.7	.4	.65	.28	.01	-	-
85	90	5	40.2	13.5	.1	.50	.28	.01	-	-
90	95	5	39.3	14.0	.2	.40	.28	.01	-	-
95	100	5	41.1	12.6	.4	.45	.30	.01	-	-
100	105	5	41.0	12.8	.3	.45	.40	.01	-	-
105	110	5	43.6	10.6	.3	.50	.31	.01	-	-
110	115	5	48.0	6.5	.3	.53	.35	.01	-	-
115	120	5	44.2	9.6	.2	.40	.34	.01	-	-
120	125	5	40.4	12.5	.65	.55	.48	.01	-	-
125	130	5	43.4	9.8	.25	.65	.34	.01	-	-
130	135	5	45.9	8.1	.45	.5	.45	.01	-	-
135	140	5	44.9	8.6	.65	.6	.43	.01	-	-
140	145	5	45.0	8.9	.60	.6	.42	.01	-	-
145	150	5	47.6	6.1	.85	.75	.54	.01	-	-
150	155	5	47.5	6.8	.45	.45	.33	.01	-	-
155	160	5	42.4	11.3	.40	.45	.34	.01	-	-
160	165	5	48.7	5.6	.65	.5	.28	.01	-	-
165	170	5	46.3	7.4	.70	.75	.31	.01	-	-
170	175	5	46.5	7.8	.40	.45	.31	.01	-	-
175	180	5	46.8	7.3	.40	.4	.27	.01	-	-
180	185	5	48.6	4.7	1.4	1.05	.41	.01	-	-
185	190	5	50.4	3.7	1.0	.6	.30	.01	-	-
190	195	5	49.8	3.8	2.1	.85	.31	.01	-	-
195	200	5	48.4	5.7	.85	.65	.26	.01	-	-
200	205	5	48.6	5.3	1.05	.6	.40	.01	-	-
205	210	5	51.2	2.4	.8	.7	.33	.01	-	-
210	215	5	51.2	3.2	.75	.7	.34	.01	-	-
215	220	5	50.0	5.3	.40	.5	.26	.01	-	-
220	225	5	51.6	3.8	.15	.4	.20	.01	-	-
225	230	5	50.2	4.1	1.1	.5	.23	.01	-	-
230	235	5	51.6	3.7	.3	.4	.24	.01	-	-
235	240	5	51.0	4.0	.45	.45	.20	.01	-	-
240	245	5	47.8	6.6	.6	.45	.21	.01	-	-
245	250	5	50.4	3.6	1.9	.45	.19	.01	-	-
250	255	5	51.4	3.4	.6	.75	.23	.01	-	-
255	260	5	50.0	4.5	.8	.7	.27	.01	-	-
260	265	5	50.5	3.9	1.2	.85	.38	.01	-	-
265	270	5	49.4	4.7	1.15	.95	.37	.01	-	-
270	275	5	51.1	2.8	2.15	1.00	.24	.01	-	-
275	280	5	49.0	3.9	3.25	1.05	.36	.01	-	-
280	285	5	51.0	2.6	2.9	.85	.21	.01	1/0.01	1/0.01
285	290	5	52.3	1.7	2.65	.75	.23	.01	-	-
290	295	5	50.5	2.1	3.1	1.45	.43	.01	-	-

1/ Composite

Drill hole 8 (Cont.)

Footage From-	Footage To-	Inter-val	CaO percent	MgO percent	SiO_2 percent	Al_2O_3 percent	Fe_2O_3 percent	SO_3 percent	Na_2O percent	K_2O percent
295	300	5	51.5	1.5	2.15	1.35	0.47	0.01	-	-
300	305	5	52.4	.7	2.6	1.25	.43	.01	-	-
305	310	5	52.1	.9	2.7	1.25	.43	.01	-	-
310	315	5	50.4	.9	2.5	.95	.40	.01	-	-
315	320	5	52.5	1.1	3.6	1.6	.58	.01	-	-
320	325	5	50.5	1.7	3.0	1.65	.37	.01	-	-
325	330	5	49.8	1.7	3.7	1.8	.67	.01	-	-
330	335	5	49.8	1.8	3.7	2.0	.64	.01	-	-
335	340	5	46.6	2.9	5.5	2.95	.79	.01	-	-
340	345	5	46.8	2.5	5.9	3.0	.82	.01	-	-
345	350	5	48.8	2.8	4.25	1.8	.57	.01	-	-
350	355	5	48.1	2.8	4.5	2.15	.61	.01	-	-
355	360	5	49.1	2.0	3.35	1.85	.55	.01	-	-
360	365	5	47.4	3.8	3.9	2.15	.65	.01	-	-
365	370	5	46.8	3.3	5.2	2.6	.76	.01	-	-
370	375	5	46.6	2.7	6.3	3.2	.92	.01	-	-
375	380	5	44.9	2.3	7.5	3.75	1.17	.01	-	-
380	385	5	35.7	3.0	21.55	4.35	1.85	.01	-	-
385	390	5	37.0	1.5	22.5	4.75	1.43	.01	-	-
390	395	5	29.2	3.1	28.7	6.55	2.88	.01	-	-
395	415	20	Green quartzite.							
Drill hole 9										
0.0	12.0	12.0	50.6	3.2	2.2	.9	.40	.02	-	-
12.0	13.9	1.9	55.1	.5	.8	.52	.18	.02	-	-
13.9	16.0	2.1	53.6	1.7	1.1	.36	.24	.02	-	-
16.0	20.0	4.0	54.8	.7	1.0	.37	.13	.02	-	-
20.0	26.0	6.0	55.0	.4	.7	.39	.11	.03	-	-
26.0	29.0	3.0	54.8	.3	.6	.46	.14	.05	-	-
29.0	34.0	5.0	54.4	.9	1.0	.43	.17	.05	-	-
34.0	39.0	5.0	51.2	2.0	3.7	.63	.27	.05	-	-
39.0	44.0	5.0	51.6	3.0	1.9	.44	.16	.05	-	-
44.0	47.0	3.0	53.0	2.3	.7	.40	.20	.05	-	-
47.0	54.0	7.0	52.4	2.4	1.0	.42	.18	.05	-	-
54.0	59.0	5.0	49.0	5.5	1.1	.46	.34	.05	-	-
59.0	61.0	2.0	50.8	4.1	1.1	.58	.22	.05	-	-
61.0	64.0	3.0	50.6	4.2	1.2	.38	.22	.05	-	-
64.0	69.0	5.0	53.0	2.2	1.1	.27	.13	.05	-	-
69.0	74.0	5.0	49.8	5.1	1.2	.38	.32	.05	-	-
74.0	79.0	5.0	51.4	3.9	1.1	.39	.21	.05	-	-
79.0	84.0	5.0	54.8	1.4	.5	.21	.09	.04	-	-
84.0	90.0	6.0	55.7	.5	.5	.21	.09	.03	-	-
90.0	95.0	5.0	54.8	1.3	.6	.21	.09	.03	-	-
95.0	100.0	5.0	48.0	6.7	1.0	.33	.17	.03	-	-
100.0	104.0	4.0	50.0	4.7	1.2	.33	.17	.04	-	-
104.0	109.0	5.0	50.4	3.9	2.2	.26	.14	.05	-	-
109.0	114.0	5.0	52.4	1.1	3.9	.29	.11	.06	-	-
114.0	115.0	1.0	53.2	1.2	2.7	.23	.17	.07	-	-

Drill hole 9 (Cont.)

Footage		Inter-val	CaO percent	MgO percent	SiO_2 percent	Al_2O_3 percent	Fe_2O_3 percent	SO_3 percent	Na_2O percent	K_2O percent
From-	To-									
115.0	120.0	5.0	51.7	2.3	2.2	0.50	0.20	0.08	-	-
120.0	124.0	4.0	51.2	3.2	2.0	.61	.29	.08	-	-
124.0	130.0	6.0	49.6	3.6	2.7	.86	.34	.07	-	-
130.0	134.0	4.0	47.9	5.1	2.8	.89	.31	.07	-	-
134.0	140.0	6.0	51.9	1.6	3.1	.53	.17	.06	-	-
140.0	144.0	4.0	53.0	1.2	2.7	.31	.09	.07	-	-
144.0	150.0	6.0	50.0	3.8	2.0	.67	.23	.08	-	-
150.0	154.0	4.0	49.5	4.4	1.8	.79	.31	.09	-	-
154.0	159.0	5.0	49.6	3.9	2.4	.73	.37	.11	-	-
159.0	164.0	5.0	48.8	4.1	5.5	1.16	.54	.05	-	-
164.0	169.0	5.0	50.6	2.9	2.5	.91	.29	.02	-	-
169.0	174.0	5.0	50.0	3.5	3.1	.94	.26	.02	-	-
174.0	180.0	6.0	50.2	4.2	1.4	.63	.17	.01	-	-
180.0	183.0	3.0	48.2	6.2	.8	.54	.26	.01	-	-
183.0	188.0	5.0	47.0	6.7	1.2	.67	.43	.01	-	-
188.0	194.0	6.0	51.6	2.8	1.1	.44	.26	.02	-	-
194.0	197.6	3.6	46.4	7.0	2.1	.74	.46	.02	-	-
197.6	200.0	2.4	46.6	6.5	1.9	.86	.54	.02	-	-
200.0	204.0	4.0	47.0	5.9	2.0	.91	.49	.02	-	-
204.0	206.0	2.0	45.0	8.9	1.1	.73	.37	.04	-	-
206.0	211.0	5.0	47.4	6.3	1.3	.69	.31	.05	-	-
211.0	215.0	4.0	51.0	3.0	1.4	.56	.34	.02	-	-
215.0	224.0	9.0	47.2	5.9	2.2	1.04	.46	.05	-	-
224.0	228.0	4.0	44.6	8.7	1.2	.77	.43	.03	-	-
228.0	230.0	2.0	45.4	8.5	.9	.67	.43	.01	-	-
230.0	235.0	5.0	44.6	9.8	.4	.57	.23	.02	-	-
235.0	240.0	5.0	43.8	10.6	.4	.36	.34	.04	-	-
240.0	245.0	5.0	46.0	7.9	.9	.53	.37	.02	-	-
245.0	250.0	5.0	45.8	8.3	.8	.51	.49	.02	-	-
250.0	251.6	1.6	38.8	13.9	1.1	.53	.57	.12	-	-
251.6	254.5	2.9	43.4	8.7	1.0	.48	.52	.14	-	-
254.5	260.0	5.5	42.8	10.7	.8	.54	.46	.14	-	-
260.0	265.0	5.0	43.6	10.5	.6	.44	.46	.13	-	-
265.0	266.5	1.5	46.9	7.4	.6	.41	.49	.10	-	-
266.5	270.0	3.5	45.6	8.8	.5	.41	.49	.08	-	-
270.0	273.0	3.0	46.4	8.3	.4	.50	.40	.06	-	-
273.0	280.0	7.0	47.8	6.8	.4	.33	.37	.04	-	-
280.0	285.0	5.0	43.8	10.4	.6	.37	.43	.06	-	-
285.0	290.0	5.0	50.1	5.1	.6	.31	.29	.06	-	-
290.0	295.0	5.0	53.1	2.1	.9	.48	.26	.07	-	-
295.0	300.0	5.0	47.9	6.2	1.3	.64	.66	.07	-	-
300.0	305.0	5.0	54.7	.4	1.3	.51	.29	.07	-	-
305.0	310.0	5.0	52.6	1.4	2.8	.46	.34	.07	-	-
310.0	315.0	5.0	51.6	2.3	3.0	2.20	.40	.07	-	-
315.0	320.0	5.0	54.0	1.2	2.8	.81	.49	.08	-	-
320.0	325.0	5.0	48.0	6.4	1.1	.74	.46	.08	-	-
325.0	330.0	5.0	44.6	9.8	.8	.40	.40	.08	-	-

Drill hole 9 (Cont.)

