RI bureau of mines
report of investigations 6002

SOME NONMETALLIC MINERAL RESOURCES FOR ALASKA'S CONSTRUCTION INDUSTRY

By R. S. Warfield

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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UNITED STATES DEPARTMENT OF THE INTERIOR
Stewart L. Udall, Secretary

BUREAU OF MINES
Marling J. Ankeny, Director

This publication has been cataloged as follows:

Warfield, Robert S

Some nonmetallic mineral resources for Alaska's construction industry. [Washington] U. S. Dept. of the Interior, Bureau of Mines [1962]

ii, 25 p. illus., maps, tables. 27 cm. (U. S. Bureau of Mines. Report of investigations, 6002)

1. Mines and mineral resources—Alaska. 2. Construction industry—Alaska. I. Title: Nonmetallic mineral resources for Alaska's construction industry. (Series)

TN23.U7 no. 6002 622.06173

U.S. Dept. of the Int. Library

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by

R. S. Warfield[2]

INTRODUCTION AND SUMMARY

Following World War II, the rapid increase in both military and civilian activity in the area served by the Alaska Railroad stimulated interest in the availability of local sources of nonmetallic minerals that might be used for building materials. Except for abundant sand and gravel and some pumice, the construction industry of the area depended entirely on high-cost imports for building materials of mineral origin. Because continued rapid growth was anticipated, development and use of local sources of such materials was advocated by both military and civil authorities to reduce the high costs of construction and bolster the unstable economy of the area. The U.S. Department of the Interior began a program that included examining the numerous deposits of nonmetallic minerals accessible to the Alaska Railroad to determine their possible use as raw materials for the construction industry.

Preliminary field investigations were made by the Geological Survey. The more promising deposits were subsequently examined and sampled by Bureau of Mines engineers, and the samples were subjected to the laboratory tests necessary to indicate the chemical and physical characteristics of the raw materials or their products. Such field and laboratory investigations were conducted on clay, shale, argillite, limestone, gypsum, and pumice taken from various parts of the area. In initial phases of the work, done from 1948 through 1952, many of the deposits examined were suitable for producing building materials. Results of the work completed during that period have been published in a Bureau of Mines report[3] giving general information and detailed data on more than 35 deposits that were investigated.

After publication of the report, more laboratory testing was done on production of expanded shale and mineral wool, and more extensive sampling was

[1]Work on manuscript completed April 1961.

[2]Mining engineer, Alaska Office of Mineral Resources, Region I, Bureau of Mines, Juneau, Alaska.

[3]Ruthledge, F. A., Thorne, R. L., Kerns, W. H., and Mulligan, J. J., Preliminary Report: Nonmetallic Deposits Accessible to the Alaska Railroad as Possible Sources of Raw Materials for the Construction Industry: Bureau of Mines Rept. of Investigations 4932, 1953, 129 pp.

done on limestone and shale deposits in the Cantwell vicinity. Laboratory tests indicated that at least three of the shales previously tested would produce a good grade of lightweight aggregate over a greater firing range than that originally determined. Excellent mineral wool was produced experimentally in the laboratory by mixing approximately equal portions of shale and limestone from deposits near Cantwell. Samples from the extensive limestone deposits in the Foggy Pass area (near Cantwell) contained a minimum of impurities that are objectionable in cement.

This report presents detailed data on the foregoing field and laboratory investigations that were conducted after the publication of Report of Investigations 4932.

LIGHTWEIGHT AGGREGATE--TEST RESULTS

As a result of work completed before 1950, three deposits of shale were determined to be worth more thorough firing tests; these were selected for reasons of location, favorable bloating characteristics, or interest shown by potential private users. The deposits are located at Mile 67, Glenn Highway; Mile 16, Matanuska Branch of the Alaska Railroad; and a railroad cut along Indian River, 166 miles north of Anchorage (fig. 1).

Work included additional firing tests in a stationary kiln and rotary kiln runs in a laboratory-size kiln to simulate commercial practice. The reason for making these later tests on relatively large samples was to define more closely the temperature range of bloating and thus, the temperature range within which an acceptable lightweight aggregate could be produced commercially.

Mile 67, Glenn Highway, Sample 690

Sample 690 (about 2,300 pounds of raw material) was taken from material exposed by the highway cut; this was the same location from which preliminary samples 3, 4, 5, 6, and 32[4] were taken (fig. 2). The deposit is a nearly uniform shale with only small amounts of grit; the material crushes readily to the desired size, producing a relatively low proportion of fines.

The later series of firing tests (fig. 3) indicated a much greater firing range than had been determined by the earlier tests. Bloating started at about 1,950° F., reached a peak of good bloating at about 2,100° F., and continued through 2,200° F. At the last temperature the material was becoming overbloated, making it structurally weak.

An excellent feature of the wide bloating range was the lack of stickiness until the temperature approached 2,200° F.; thus, the full bloating range of 250° F. could be used in commercial processing. It was demonstrated in the laboratory-size rotary kiln that the material was easy to handle, and pelletizing or pretreatment other than crushing and sizing was not necessary.

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[4]Work cited in footnote 3 (p. 1), pp. 54-60.

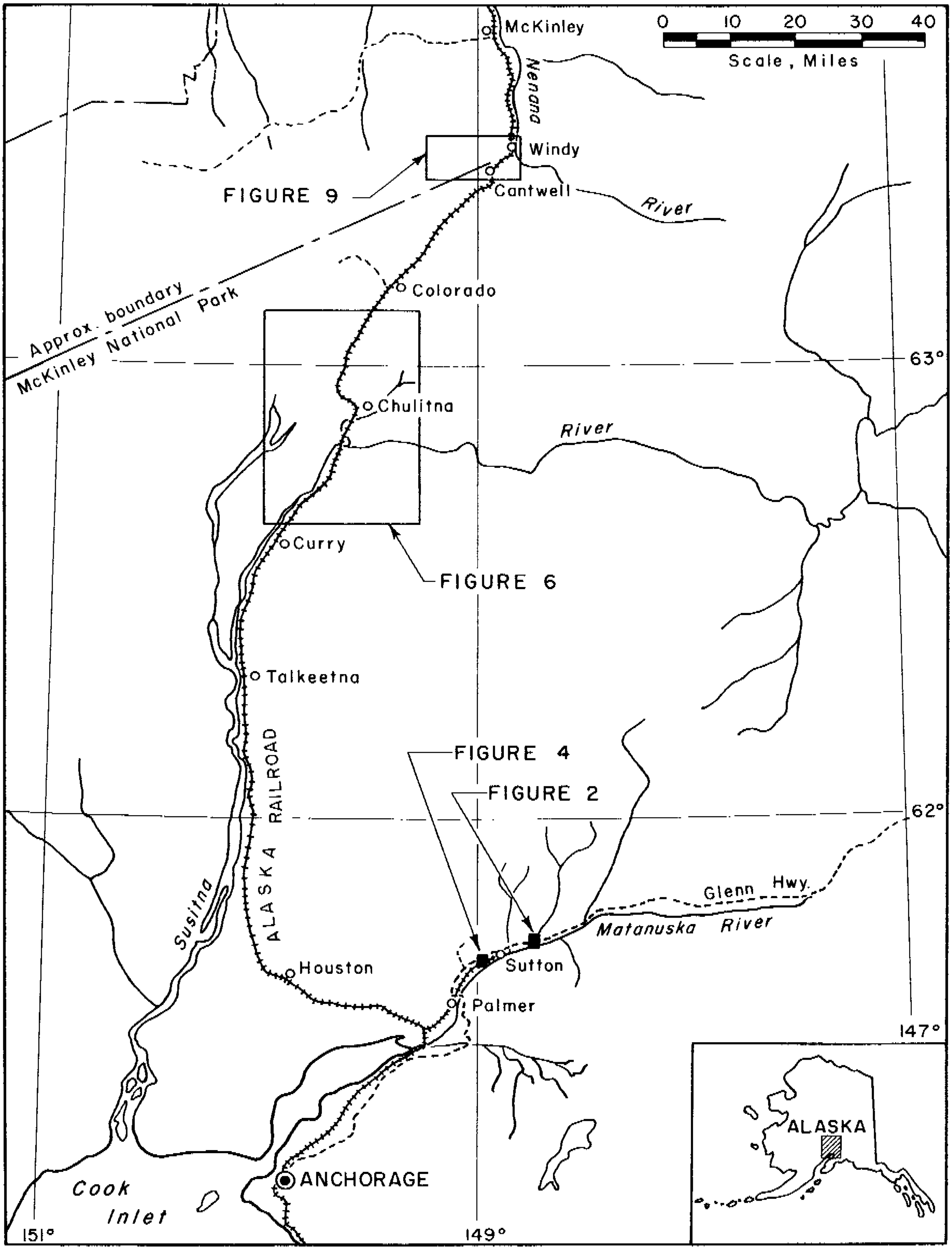

FIGURE 1. - Location Map of Alaska Railbelt Nonmetallic Deposits.