Footage		Inter-	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	SO_3	Na_2O	K_2O
From-	To-	val	percent	percent	percent	percent	percent	percent	percent	percent
330.0	335.0	5.0	49.4	5.3	0.8	0.51	0.29	0.07	-	-
335.0	340.0	5.0	49.4	4.9	.7	.26	.34	.09	-	-
340.0	345.0	5.0	47.2	7.2	.8	.41	.49	.09	-	-
345.0	350.0	5.0	47.0	7.7	.6	.39	.31	.09	-	-
350.0	355.0	5.0	47.5	6.2	1.3	.81	.49	.09	-	-
355.0	360.0	5.0	49.7	4.8	1.0	.87	.43	.08	-	-
360.0	365.0	5.0	45.2	9.0	1.1	.44	.46	.09	-	-
365.0	368.0	3.0	44.7	9.4	1.0	.64	.46	.08	-	-
368.0	375.0	7.0	48.5	6.3	.6	.69	.31	.08	-	-
375.0	380.0	5.0	46.0	8.7	.5	.34	.26	.09	-	-
380.0	385.0	5.0	45.4	7.7	.9	.63	.37	.08	-	-
385.0	390.0	5.0	50.0	4.8	1.1	.69	.31	.07	-	-
390.0	395.0	5.0	51.4	3.7	.7	.49	.31	.08	-	-
395.0	400.0	5.0	51.0	3.8	1.5	.49	.31	.08	-	-
400.0	405.0	5.0	52.2	2.5	.9	.34	.26	.08	-	-
405.0	408.0	3.0	49.4	5.6	.9	.51	.29	.09	-	-
408.0	413.0	5.0	48.4	6.2	.9	.34	.26	.09	-	-
413.0	420.0	7.0	49.8	4.8	.8	.49	.31	.09	-	-
420.0	425.0	5.0	52.2	2.7	.8	.39	.31	.10	-	-
425.0	430.0	5.0	53.6	1.5	.7	.47	.23	.09	-	-
430.0	435.0	5.0	51.8	3.3	.7	.39	.31	.10	-	-
435.0	440.0	5.0	52.8	2.3	.6	.36	.34	.10	-	-
440.0	445.0	5.0	53.6	1.4	1.0	.47	.23	.10	-	-
445.0	450.0	5.0	52.4	2.3	1.4	.47	.23	.11	-	-
450.0	455.0	5.0	50.2	4.1	1.1	.54	.26	.10	-	-
455.0	460.0	5.0	48.4	5.1	2.4	.54	.26	.12	-	-
460.0	465.0	5.0	51.6	2.5	1.6	.61	.29	.10	-	-
465.0	470.0	5.0	51.2	2.9	1.4	.76	.34	.10	-	-
470.0	475.0	5.0	52.0	2.6	1.1	.72	.28	.07	-	-
475.0	480.0	5.0	52.8	1.6	1.0	.81	.19	.09	-	-
480.0	485.0	5.0	51.6	3.1	.6	.50	.20	.12	-	-
485.0	490.0	5.0	50.0	4.6	.8	.60	.30	.23	-	-
490.0	495.0	5.0	52.2	2.5	.8	.57	.23	.19	-	-
495.0	500.0	5.0	49.0	3.8	3.1	1.13	.37	.34	-	-
500.0	505.0	5.0	49.2	3.3	3.6	1.06	.34	.16	-	-
505.0	510.0	5.0	46.6	5.4	4.3	1.03	.37	.20	-	-
510.0	515.0	5.0	46.0	4.9	4.3	1.87	.53	.49	-	-
515.0	520.0	5.0	46.8	4.8	3.9	1.33	.37	.22	-	-
520.0	525.0	5.0	49.3	2.8	3.3	1.28	.42	.32	-	-
525.0	530.0	5.0	49.1	3.7	3.6	1.34	.26	.21	-	-
530.0	535.0	5.0	51.9	1.2	3.2	.93	.47	.16	-	-
535.0	540.0	5.0	50.7	.7	4.4	1.82	.78	.50	-	-
540.0	543.0	3.0	50.3	.9	6.1	1.08	.32	.05	-	-
543.0	548.0	5.0	50.1	1.3	5.0	1.62	.58	.34	-	-
548.0	550.0	2.0	40.4	5.3	9.5	4.07	1.73	1.76	-	-
550.0	555.0	5.0	27.0	1.9	41.5	2.93	1.47	.77	-	-

Drill hole 9 (Cont.)

Footage		Interval	CaO percent	MgO percent	SiO_2 percent	Al_2O_3 percent	Fe_2O_3 percent	SO_3 percent	Na_2O percent	K_2O percent
From-	To-									
555.0	560.0	5.0	47.2	2.8	6.2	2.21	0.59	0.32	-	-
560.0	565.0	5.0	46.2	3.3	7.4	2.28	.72	.40	-	-
565.0	570.0	5.0	5.8	.7	77.6	4.73	2.67	1.90	-	-
570.0	575.0	5.0	31.2	2.3	29.4	4.50	2.10	1.76	-	-
575.0	580.0	5.0	34.8	4.9	18.0	4.82	2.18	2.15	-	-
580.0	585.0	5.0	9.8	1.7	64.4	6.44	3.16	2.41	-	-
610.0	620.0	10.0	4.3	1.4	80.0	3.32	3.08	1.29	-	-

Composite 0.0 - 548.0 0.30 Na_2O 0.18 K_2O

Drill hole 10

Footage From-	Footage To-	Interval	CaO percent	MgO percent	SiO_2 percent	Al_2O_3 percent	Fe_2O_3 percent	SO_3 percent	Na_2O percent	K_2O percent
0.0	4.0	4.0	44.8	9.3	0.7	0.51	0.49	0.02	-	-
4.0	9.0	5.0	44.2	9.7	.6	.54	.46	.03	-	-
9.0	14.0	5.0	47.8	6.2	1.0	.87	.43	.02	-	-
14.0	19.0	5.0	45.4	8.5	.8	.54	.43	.01	-	-
19.0	24.0	5.0	47.0	7.6	.6	.40	.40	.01	-	-
24.0	29.0	5.0	44.4	9.4	.7	.48	.32	.02	-	-
29.0	34.0	5.0	45.2	8.5	1.4	.58	.32	.03	-	-
34.0	39.0	5.0	45.4	8.3	1.1	.46	.34	.03	-	-
39.0	44.0	5.0	45.4	7.8	2.3	.56	.34	.02	-	-
44.0	49.0	5.0	47.4	6.6	1.5	.41	.29	.02	-	-
49.0	54.0	5.0	44.8	8.9	1.1	.61	.49	.03	-	-
54.0	59.0	5.0	44.0	8.6	2.2	.67	.63	.02	-	-
59.0	64.0	5.0	47.6	3.6	3.9	2.00	1.10	.02	-	-
64.0	69.0	5.0	45.4	5.7	6.2	.80	.40	.03	-	-
69.0	74.0	5.0	46.4	5.9	4.6	.78	.32	.03	-	-
74.0	79.0	5.0	47.6	4.8	4.0	.84	.46	.07	-	-
79.0	84.0	5.0	47.8	5.1	4.0	.87	.43	.04	-	-
84.0	89.0	5.0	49.8	3.9	2.0	.47	.23	.02	-	-
89.0	94.0	5.0	48.8	5.3	2.0	.71	.29	.03	-	-
94.0	99.0	5.0	49.4	5.2	.9	.68	.32	.02	-	-
99.0	104.0	5.0	52.0	3.3	.4	.50	.20	.02	-	-
104.0	109.0	5.0	51.8	3.4	.6	.41	.29	.03	-	-
109.0	114.0	5.0	50.8	3.7	1.5	.53	.37	.03	-	-
114.0	119.0	5.0	49.2	5.1	.8	.61	.29	.02	-	-
119.0	124.0	5.0	51.4	2.8	1.7	.90	.40	.03	-	-
124.0	129.0	5.0	50.4	4.3	.6	.46	.34	.03	-	-
129.0	134.0	5.0	50.0	3.8	2.7	.70	.40	.03	-	-
134.0	139.0	5.0	49.2	2.5	5.8	.91	.29	.02	-	-
139.0	144.0	5.0	51.0	2.7	2.1	.86	.34	.02	-	-
144.0	149.0	5.0	50.0	.9	6.3	.98	.32	.03	-	-
149.0	154.0	5.0	51.0	1.1	5.2	1.03	.37	.03	-	-
154.0	159.0	5.0	49.8	3.0	4.3	.81	.29	.02	-	-
159.0	164.0	5.0	49.8	2.7	4.6	.81	.29	.03	-	-
164.0	169.0	5.0	49.6	2.5	4.6	1.11	.29	.03	-	-
169.0	174.0	5.0	48.4	2.3	5.6	2.20	.60	.03	-	-
174.0	179.0	5.0	51.6	.9	2.1	1.43	.37	.04	-	-
179.0	184.0	5.0	51.0	.7	3.0	5.81	.69	.05	-	-

Drill hole 10 (Cont.)

Footage		Inter-val	CaO percent	MgO percent	SiO_2 percent	Al_2O_3 percent	Fe_2O_3 percent	SO_3 percent	Na_2O percent	K_2O percent
From-	To-									
184.0	189.0	5.0	51.6	1.1	2.3	1.16	0.34	0.01	-	-
189.0	194.0	5.0	49.6	1.7	4.6	1.59	.51	.01	-	-
194.0	196.0	2.0	51.6	1.4	.3	.13	.37	.01	-	-

Composite 0.0 - 196.0 0.035 Na_2O 0.16 K_2O

Drill hole 11

.0	5.0	5.0	44.4	9.6	.4	.46	.34	.02	-	-
5.0	10.0	5.0	47.0	7.8	3.9	1.00	.20	.01	-	-
10.0	15.0	5.0	46.6	7.9	.5	.50	.20	.01	-	-
15.0	20.0	5.0	48.8	5.7	.8	.57	.23	.01	-	-
20.0	24.0	4.0	45.8	8.6	.4	.23	.37	.02	-	-
24.0	30.0	6.0	49.0	5.1	1.0	.54	.46	.01	-	-
30.0	35.0	5.0	50.4	4.1	1.4	.54	.46	.01	-	-
35.0	39.0	4.0	44.8	7.9	2.6	.64	.46	.01	-	-
39.0	44.0	5.0	42.0	11.2	1.0	.47	.63	.01	-	-
44.0	50.0	6.0	42.4	10.3	2.4	.53	.37	.03	-	-
50.0	55.0	5.0	45.0	8.9	1.2	.41	.49	.01	-	-
55.0	60.0	5.0	44.0	9.6	1.7	.43	.37	.01	-	-
60.0	65.0	5.0	44.0	9.3	1.7	.40	.40	.03	-	-
65.0	70.0	5.0	45.0	7.8	2.3	.64	.46	.01	-	-
70.0	75.0	5.0	46.2	7.4	1.8	.51	.49	.01	-	-
75.0	80.0	5.0	49.8	4.4	1.7	.64	.46	.01	-	-
80.0	85.0	5.0	49.0	5.7	1.2	.47	.23	.01	-	-
85.0	90.0	5.0	49.0	5.4	1.1	.74	.26	.01	-	-
90.0	95.0	5.0	49.6	5.1	1.0	.54	.26	.01	-	-
95.0	100.0	5.0	52.2	2.6	1.5	.43	.17	.01	-	-
100.0	105.0	5.0	48.6	6.2	1.0	.37	.23	.01	-	-
105.0	110.0	5.0	50.6	3.9	1.2	.74	.26	.01	-	-
110.0	114.0	4.0	49.2	5.4	.9	.67	.23	.01	-	-
114.0	120.0	6.0	49.0	5.7	.9	.61	.23	.01	-	-
120.0	125.0	5.0	48.8	5.9	.9	.64	.26	.01	-	-
125.0	130.0	5.0	48.4	5.7	1.6	.64	.26	.01	-	-
130.0	133.0	3.0	51.0	3.6	1.1	.67	.23	.01	-	-
133.0	138.0	5.0	52.0	3.3	.9	.53	.17	.01	-	-
138.0	143.0	5.0	52.6	2.5	.9	.33	.17	.01	-	-
143.0	150.0	7.0	50.0	5.0	.6	.30	.20	.01	-	-
150.0	155.0	5.0	48.8	6.5	.4	.47	.23	.01	-	-
155.0	160.0	5.0	47.8	6.7	.5	.64	.26	.03	-	-
160.0	165.0	5.0	52.6	3.2	.5	.43	.17	.01	-	-
165.0	170.0	5.0	49.0	6.0	.5	.51	.29	.01	-	-
170.0	175.0	5.0	46.0	8.6	.5	.46	.34	.02	-	-
175.0	180.0	5.0	49.8	3.8	2.8	.56	.34	.01	-	-
180.0	185.0	5.0	48.6	5.9	1.1	.61	.29	.03	-	-
185.0	190.0	5.0	52.4	1.8	2.0	.57	.23	.01	-	-
190.0	195.0	5.0	51.6	3.4	1.1	.50	.20	.02	-	-
195.0	200.0	5.0	48.6	5.2	2.0	.79	.31	.02	-	-
200.0	205.0	5.0	50.8	3.3	2.7	.60	.20	.02	-	-

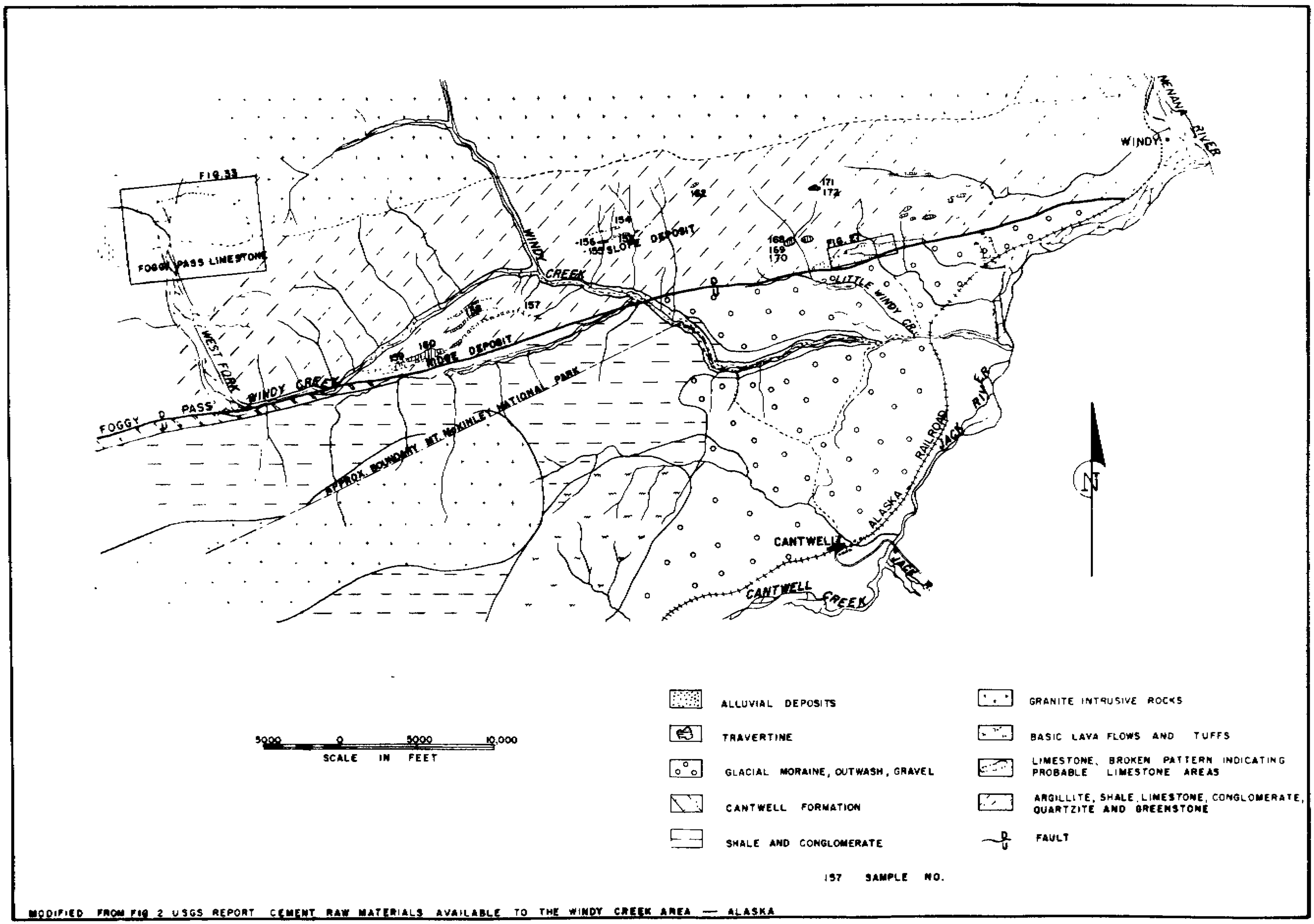
Drill hole 11 (Cont.)

Footage		Interval	CaO percent	MaO percent	SiO_2 percent	Al_2O_3 percent	Fe_2O_3 percent	SO_3 percent	Na_2O percent	K_2O percent
From-	To-									
205.0	210.0	5.0	49.2	4.2	2.5	0.61	0.29	0.02	-	-
210.0	215.0	5.0	49.0	4.4	2.9	.67	.23	.02	-	-
215.0	220.0	5.0	47.4	4.6	5.1	.81	.29	.02	-	-
220.0	223.0	3.0	50.4	3.7	2.5	.67	.23	.02	-	-
223.0	228.0	5.0	52.4	1.4	2.4	.81	.29	.03	-	-
228.0	234.0	6.0	50.4	.9	5.2	1.44	.66	.04	-	-
234.0	240.0	6.0	50.2	.3	5.3	1.90	.80	.02	-	-
240.0	245.0	5.0	52.8	.4	3.6	.66	.34	.02	-	-
245.0	250.0	5.0	52.4	.4	.6	5.47	.43	.02	-	-
250.0	255.0	5.0	53.6	.4	1.7	.19	.31	.03	-	-
255.0	260.0	5.0	47.8	4.4	5.2	1.33	.57	.04	-	-
260.0	265.0	5.0	53.2	1.4	1.8	.24	.26	.03	-	-
265.0	270.0	5.0	53.4	.4	2.5	.24	.26	.01	-	-
270.0	275.0	5.0	43.9	.5	13.9	2.23	.97	.01	-	-
275.0	280.0	5.0	33.1	1.3	29.0	4.35	2.05	.94	-	-
280.0	284.0	4.0	37.0	1.1	21.4	5.90	1.70	.62	-	-

Composite hole 11 0.0 - 270.0
0.050% Na_2O
0.15% K_2O

Drill hole 12

.0	10.0	10.0	45.4	8.5	.6	.51	.29	.01	-	-
10.0	15.0	5.0	43.4	10.4	.6	.61	.29	.01	-	-
15.0	20.0	5.0	45.6	8.5	.3	.47	.23	.01	-	-
20.0	25.0	5.0	44.4	9.7	.3	.37	.23	.01	-	-
25.0	30.0	5.0	45.0	9.1	.4	.37	.23	.01	-	-
30.0	35.0	5.0	46.4	8.5	.4	.40	.20	.01	-	-
35.0	40.0	5.0	45.2	9.2	.4	.37	.23	.01	-	-
40.0	48.0	8.0	45.8	8.8	.5	.37	.23	.01	-	-
48.0	55.0	7.0	44.6	9.4	.4	.34	.26	.01	-	-
55.0	61.0	6.0	44.2	9.9	.4	.30	.20	.01	-	-
61.0	65.0	4.0	43.8	9.6	1.1	.41	.29	.01	-	-
65.0	70.0	5.0	44.6	9.5	.4	.34	.26	.01	-	-
70.0	75.0	5.0	43.6	10.4	.6	.44	.36	.01	-	-
75.0	80.0	5.0	43.8	10.2	.6	.41	.29	.01	-	-
80.0	85.0	5.0	46.2	8.0	.7	.51	.29	.01	-	-
85.0	90.0	5.0	46.3	6.7	3.1	.61	.29	.01	-	-
90.0	95.0	5.0	43.7	9.6	1.7	.54	.26	.01	-	-
95.0	100.0	5.0	46.8	7.6	1.0	.40	.20	.01	-	-
100.0	105.0	5.0	47.2	6.7	.9	.40	.40	.01	-	-
105.0	110.0	5.0	49.6	1.6	1.7	.66	.54	.01	-	-
110.0	115.0	5.0	54.6	.3	.6	.30	.20	.01	-	-
115.0	120.0	5.0	52.2	.9	1.1	.59	.31	.01	-	-
120.0	125.0	5.0	51.0	1.6	1.5	.34	.26	.02	-	-
125.0	130.0	5.0	51.6	.8	2.8	.74	.26	.01	-	-
130.0	135.0	5.0	51.8	1.3	2.0	.57	.23	.01	-	-
135.0	140.0	5.0	50.0	2.7	3.0	.67	.23	.01	-	-



MODIFIED FROM FIG 2 USGS REPORT CEMENT RAW MATERIALS AVAILABLE TO THE WINDY CREEK AREA — ALASKA

Figure 41. - Geologic map of Windy-Foggy Pass area.