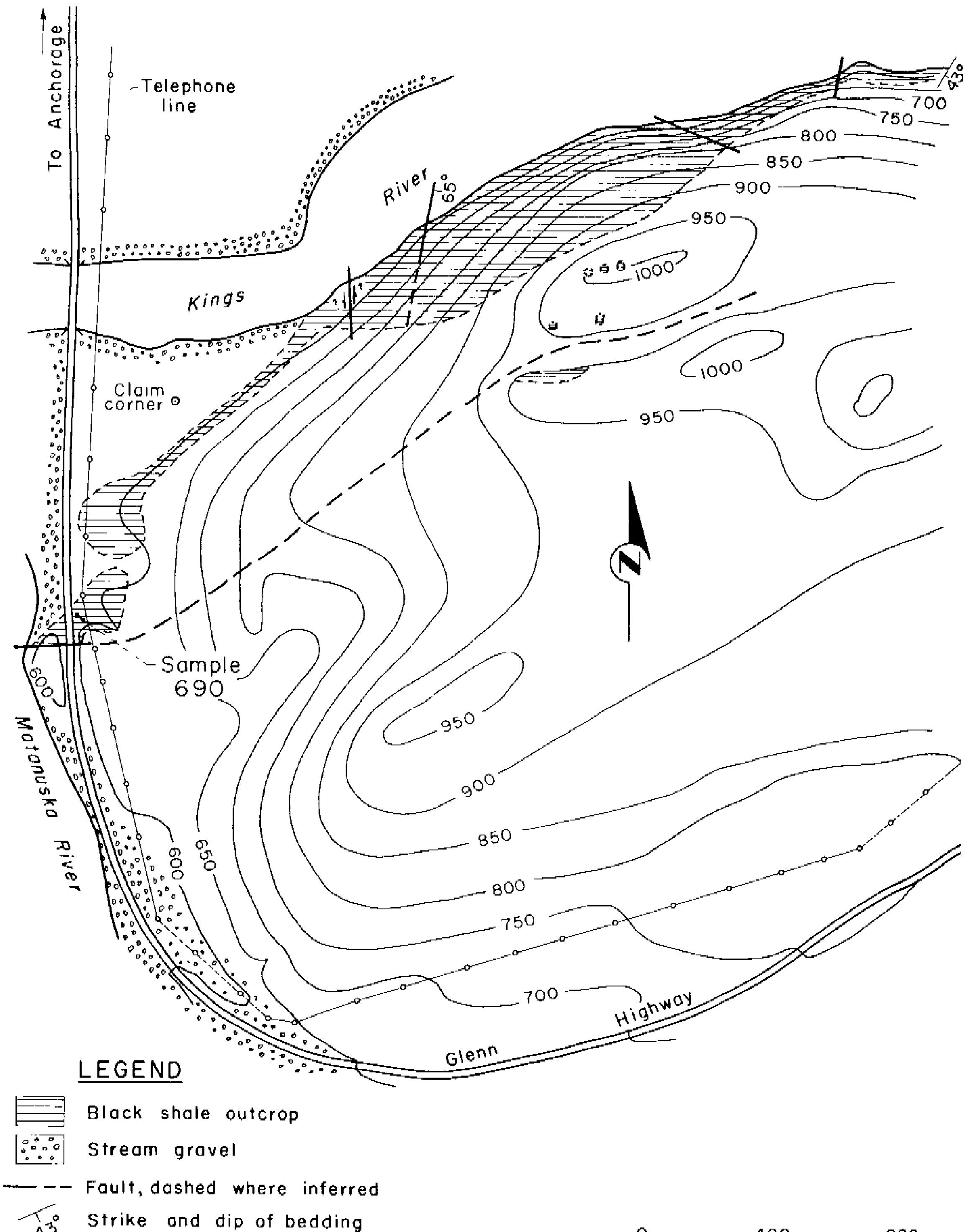

FIGURE 2. - Geologic Map, Mile 67 Shale Deposit.
(Geology from USGS Preliminary Map.)

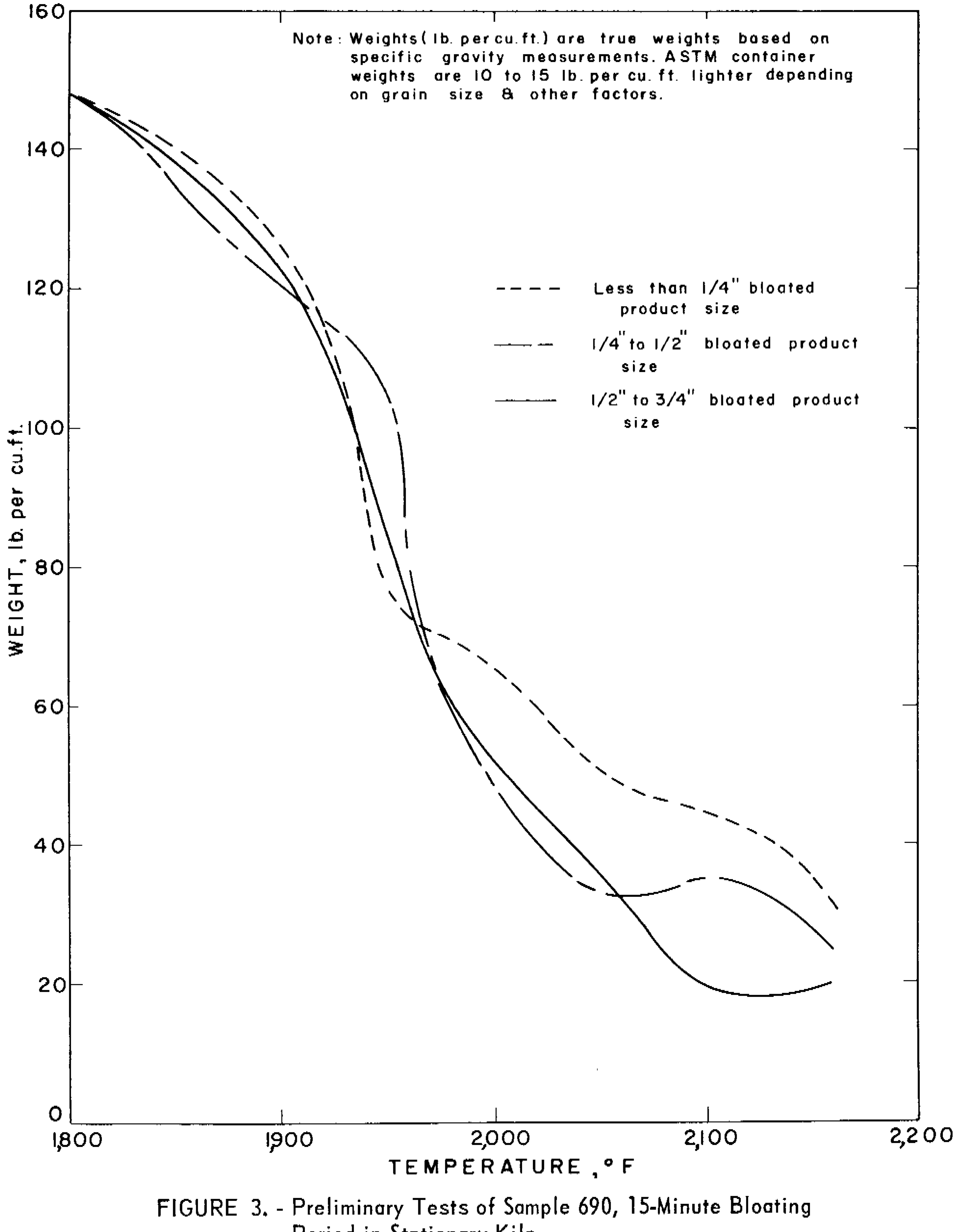

FIGURE 3. - Preliminary Tests of Sample 690, 15-Minute Bloating Period in Stationary Kiln.