Drill hole 12 (Cont.)

Footage		Interval	CaO percent	MaO percent	SiO_2 percent	Al_2O_3 percent	Fe_2O_3 percent	SO_3 percent	Na_2O percent	K_2O percent
From-	To-									
140.0	145.0	5.0	51.0	1.7	1.5	0.47	0.23	0.01	-	-
145.0	150.0	5.0	45.8	5.5	1.6	.41	.29	.02	-	-
150.0	155.0	5.0	50.4	1.3	2.3	1.01	.49	.02	-	-
155.0	160.0	5.0	50.2	1.9	2.1	.56	.34	.01	-	-
160.0	165.0	5.0	53.2	.7	.9	.37	.23	.01	-	-
165.0	170.0	5.0	53.2	1.5	.6	.37	.23	.01	-	-
170.0	175.0	5.0	47.6	3.4	4.0	2.20	1.00	.04	-	-
175.0	180.0	5.0	53.6	1.2	1.0	.44	.26	.01	-	-
180.0	185.0	5.0	52.2	1.6	2.5	.43	.17	.01	-	-
185.0	190.0	5.0	51.0	1.3	4.9	.61	.29	.01	-	-
190.0	195.0	5.0	51.2	1.8	2.9	.73	.37	.01	-	-
195.0	200.0	5.0	50.2	2.0	4.4	.64	.26	.01	-	-
200.0	205.0	5.0	49.8	2.5	3.9	1.29	.31	.01	-	-
205.0	206.0	1.0	50.0	1.0	5.3	2.10	.60	.02	-	-
206.0	210.0	4.0	50.2	.7	5.4	2.08	.92	.01	-	-
210.0	215.0	5.0	50.6	1.1	4.5	1.78	.52	.01	-	-
215.0	220.0	5.0	51.6	1.2	3.7	1.36	.34	.01	-	-
220.0	225.0	5.0	51.4	.8	3.9	1.38	.52	.04	-	-
225.0	230.0	5.0	51.0	1.7	2.9	1.53	.37	.02	-	-
230.0	240.0	10.0	49.0	1.4	5.4	2.39	.71	.05	-	-

Composite hole 12 0.0 - 240.0

0.025% Na_2O

0.16% K_2O

Other Limestone Deposits in Windy Creek Area

Location and Accessibility

Numerous other limestone deposits of the same age and type as that of Windy limestone are in the Windy Creek area. The location of the deposits sampled in 1949 are shown on figure 35 with a prefix W before the sample number. Deposits sampled in 1950 and located west of the above area are indicated by the sample numbers on figure 41.

Most of the deposits sampled were indicated to be smaller than the Windy limestone deposit. Other deposits that approached the Windy deposit in size were located at higher altitudes, farther from the railroad, and were less accessible.

Description of Deposits

Samples W-1 through W-12, represent the samples taken in 1949. The analytical results are given in table 45. Samples W-7 and W-8 were cut obliquely across a single limestone body near Little Windy Creek. The analyses of these samples indicate a limestone whose magnesia is too high to merit additional exploration when the size of the deposit also is considered.

Samples W-1 through W-5 were taken from a series of limestone outcrops northeast of the Windy limestone deposit. Except for sample W-1, the analyses indicate a good grade of limestone. Lateral extent of the deposits is small. Inasmuch as these bodies lie above an altitude of 3,200 feet, access to them would be more difficult and expensive than to the Windy deposit.

Sample W-6 was taken from an isolated outcrop of limestone at an altitude of 3,800 feet, which forms a pinnacle between Bain and Little Windy Creeks. The indicated grade of the limestone is good, but its relatively remote location and its small size discourage further exploration.

Samples W-9 through W-12 were taken from narrow outcrops of cherty limestone occurring along the course of Bain Creek. It is possible that the limestone found in these ledges could be used in the production of portland cement, but their small size and unfavorable location discourage further investigation.

The analyses of the samples taken during the 1950 field season are included in table 46; their location is indicated in figure 41.

TABLE 46. - Limestone analyses in Windy Creek area

Sample No.	Length feet	Direction sampled	Percent					
			CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	SO_3
W-1	21	N-S	50.95	3.7	0.7	0.8	0.30	0.06
W-2	110	N-S	53.45	.8	1.8	1.0	.36	.04
W-3	15	N-S	54.70	.5	.9	.6	.26	.01
W-4	150	N-S	54.20	.7	1.5	.65	.14	.01
W-5	200	N-S	54.00	.55	1.7	.6	.28	.01
W-6	210	N-S	52.55	.5	4.8	.4	.18	.01
W-7	150	NE-SW	50.95	2.95	1.8	1.35	.43	.01
W-8	150	NE-SW	49.20	4.95	1.0	.85	.36	.01
W-9	95	N-S	52.25	.4	5.0	.8	.17	.01
W-10	125	N-S	44.25	.65	16.2	1.8	.50	.07
W-11	50	N-S	47.60	.7	10.4	1.7	.37	.08
W-12	45	N-S	42.75	.45	18.7	2.0	.44	.02
153	25	N-S	50.9	.1	5.5	.7	1.38	-
154	20	N-S	55.2	.05	1.4	.3	.20	-
155	80	N-S	51.8	1.85	1.7	.4	.28	-
157	162	N-S	54.9	.05	.7	.25	.15	-
158	150	N-S	54.4	.15	.7	.2	.18	-
159	180	N-S	55.2	.05	.7	.3	.17	-
160	100	N-S	55.2	.05	.5	.15	.14	-
162	25	N-S	55.4	.05	.7	.25	.25	-
168	165	N-S	46.0	5.25	5.0	1.4	.50	-
169	150	N-S	50.2	1.5	2.5	1.15	.44	-
170	125	N-S	51.8	.4	4.0	.85	.25	-
171	115	N-S	52.4	.05	5.4	.6	.13	-
172	72	N-S	47.6	.05	11.4	.85	.33	-

Samples, 171 and 172, were taken from the limestone pinnacle between Bain and Little Windy Creek. The strike of the lens of limestone forming this pinnacle is N. 65° E. The dip is 60° SE. The limestone in this deposit is fine-grained and medium to dark gray, with many narrow veinlets of calcite. Where exposed, the limestone is fractured and badly weathered.

Three samples - 168, 169, and 170 - were taken across the face of a limestone bluff on the west side of Little Windy Creek approximately 1-1/2 miles west of the Windy limestone deposit. This limestone is very similar to that of the deposit drilled. It is gray to dark gray and fine-grained, and contains thin seams of crystalline calcite. Some interbedding with shale was noted near the footwall of the deposit. The magnesia content of this deposit is very erractic; often it is above the limits allowed for the production of portland cement.

A series of outcrops along the slope on the left limit of Windy Creek appears to form two thin, parallel beds of limestone. These deposits are approximately 1-1/2 miles north of the ranger cabin on Windy Creek and 6-1/2 miles by trail northwest of Cantwell. The altitude of the outcrops ranges from 3,300 to 3,900 feet. The general strike of the outcrops is N. 30 E. The beds dip 70° to 80° to the southeast. Four samples, whose locations are shown in figure 41, were taken from the outcrops in this area. These samples - 153, 154, 155, and 162 - were taken from individual exposures. Several similar outcrops were not sampled.

Another series of outcrops is on the ridge parallel to, and on, the right limit (south side) of the West Fork of Windy Creek above its confluence with Windy Creek. Four samples - 157, 158, 159, and 160 - were taken in this area. The sample locations are shown on figure 41. The first outcrop is 2 miles west of the ranger cabin. The series of outcrops extend from there 2-1/2 miles to the southwest. The strikes of the deposits range from S. 70° W. to S. 85° W. The beds dip 60° to 75° southeast. The largest outcrop in this area is second in size only to the Windy limestone deposit, which it resembles. The outcrops are composed of highly fractured, fine-grained, gray to dark-gray limestone, which contains numerous veinlets of calcite.

Foggy Pass Limestone

Location and Accessibility

The limestone deposit near the headwaters of the West Fork of Windy Creek has been called the Foggy Pass limestone deposit (figs. 41 and 42). This deposit is approximately 15 miles northwest of Cantwell, Alaska. A tractor trail can easily be built to the deposit by extending the tractor trail that now connects Cantwell with the ranger cabin on Windy Creek.

Physical Features

The limestone deposit is near the head of a wide, glaciated, U-shaped, north-south valley at the entrance of Foggy Pass (fig. 41). Near the entrance of Foggy Pass, the West Fork of Windy Creek swings east until it joins Windy Creek, which also heads in the mountains to the north. Below the confluence, Windy Creek continues southeastward until it enters the Jack River.

Mountains in the area are steep and often bare of vegetation. The Foggy Pass limestone deposit forms a steep, northeast-trending ridge that is bisected by the West Fork of Windy Creek.

General Geology

The Foggy Pass limestone deposit is the eastern end of a band of Middle Devonian limestone,[77] which is exposed from east of the West Fork of Windy Creek to the head of Bull River. The limestone is a part of a series of metamorphosed sedimentary rocks composed of shale, argillite, conglomerate, limestone, quartzite, slate, and graywacke.

Description of Deposit

The outcrop is composed of gray, recrystallized limestone. Folding and contortion are evident, but the limestone does not appear to be fractured or broken, as are the other limestone deposits in the Windy-Foggy Pass area. Figure 42 is a plan map of the Foggy Pass deposit; it shows the locations of the Bureau of Mines samples.

The total horizontal width of the limestone, as exposed along the valley of the West Fork of Windy Creek, is approximately 3,000 feet. The strike of the deposit generally is east and west. The beds dip 40° to 80° south.

Five samples, 163, 164, 165, 166, and 167, were taken of the Foggy Pass deposit at the locations indicated on figure 42. Sample 163 was collected from the talus slope on the left limit of the creek; it represents the entire width of the outcrop. Three samples, 165, 166, and 167, were taken along the creek bank. An average of these three samples also represents the entire width of the deposit. Analyses of the Foggy Pass samples are given in table 47, as follows:

TABLE 47. - Foggy Pass limestone analyses

Sample No.	Length feet	Percent				
		CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3
163	3,000	51.4	0.35	4.1	1.15	0.43
164	1,000	47.1	.75	7.7	2.2	.68
165	1,200	49.8	.25	5.9	1.6	.58
166	1,100	50.3	.65	5.4	1.6	.51
167	1,100	51.4	.4	4.0	1.3	.50

Sodium and potassium oxides on all of the above samples were less than 0.01 percent.

West Fork of Chulitna River Area Limestone

Location and Accessibility

The West Fork of the Chulitna River area is in the Broad Pass region on the south slope of the Alaska Range. The two principal limestone deposits, at the heads of Long and Copeland Creeks, are, respectively, west and southwest of the Golden Zone mine (fig. 26).

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[77] Work cited in footnote 2, p. 102.

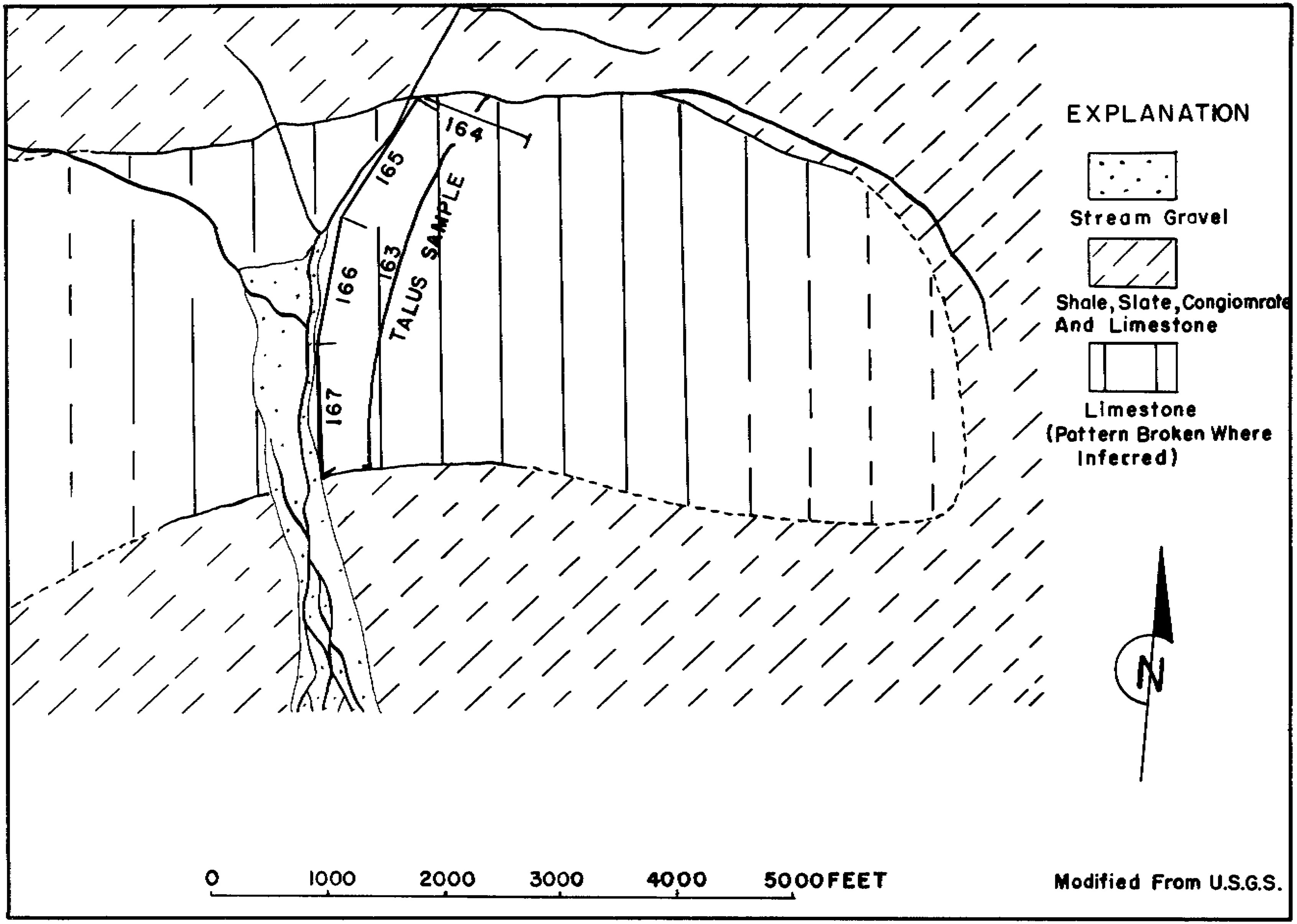

Figure 42. - Plan map of Foggy Pass deposit, showing location of Bureau of Mines samples.

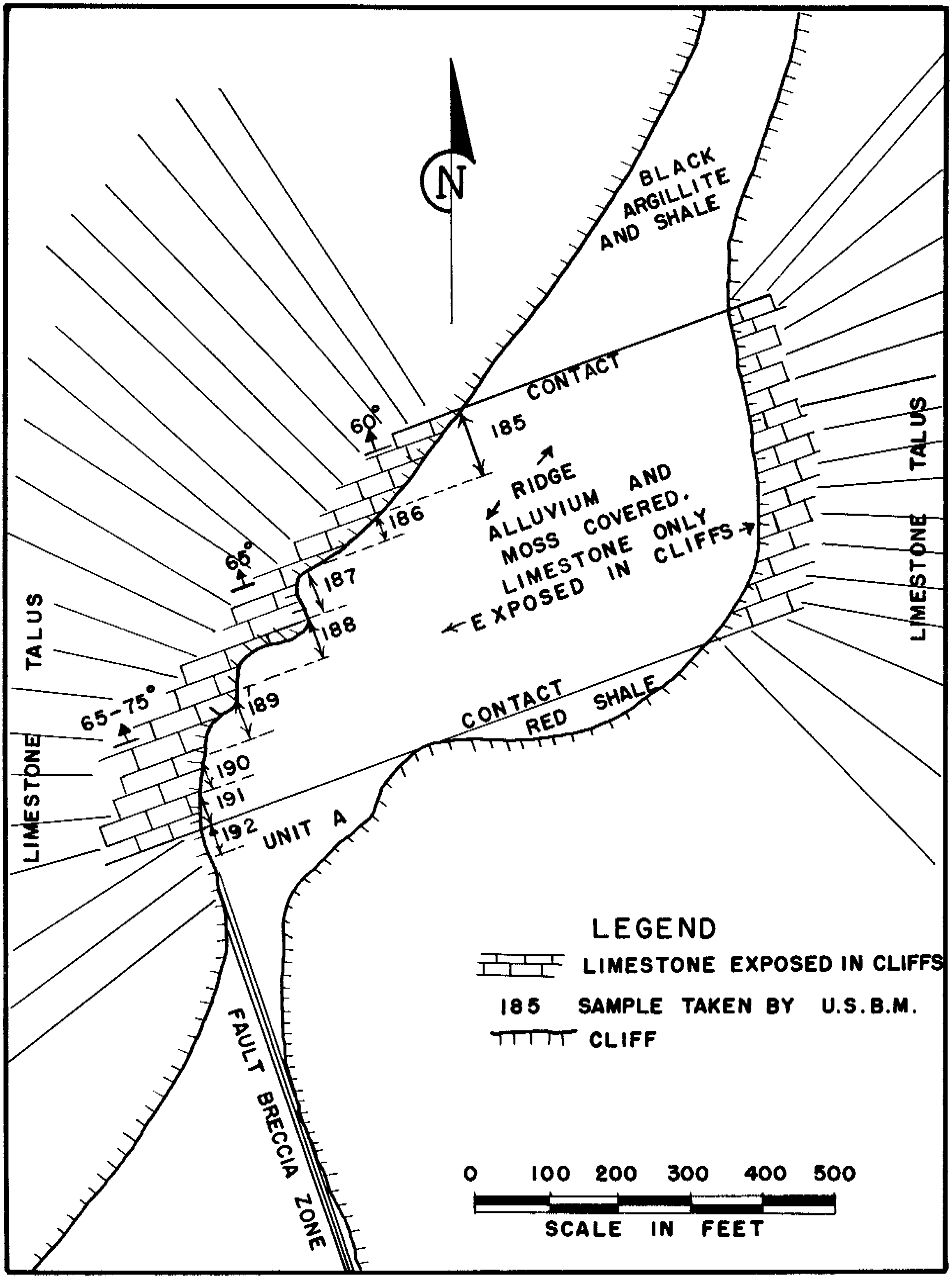

Figure 43. - Sketch of limestone deposit between Long Creek and Copeland Creek, showing sample locations.

A road down the West Fork of the Chulitna River connects the Golden Zone mine to the Alaska Railroad at Colorado Station, but the limestone deposits are in a different drainage system, consequently they are not easily reached. If necessary, roads can be constructed up Long and Copeland Creeks, but bridges across the main Chulitna River will be required. Both creeks have cut narrow gorges along their lower courses.

Physical Features and Climate

Both Long and Copeland Creeks head in the mountains south of the West Fork of the Chulitna River and flow southward to join the Chulitna River. U-shaped valleys and braided silt-ladened rivers are signs of the glaciation this area has undergrone.

In the vicinity of the limestone outcrops, the mountains slopes are steep and partly covered with talus. Vegetation at this altitude consists entirely of the low brush, grass, and moss commonly found above timberline in this part of Alaska.

Precipitation in the district is approximately 35 inches a year. Snowfall is frequent from September to June. During the summer months, rain and fog occur frequently. Temperature extremes are reported to have ranged from a high of 90° F. to a low of -50° F.

General Geology

Both limestone beds that were sampled have been assigned by Ross[78] to the Triassic period. The rocks representing the oldest formation in the area are metamorphosed sedimentary rocks that probably are Devonian. Above these is a series of Carboniferous rocks composed of argillite, tuff, chert, lava, and limestone that have been classified lithologically into several units. The Triassic limestone and argillite lie above the Carboniferous rocks.

Description of Deposits

Two area of limestone in the West Fork of the Chulitna River area were sampled as a possible source of limestone for the production of portland cement (fig. 26). The first area is 4 miles southwest of the Golden Zone mine between Long Creek and the head of Copeland Creek. A sketch of this deposit showing the sample locations is shown on figure 43.