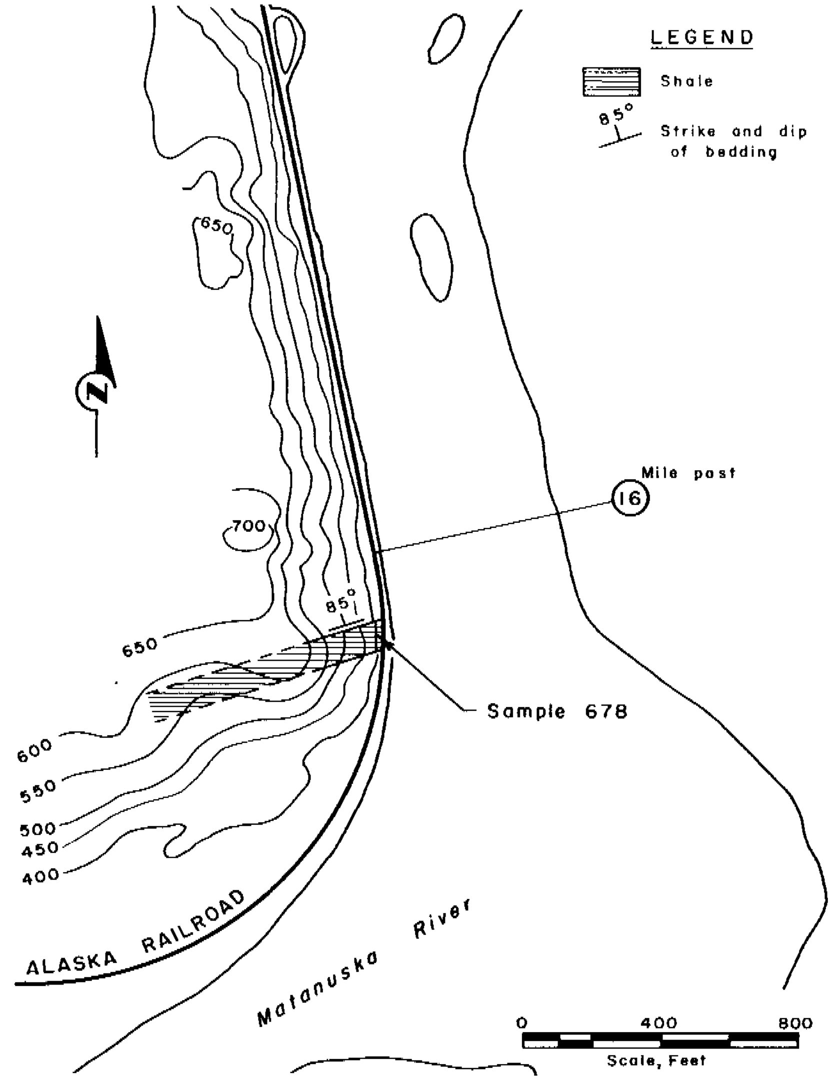

FIGURE 4. - Mile 16 Shale Deposit.

The bulk density of the bloated product varied with the temperature used and somewhat with the size of the raw material; the fines bloated to a heavier product than the coarse. Similar density variation is also common in commercial operations.

An excellent-appearing lightweight aggregate was produced from the shale from the Mile 67 deposit. The bloated lumps had a fine vesicular structure with uniformly spaced pores; also, the lumps tended to be spherical with a good surface coating. In general, the test work has indicated this shale to be highly acceptable for commercial production of a lightweight aggregate.

Table 1 and figure 3 illustrate results of this test work.

TABLE 1. - Data from rotary kiln products

Sample	Mesh size	Temperature, ° F.	Apparent specific gravity	Bulk density lb./cu.ft.	Absorption, percent
690...	Plus 4	1,920	1.28	79.7	11.9
	Minus 4, plus 8	1,920	1.45	90.3	11.7
	Plus 4	2,000	.69	43.0	10.0
	Minus 4, plus 8	2,000	.97	60.4	11.8
679...	Minus 2, plus 8	1,950	1.80	112.0	11.0
680...	Plus 4	2,000	1.01	62.9	10.4
	Minus 4, plus 8	1,920	1.08	67.2	10.3