The limestone in this outcrop is white to gray and fossiliferous. The fractured and weathered limestone is interbedded with shales and siliceous material. The limestone outcrop cuts across a ridge at a slight angle and is exposed in steep cliffs along both sides of the ridge. Slopes below the cliffs are mantled with limestone talus.

The general strike of the limestone beds is N. 60° E. to N. 70° E. The beds dip 60° to 70° northwest. The hanging wall of the deposit is black argillite and shale of unit C; the footwall is red shale from unit A.

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[78] Work cited in footnote 13, p. 293.

The second area is at the head of Long Creek, 3 miles southwest of the Golden Zone mine. Here an outcrop of crystalline limestone was mapped by Ross[79] in an area of Triassic limestone. The inferred outline of this deposit is shown on figure 44 in dashed lines. Limestone outcrops sampled by the Bureau of Mines are designated by sample numbers and solid lines.

The limestone outcrops are very prominent, white to gray, and the limestone is extremely fractured and weathered. This limestone is also fossiliferous. The general strike of the deposit is N. 25° E.

Seven samples, 185 through 191, were taken across the width of the deposit illustrated by figure 43. Analyses and true widths of the samples are given in table 47. One sample, 192, was taken of the red shale, which forms the footwall of the deposit. An analysis of this sample is included in table 47.

A total of 10 samples, 173 through 182, was taken of limestone outcrops in the second area (fig. 44). Two of these, 174 and 179, were taken from outcrops of the limestone surrounding the zone of crystalline limestone. Analyses of all samples are given in table 48.

TABLE 48. - Analyses of limestone samples from West Fork of Chulitna River

Sample No.	Length feet	Percent				
		CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3
173	160	54.0	1.1	1.1	0.53	0.37
174	125	53.8	.6	2.7	.83	.37
175	200	54.5	.6	1.5	.76	.34
176	100	54.4	.3	1.7	.69	.31
177	160	46.4	.9	10.0	3.40	1.40
178	170	52.4	.7	2.6	1.36	.54
179	170	53.4	.6	2.6	1.10	.40
180	75	53.5	.5	2.4	1.05	.45
181	173	52.6	.7	3.2	1.64	.66
182	175	51.6	.8	3.5	1.87	.63
185	100	50.8	.01	5.9	1.79	.51
186	35	53.0	.1	3.7	.97	.23
187	65	48.2	.1	10.8	1.52	.28
188	60	37.6	.1	22.8	5.25	1.35
189	70	47.0	.1	10.4	2.43	.57
190	45	50.6	.1	7.2	1.52	.48
191	45	41.0	.1	19.0	5.15	1.05
192	45	31.0	.6	26.0	8.90	4.30

Fox Limestone

Location and Accessibility

A small lens of limestone occurs in the Birch Creek schist near Fox, Alaska. Fox is at the junction of the Elliott and Steese Highways, 10 miles north of Fairbanks (figs. 2 and 3). The road to Fairbanks is well-maintained and open for traffic throughout the year.

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[79] Work cited in footnote 13, plate 25.

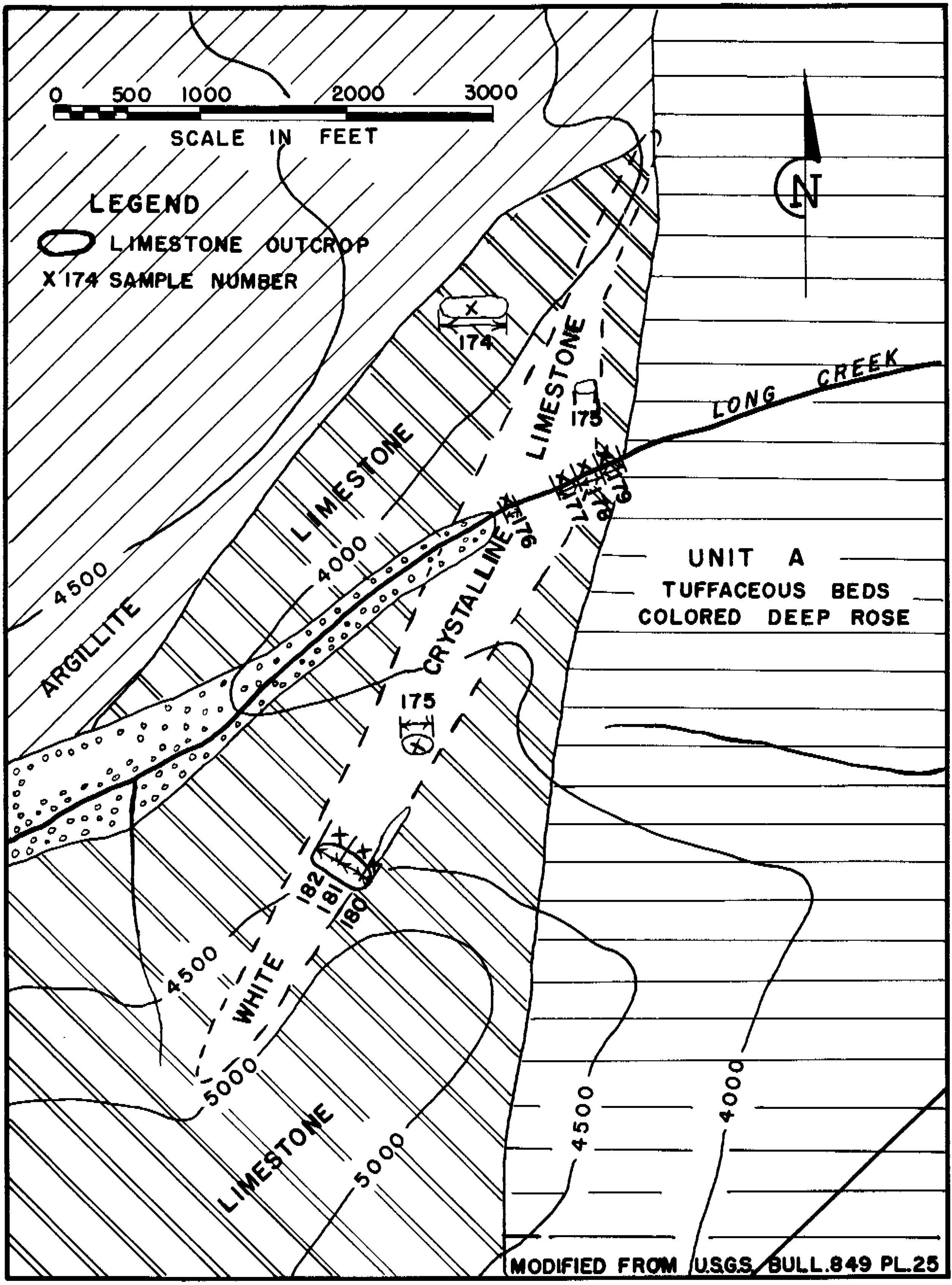

Figure 44. - Limestone outcrop at head of Long Creek, showing sample locations.

Description of Deposit

The limestone outcrops along the base of a slope on the right limit of Gilmore Creek just above its confluence with Goldstream. In the Birch Creek schist, the lens of limestone is approximately 15 feet thick and can be traced for over 300 feet along the base of the hill. The strike of the deposit is N. 90° E; it dips 35° W. into the hill. An analysis across the outcrop follows:

Sample No.	Length, feet	Percent				
		CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3
43	15	29.9	19.6	26.2	0.4	0.3

Castle Mountain Limestone

Location and Accessibility

There is a limestone deposit behind Castle Mountain between King's and Chickaloon Rivers.[80] The deposit is approximately 14 miles north of the Glenn Highway and is at least 3,500 feet higher. Nearly 3,000 feet of this rise takes place in the last 2 miles.

The area is remote and inaccessible.

Physical Features and Climate

King's and Chickaloon Rivers head in the Talkeetna Mountains north of the Matanuska Valley and flow south to join the Matanuska River. Castle Mountain is a flat-topped, basaltic-capped mountain between King's and Chickaloon Rivers just north of the Matanuska Valley.

U-shaped valleys and other evidence of glaciation are found throughout the region.

Spruce, birch, and cottonwood grow along the streams and valleys, but above 2,500 feet the vegetation is limited to alders and other low bushes, moss, and grass.

The climate of the area is very similar to that of Anchorage and the Matanuska Valley but, because of the higher altitude, is slightly more rigorous.

General Geology and Description of Deposit

The limestone on the crest of the ridge north of Castle Mountain rests unconformably upon Lower Jurassic volcanic rocks.[81] The main body of the limestone sampled is fractured and marbleized and is gray to white. The high silica analyses of the samples indicate that many of the beds are very cherty.

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[80] Martin, G. C., and Katz, F. J., Geology and Coal Fields of the Lower Mantanuska Valley, Alaska; Geol. Survey Bull. 500, pl. V.

[81] Work cited in footnote 7, pp. 32-33.

Two samples of this deposit were taken by the Bureau of Mines from the outcrop at 4,500 feet. The first, sample 56, was taken of a fractured, nearly white limestone near the western end of the main deposit. The second sample, 57, was of a dark-gray limestone below the first. At the location sampled, the beds strike N. 90 E. and dip approximately 60° N.

Analyses of the samples are given in table 49.

TABLE 49. - Analyses of Castle Mountain limestone

Sample No.	Length feet	Percent				
		CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3
56	50	8.9	6.1	46.6	14.4	12.9
57	200	4.5	.7	64.0	14.6	4.6

Seldovia Limestone

Location and Accessibility

Seldovia, Alaska, on Seldovia Bay near the tip of the Kenai Peninsula, is 16 miles southwest of Homer, Alaska. The face of the cliff forming the point on the east side of the entrance of Seldovia Bay is composed of limestone. This deposit is readily accessible by water to Cook Inlet ports (figs. 45 and 46).

Physical Features and Climate

Vegetation and climate of the Kenai Peninsula are typical of the Alaska coastal region. Abundant stands of spruce and cottonwood, with a dense undergrowth of devil's club, alder, willow, grass, and moss, grow along the coast. Rainfall is abundant but not excessive. The climate of the region is characterized by cool summers and relatively mild winters.

Seldovia is on the coast at the north flank of the Kenai Mountains. Evidence of glaciation is seen in U-shaped and hanging valleys. The Kenai Mountains contain numerous glaciers.

History, Production, and Ownership

The limestone deposit at the entrance of Seldovia Bay was considered a future source of limestone for industry or agriculture as early as 1911.[82] Soon after World War II, interest was shown in this limestone for production of cement. The Alaska Cement Corp. was organized, with Basil Sinclair, Anchorage, as president and principal stockholder. Plans were made to use coal from the extensive deposits near Homer, Alaska, and two possible plant sites were located. One site was adjacent to the limestone deposit; the other was on the spit at Homer. Claims on the limestone deposit and mill sites were filed by Parker A. Lyle and Charles B. Abbott, Anchorage. These locations were assigned to the Alaska Cement Corp.