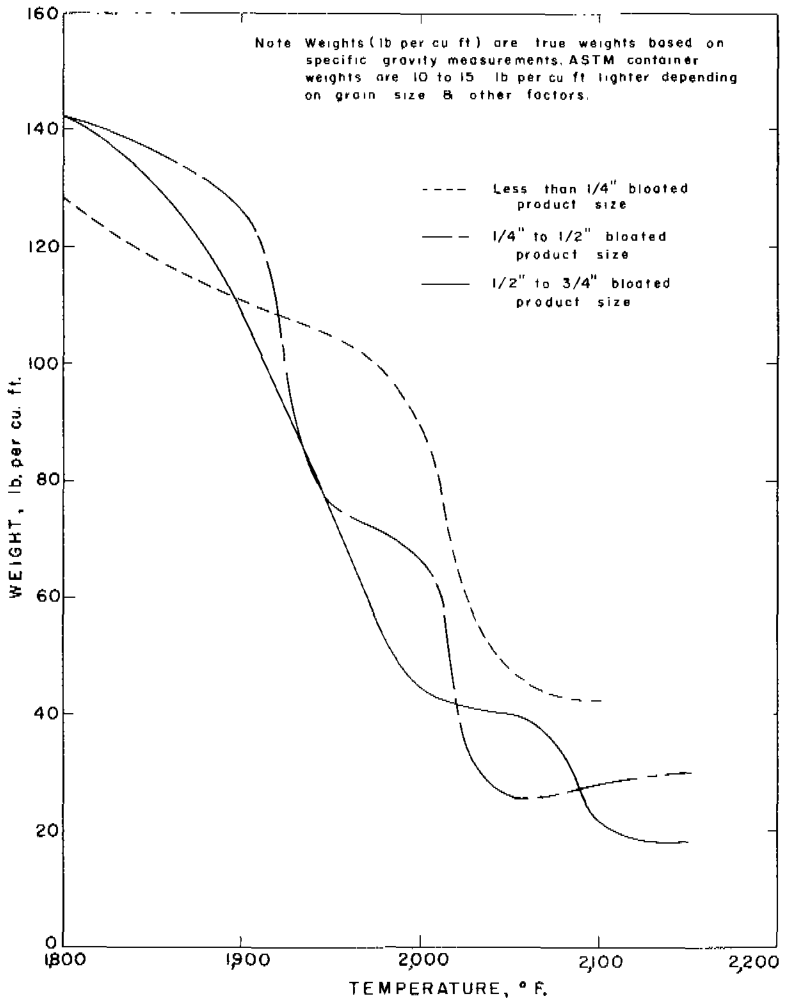

FIGURE 5. - Preliminary Tests of Sample 678, 15-Minute Bloating Period in Stationary Kiln.

Mile 16, Matanuska Branch, Sample 678

Sample 678 was taken from shale exposed in a railroad cut at the base of the bluff along the right bank of the Matanuska River (this deposit was represented by preliminary samples 53 and 54,[5] figure 4). The sample was cut across 100 feet of the shale deposit, located 280 feet south of Mile 16 on the Matanuska Branch of the Alaska Railroad.

Test work on the large sample from this deposit yielded results practically identical to those obtained from the Mile 67 deposit. The material crushed uniformly, and the size of the bloated product could be controlled readily by sizing the raw feed.

Figure 5 illustrates results of the test work.

Indian River Argillite, Samples 679 and 680

Samples 679 and 680 were taken from argillites exposed in the cut of the Alaska Railroad along Indian River, 4 miles south of Chulitna Station. Sample 679 corresponds to preliminary sample 204,[6] which was taken across 40 feet of argillite, 50 feet south of the Indian River bridge at Mile 269.9. Sample 680 corresponds to preliminary sample 205 and was taken across 90 feet of interbedded argillite, 50 feet north of the same bridge (fig. 6).

From testing sample 679, it was determined that the deposit of argillite it represented would not be suitable for production of lightweight aggregate. The sample was a fairly soft, thin, flaky shale; the crushed raw shale tended to be splintered and thin rather than in the desired lump form. When fired, only a portion of the material bloated; this occurred from 1,950° F. to about

[5]Work cited in footnote 3 (p. 1), pp. 60-61.
[6]Work cited in footnote 3 (p. 1), pp. 68-70.