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[82] Work cited in footnote 6, p. 111.

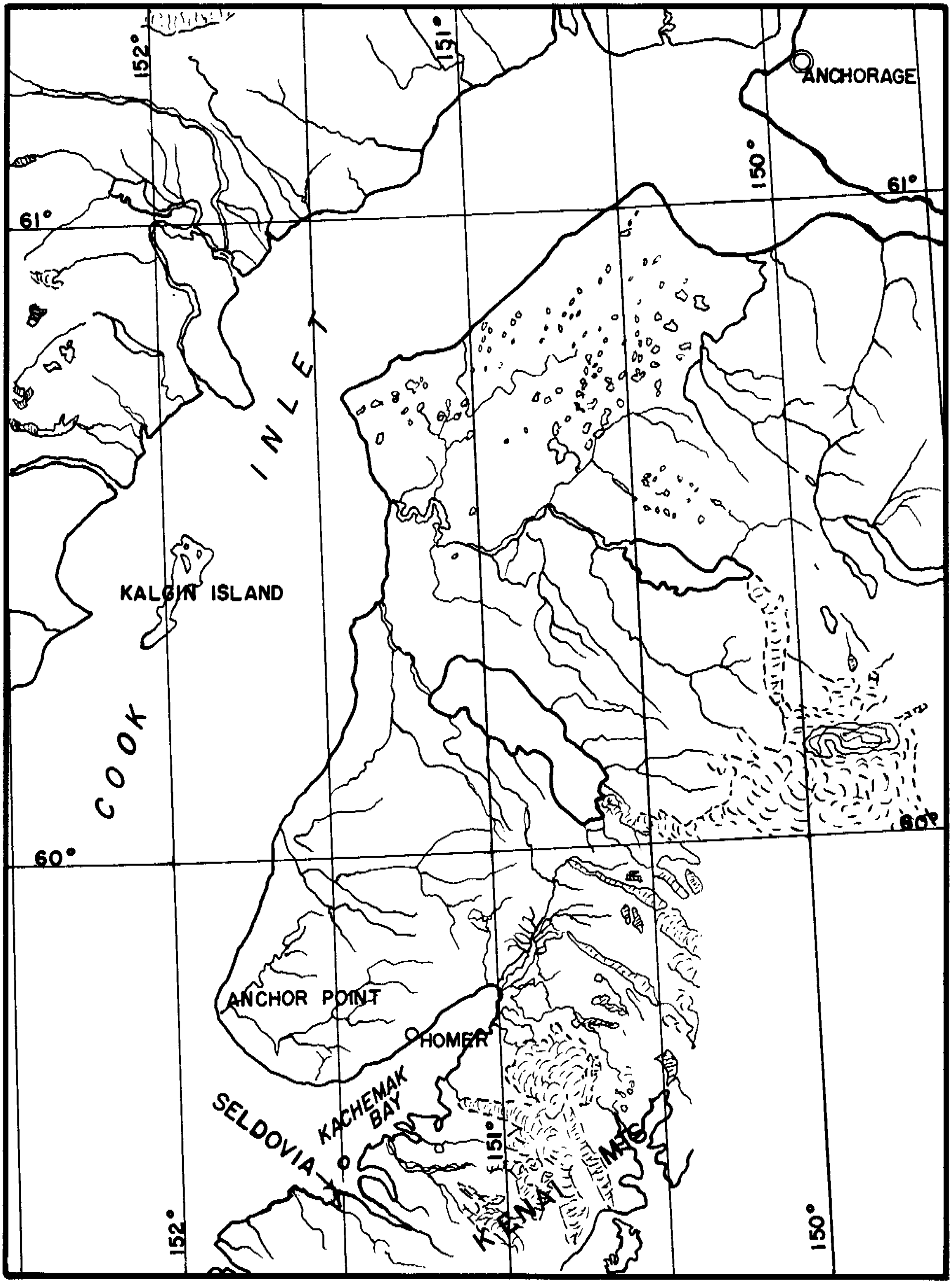
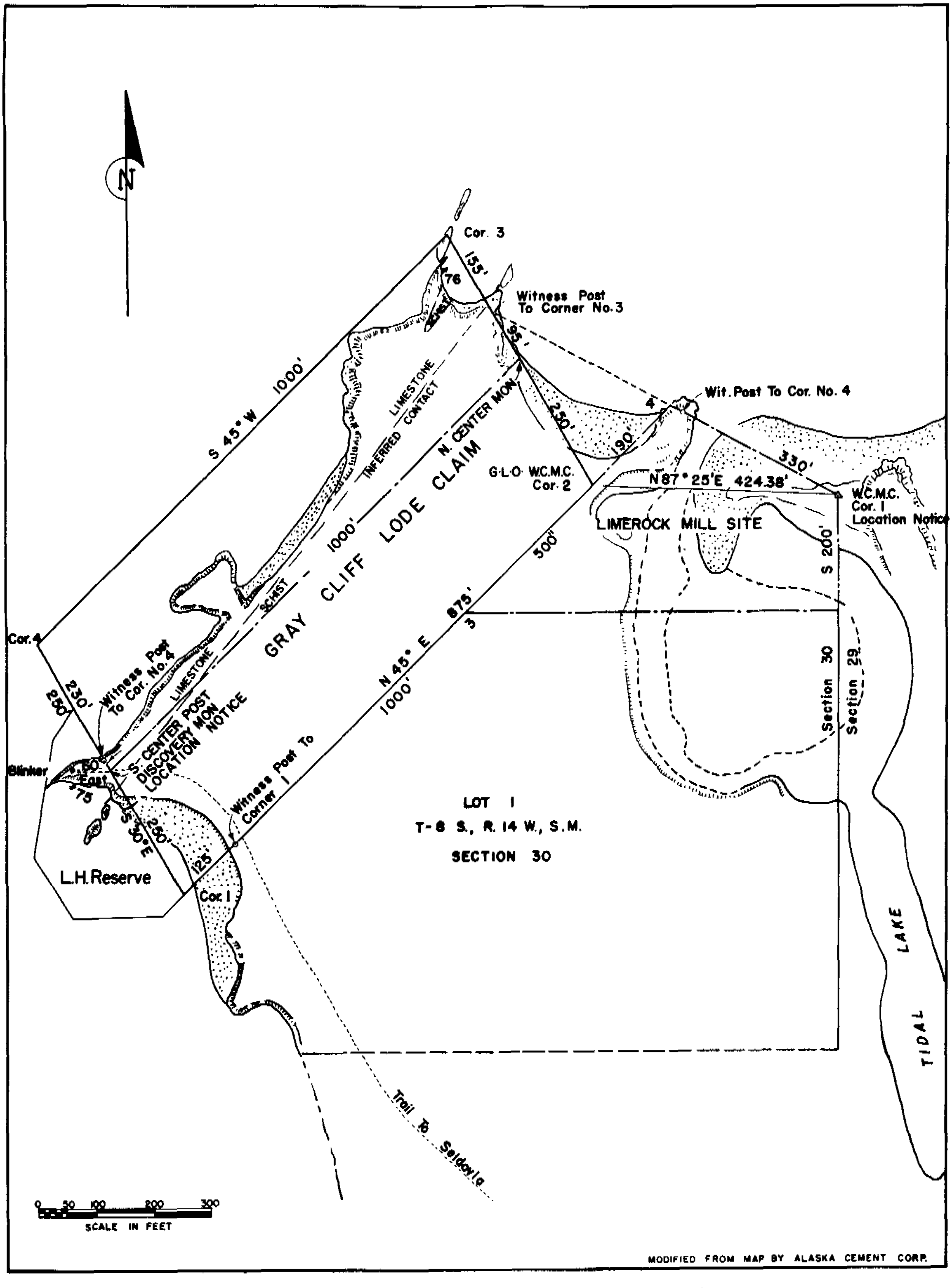


Figure 45. - Location map, Seldovia limestone.



MODIFIED FROM MAP BY ALASKA CEMENT CORP.

Figure 46. - Sample locations, Seldovia limestone deposit.

After Sinclair was unable to obtain enough capital to construct plant facilities, he disposed of his interest in the Alaska Cement Corp. to John T. Howell of Anchorage, Alaska. At present, June 1951, the corporation is not active in development of the property.

No production from this deposit has been made.

General Geology

The exact age of the Seldovia limestone or Gray Cliff deposit is unknown. The limestone is part of a highly metamorphosed series of uncertain age. The series includes schist, quartzite, and crystalline limestone.

Description of Deposit

The Gray Cliff deposit forms the end of the point at the north side of the entrance to Seldovia Bay. The limestone, massive and crystalline, is gray to white. The face of the deposit rises about 60 feet above mean high tide and is exposed across the entire face of the point.

Two samples, 75 and 76, were taken at the places indicated on figure 46. The approximate limestone-schist contact is shown in dashed lines. One 30-foot lens of schist in the limestone on the northeast side of the point was not included in sample 76. Analyses of samples 75 and 76 follow:

Sample No.	Length, feet	Percent				
		CaO	MgO	SiC_2	Al_2O_3	Fe_2O_3
75	95	50.4	5.0	0.6	0.25	0.15
76	75	49.4	5.6	.9	.2	.2

Conclusions

Limestones in the Windy-Foggy Pass area are more suitable for the economic production of a limestone meeting the requirements for Portland cement than are any other limestones that were examined in the Alaska Railroad belt.

Preliminary investigations indicate that a large quantity of limestone that meets the requirements for the production of Portland cement may be obtained from the Foggy Pass deposit.

Diamond drilling of the Windy limestone deposit has indicated a limestone of erratic and often high magnesia content, which would require a complex mining method and thorough blending to produce a limestone that would come within the specifications necessary for use in portland cement. This would result in relatively high costs.

Other deposits in the Windy-Foggy Pass area may be a source of limestone of the proper grade if the preliminary samples are indicative. However, these deposits are smaller and more difficult to reach than either the Foggy Pass deposit or the Windy deposit.

Shales and Other Sources of Argillaceous Material

Introduction

In the production of portland cement, it is necessary to add a source of alumina and silica to the limestone. Preliminary samples of alumina- and silica-bearing rocks that are accessible to the limestone deposits were taken during the Bureau of Mines program to ascertain if they would meet the specifications for magnesia and alkali content.

Preliminary samples were taken of deposits in the following areas.

Cantwell-Windy Area

Location and Accessibility. - There are numerous outcrops of shale in the Cantwell-Windy area that may be considered for use in cement production. Locations of the shale outcrops are shown in figure 41. Several of the outcrops sampled are along the railroad between Cantwell and Windy Creek. One exposure is on Little Windy Creek southwest of the Windy limestone deposit. Other exposures are along the probable route of a road to the Foggy Pass limestone deposit.