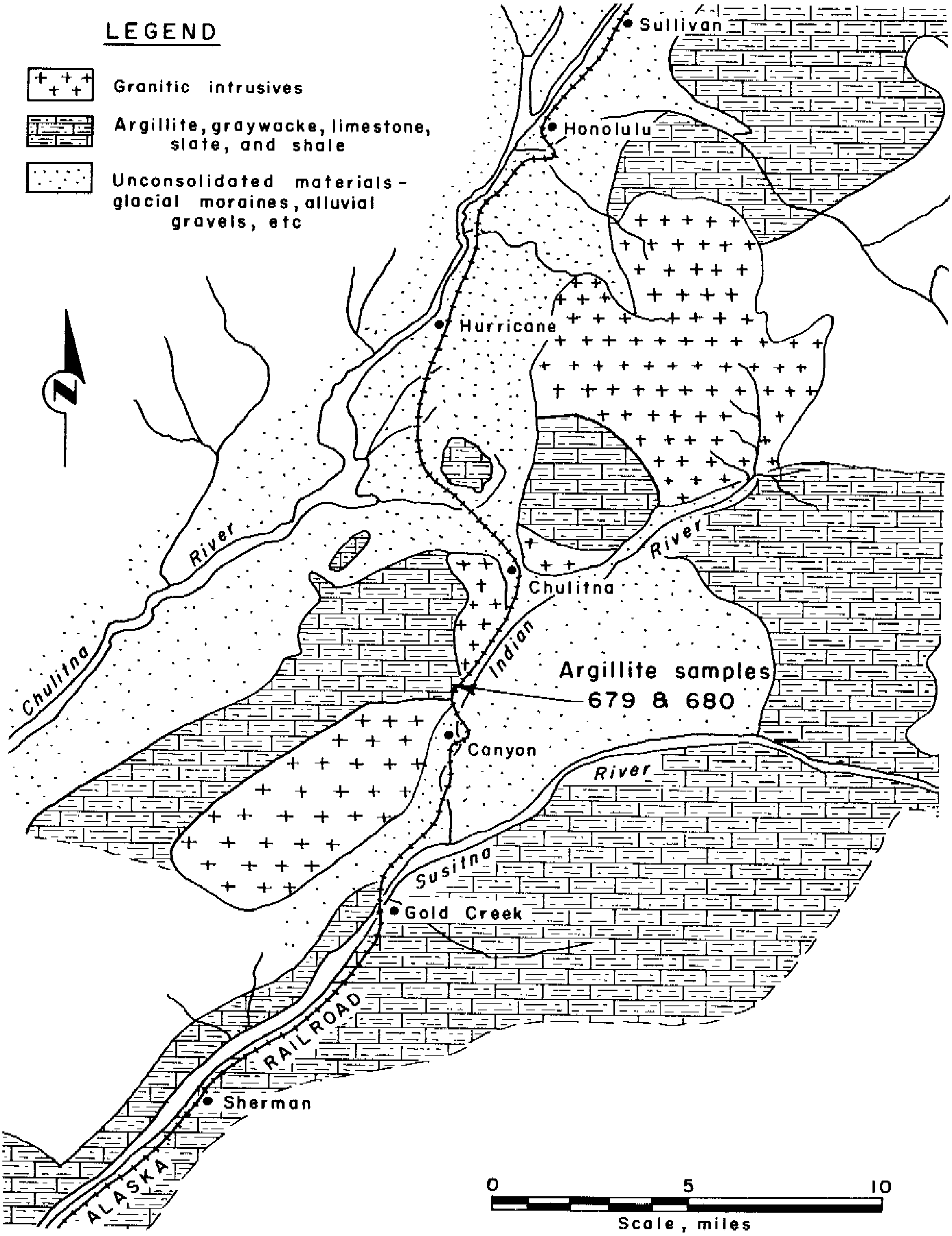

FIGURE 6. - Geologic Map of Indian River Argillite.
(Geology from USGS Map.)

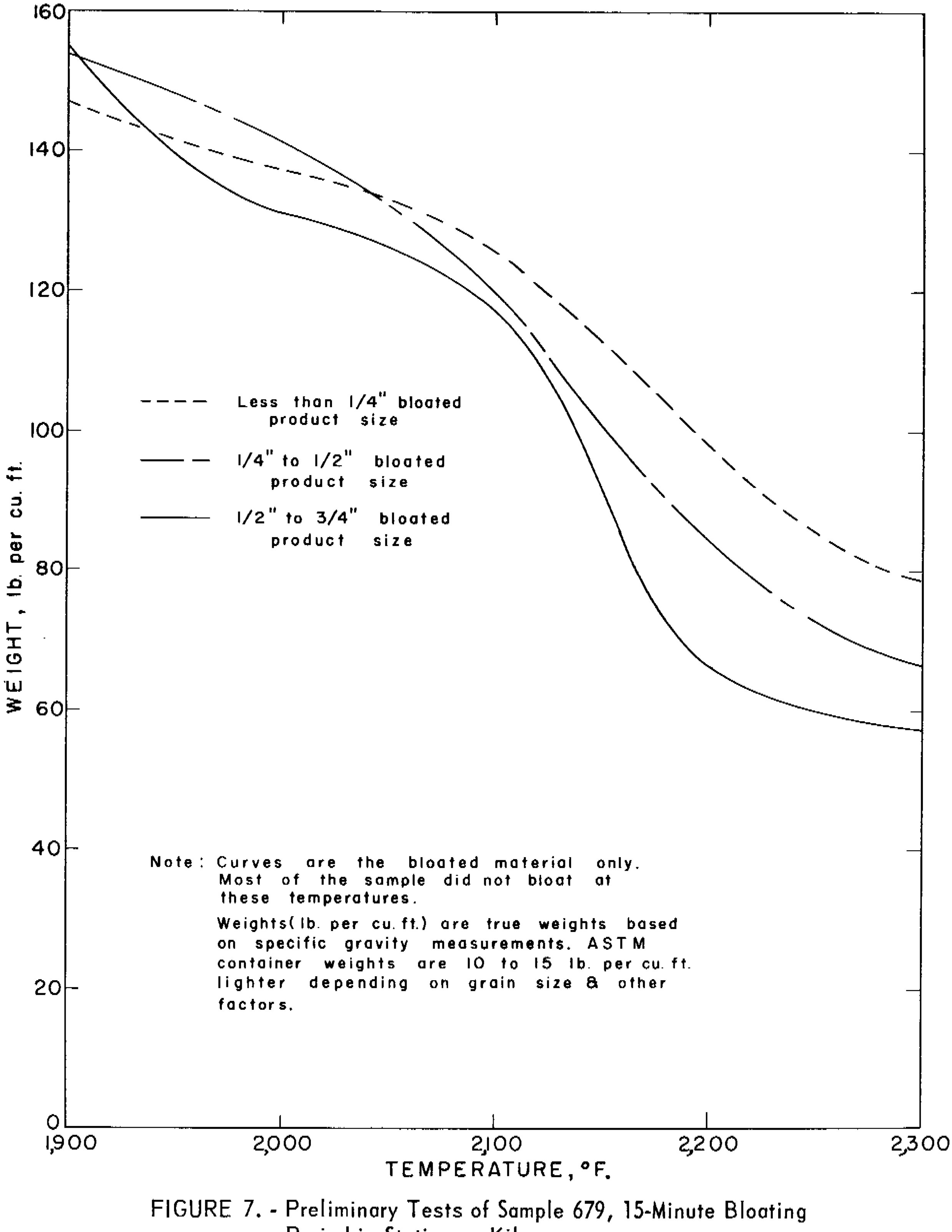

FIGURE 7. - Preliminary Tests of Sample 679, 15-Minute Bloating Period in Stationary Kiln.