General geology. - Most of the shale and conglomerate formations in the Cantwell-Windy area south of the fault shown on figure 41 have been assigned tentatively to the Jurassic (?).[83] Lesser amounts of argillite and graywacke are present also.

A belt of the Cantwell formation is adjacent to the fault in the vicinity of Foggy Pass. At this locality, the Cantwell formation consists of coarse conglomerate, sandstone, and shale.

Description of Deposits. - Jurassic (?) shale is exposed along the Alaska Railraod almost continuously from mile 321.1 to mile 322. Narrow bands of igneous material are included in the shale formation. Other similar shale beds outcrop along Windy and Little Windy Creeks and also are exposed in their tributaries.

Shale of the Cantwell formation is exposed on the right limit of the West Fork of Windy Creek below Foggy Pass. This shale is associated with conglomerate and sandstone.

Several shale beds are associated with the limestone deposits.

Analyses of two samples of shale associated with the limestone deposits have been completed. The results of analyses of preliminary samples by the Geological Survey,[84] however, indicate a plentiful supply of argillaceous material, although some does not meet the magnesia limitation; nearly all contain an excessive amount of alkali.

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[83] Capps, S. R., The Eastern Portion of Mount McKinley National Park; Geol. Survey Bull. 836-D, 1932, p. 263.

[84] Moxham, R. M., West, W. S., and Nelson, A. E., Cement Raw Materials Available to the Windy Creek Area, Alaska; Geol. Survey Prelim. Rept., 1951, pp. 36-37.

The analyses of two shale samples from the shale associated with the Slope deposit on the left limit of Windy Creek are given in the following table.

TABLE 50. - Windy Creek shale analyses

Sample No.	Percent						
	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O
156	0.6	0.15	58.8	19.3	0.15	0.29	0.01
161	9.0	.8	44.6	16.5	9.7	.59	.01

An attempt will be made by the Bureau of Mines during the 1951 field season to delimit a shale deposit of suitable composition for the production of portland cement.

Healy Area

Location and Accessibility. - The Tertiary coal-bearing formation in the Healy River Valley (fig. 14) contains a number of shale members. The shale deposits are readily accessible by the Suntrana coal mine branch of the Alaska Railroad.

Description of Deposits. - The coal-bearing formation in the Healy River Valley consists of a series of sandstones, grits, shales, claystones, fine conglomerates, and coal beds. Two of the most prominent and persistent shale beds were sampled.

The upper bed is near the top of the upper member of the Tertiary formation; at several locations it is immediately below the Nenana gravel. The other shale bed sampled lies on coal bed F approximately 1,300 feet below the upper bed.

Samples 45 and 46 were taken across the shale bed near the top of the Tertiary formation at stratigraphic section B (fig. 15). These samples were combined for analyses, the results of which are given in table 51. The other shale bed sampled (sample 47) is in the same stratigraphic section but is above bed F.

TABLE 51. - Healy River shale analyses

Sample No.	Percent						
	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O
45-46	2.8	2.2	58.3	18.3	6.1	1.58	0.20
47	2.0	1.3	61.2	16.2	6.5	.71	.25

Homer Clay

Location and Accessibility. - The clay bed near Miller's Landing in the Homer area was sampled as a source of argillaceous material for use with the Seldovia limestone in the production of cement. This deposit was sampled because of its location adjacent to the town of Homer and because of its accessibility, by barge on Cook Inlet to Anchorage or by the new Sterling Highway to both Anchorage and Seward. Homer is on the north shore of Kachemak Bay near the tip of the Kenai Peninsula.

The location of the clay outcrop near Miller's Landing is shown on figure 18.

Description of Deposit. - A 30-foot bed of blue clay outcrops 0.8 mile south of Miller's Landing in the bluff along Kachemak Bay east of Homer, Alaska. The clay lies between two coal bvds near the top of the stratigraphic section shown on figure 19. At this locality, the formation dips gently northward.

Sample 77 was taken across the 30-foot thickness of this clay bed. The results of analyses follow;

Sample No.	Percent						
	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O
77	0.5	1.9	60.4	16.0	6.4	0.01	1.78

Conclusions. - Although no readily accessible argillaceous material whose alkali content is below the maximum allowed has been sampled by the Bureau of Mines, much of the material sampled may be used in combination with the low-magnesia, low-alkali limestone from the Foggy Pass desposit.

The Bureau of Mines was to attempt to delimit a deposit of argillaceous material with less than 3.2 percent magnesia and 0.6 percent combined alkali.

Gypsum

Introduction

In the production of cement, a small amount of gypsum is added to control the set. Gypsum prevents a quick set and insures a uniform, dependable product. The gypsum is added to the clinker before it is ground to the finished product.

Enough gypsum ($CaSO_4 \cdot 2H_2O$) is added to furnish a maximum of 2 percent SO_3 in the final product. Inasmuch as the clinker already may contain up to 0.5 percent SO_3 derived from the fuel, limestone, and shale, the amount of gypsum added must be controlled closely. Each barrel of cement (376 pounds) requires 9 to 12 pounds of gypsum.

Only one deposit of gypsum is known to occur in the Alaska Railroad belt. This deposit is at Sheep Mountain on the Glenn Highway.

Location and Accessibility

The gypsum deposits on the south slope of Sheep Mountain are approximately 1 mile north of mile 113 on the Glenn Highway. The Glenn Highway is paved and open for travel throughout the year. Sutton, the nearest station on the Alaska Railroad, is 51 miles west of Sheep Mountain.

Only one of the smaller deposits (No. 6) can be reached by a rough truck road (fig. 13). The others are at higher altitudes and are more difficult to reach.

Physical Features and Climate

Sheep Mountain is an isolated, northeast-trending ridge on the north side and near the head of the Matanuska Valley. The Matanuska River flows westward between the Chugach Mountains on the south and the Talkeetna Mountains on the north. Sheep Mountain is separated from the main mass of the Talkeetna Mountains by Caribou Creek and its tributary, Squaw Creek.

Sheep Mountain is over 6,300 feet high; its slopes are steep and often barren. Evidences of glaciation are seen in the U-shaped valleys and glacial moraines in the district. The Matanuska Glacier is within a few miles of the gypsum deposits.

The climate at Sheep Mountain is more nearly that of the interior valleys of Alaska. Summers are warm and winters long and cold. The mean annual temperature at Sheep Mountain is 29.1° F. Annual mean precipitation, which falls mainly from July through November, is 10.43 inches.

History, Production, and Ownership

The gypsum deposits on Sheep Mountain were originally discovered by George Fennimore of Anchorage, Alaska. In 1948, the mineralized zone was partly covered by a group of 14 claims held by the Alaska Gypsum Queen Corp. The stockholders of the Gypsum Queen Corp. are George Fennimore, Nellie Fennimore, and Leland Johnson of Anchorage and Bob Clem of Palmer, Alaska. The property was leased to the Anchorage Gypsum Products Co. The Anchorage Gypsum Products is owned by George Fennimore, Don H. Goodman, and Ed Johanson of Anchorage.

Anchorage Gypsum Products was interested in the production of building materials containing gypsum, especially wallboard. In September 1948 the Bureau of Mines made a preliminary investigation of the gypsum deposits and procured an 800-pound sample from deposit 6 for metallurgical testing.

During the summer of 1949, the Geological Survey[85] mapped and sampled the area containing the gypsum deposits.

Approximately 50 tons of calcined gypsiferous material has been produced from deposit 6.

General Geology

The gypsum deposits at Sheep Mountain occur in an altered phase of the Jurassic Talkeetna formation.[86] This formation consists of interbedded volcanic rocks. The volcanic rocks in the vicinity of the gypsum deposits have been altered to greenstone, gypsum, and gypsiferous quartz-sericite rock.

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[85] Eckhart, R. A., Gypsiferous Deposits on Sheep Mountain, Alaska; Geol. Survey mim. rept.; 1950, 31 pp.

[86] Work cited in footnote 12, pp. 16-17.

Description of Deposits

There are six areas of gypsiferous material on Sheep Mountain that were mapped as units and in detail by Eckhart. (Fig. 13 in this report is modified from Eckhart's fig. 2)[87] The gypsiferous areas contain gypsum as irregular lenses and narrow veins, scattered grains and earthy masses of gypsum, and altered country rock.

Deposit 1 is on the ridge between Gypsum and Yellow Jacket Creeks at 4,500 feet. Deposits 2, 3, 4, and 5 are exposed along the slope on the left limit of Yellow Jacket Creek at approximately the same altitude.

Deposit 6 is in the gulch formed by Gypsum Creek at 3,500 feet; it is the only deposit accessible by truck.

During the cursory examination of the gypsum area by the Bureau of Mines in 1948, the main attention was paid to deposit 6, which was the most accessible and from which Anchorage Gypsum Products had made some production. Because the deposit contained considerable impurities in the form of altered country rock, a large sample, C, was submitted for beneficiation tests. Two small samples, A and B, were taken of small but high-grade gypsum lenses in deposit 1. Analytical results of these samples are given in table 52.

TABLE 52. - Analyses of Sheep Mountain gypsum

Sample No.	Thickness, feet	Percent							
		CaO	SO_3	SiO_2	R_2O_3	MgO	NaCl	H_2O[1]	$CaSO_4$[2]
A	1.5	24.1	34.4	21.1	3.2	0.1	0.29	14.9	58.5
B	2.0	27.5	39.9	11.2	2.7	.15	.16	16.9	66.8
C	10.0	14.2	20.1	38.1	13.4	.75	.21	8.5	34.5

[1] Combined water.
[2] Calculated $CaSO_4$.

The sample submitted for beneficiation was found to contain 24 percent gypsum and 28 percent alunite. These facts made calculation of the test results from assays meaningless because several sulfate alumina and calcium-bearing minerals are present; furthermore the water of crystallization of gypsum is very unstable. The results of a microscopic study of the ore indicated that the gypsum particles are all minus-100-mesh and that most of them are minus-200-mesh. The alunite particles are somewhat coarser, but all are minus-65-mesh. The country rock particles range in size from 20-mesh to minus-200-mesh. To liberate these minerals from one another, the ore will have to be ground at least to minus- 100-mesh. The result of this preliminary information indicates that the Sheep Mountain gypsiferous material, as represented by the sample from deposit 6, is not a very promising source of gypsum because of its low-grade, finely crystalline nature and complex mineralogy.

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[87] Work cited in footnote 83, figures 2 and 3.

Conclusions

The Sheep Mountain deposits of gypsiferous material cannot be used as a source of low-cost, high-grade gypsum for cement production.

AGGREGATES

Natural aggregates are exceedingly plentiful in Alaska. Erosion has produced an abundance of sand and gravel that is so essential not only for concrete but for all modern construction programs. Because of their plentiful supply and past performance in use, no samples were taken by the Bureau of Mines.