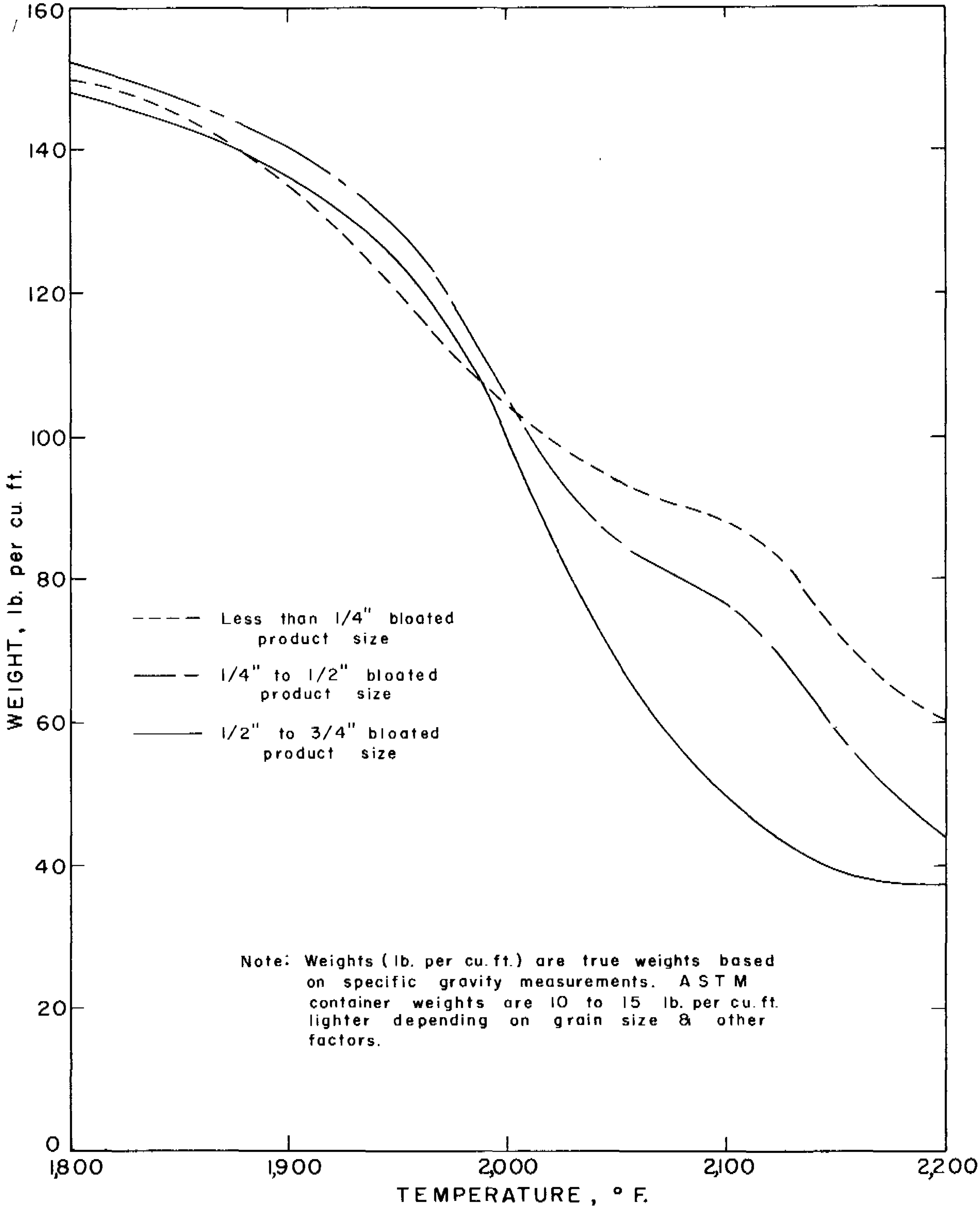

FIGURE 8. - Preliminary Tests of Sample 680, 15-Minute Bloating Period in Stationary Kiln.

2,000° F. The bloat was poor at 1,950° F. and became sticky at 2,000° F. This temperature range is considered to be too narrow for successful commercial bloating.

Sample 680 was reported to have much the same bloating characteristics as sample 690, except that the bloating range for sample 680 was about 50° F. narrower. Bloating started at about 2,000° F., reached a peak of good bloating at about 2,100° F., and continued through 2,200° F. The deposit represented by this sample is considered to be a very good potential source of raw material for lightweight-aggregate production.

Table 1 and figures 7 and 8 illustrate the results of firing tests on samples 679 and 680.

MINERAL WOOL--TEST RESULTS

Mineral wool, a calcium silicate glass in the form of fine fibers, is a processed fibrous material resembling loose wool. The principal use of mineral wool is as an insulating agent. Mineral wool, or a similar insulating agent, is of prime importance to Alaskan construction because of the rigorous climate; all insulating materials of this type presently are imported.

Mineral wool is manufactured by subjecting a calcium silicate melt to a strong blast of air or steam.

As discussed in a previous report,[7] chemical analyses of numerous samples indicated that the components needed to produce mineral wool were present in deposits of limestone and shale located in several areas.

Samples 622 and 629 of limestone and shale from the Windy-Cantwell area were submitted to the Bureau of Mines for blowing tests. (See figure 9 for sample location.) Chemical analyses of these samples are shown in table 2.

TABLE 2. - Chemical analyses of limestone and shale samples submitted for mineral-wool blowing tests

Sample	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Ignition loss	CO_2[1]	SO_3	P_2O_5	NaCl + KCl[2]	K_2O[2]	Na_2O[2]
622-limestone	51.0	0.14	0.8	0.70	1.2	41.2	39.4	0.18	0.002	0.16	-	-
629-shale....	.4	.07	60.0	15.1	9.0	4.3	-	.21	.32	-	0.66	0.4

[1] 400° to 1,000° C., direct combustion.
[2] Determined by gravimetric methods.

[7] Work cited in footnote 3 (p. 1), pp. 85-87, 91-115, 124-125.

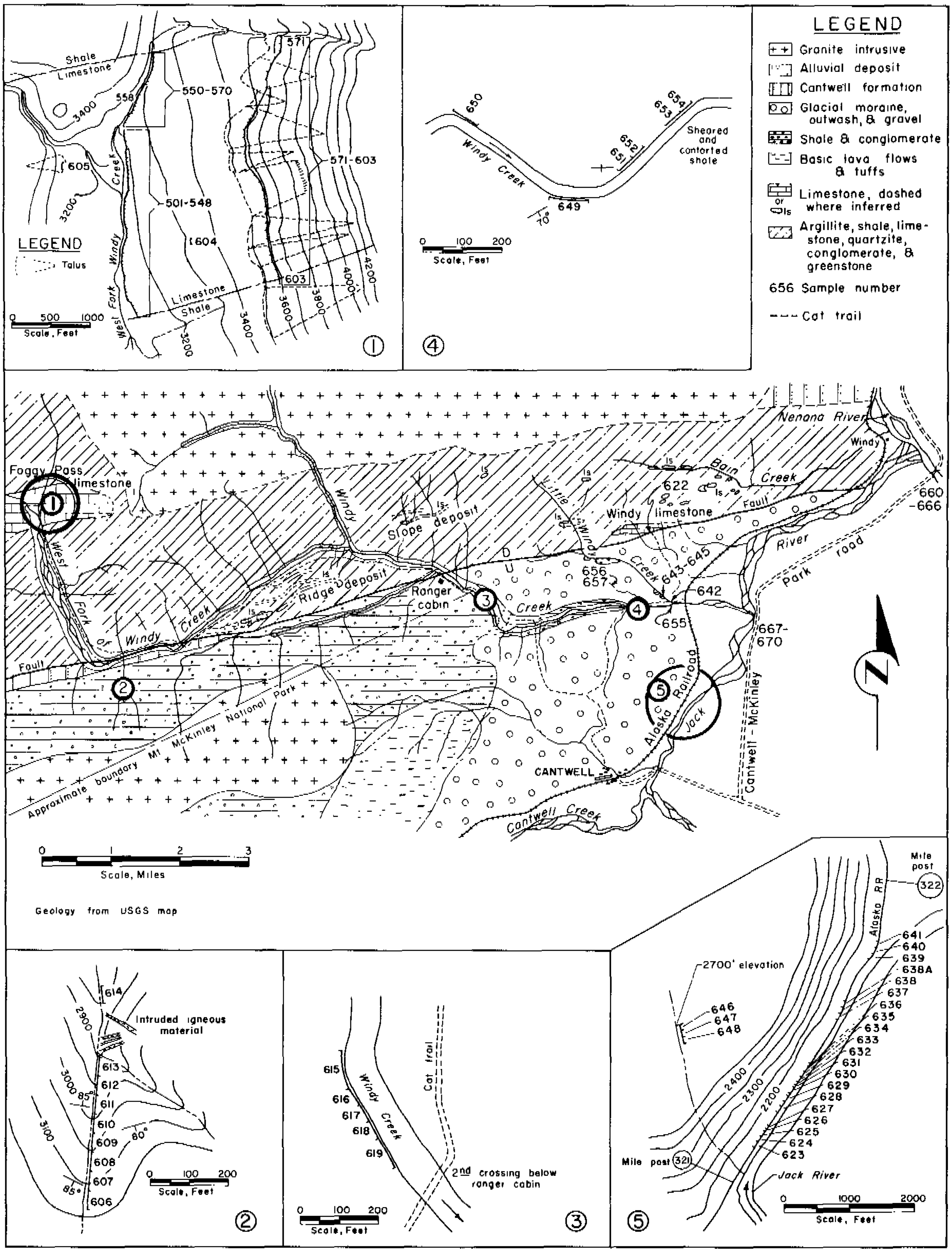

FIGURE 9. - Geologic and Sample Maps, Cantwell-Windy-Foggy Pass Area.

The limestone and shale were blended in various proportions for blowing tests. The results are quoted as follows:

"Several of the mixes produced acceptable wool as evaluated by laboratory methods. We consider wools from about 3 to 10 or 12 microns in average fiber diameter to be in the proper range. From a competitive and economic standpoint 'included shot' should preferably be less than 50 percent by weight. Iron is rather high in the shale sample but since sulfur is low there is little likelihood of forming enough hydrogen sulfide to give the wool an offensive odor.

"These data (table 3) show that a mix of 45 to 50 percent shale with the balance limestone produces the optimum mineral wool. Fast pours may be made in this range, the shot contents are not excessive and the temperatures, although high, are not out of line. Above 2,800° F., fuel requirements and corrosion on equipment accelerate rather rapidly."

TABLE 3. - Mineral wool from Alaskan shale and limestone

Test	Percent by weight		Steam p.s.i.	Melting temperature, ° F.	Time, seconds	Percent shot		Fiber diameter, microns	Remarks
	Shale	$CaCO_3$				Free	Included		
30	80	20	-	2,760	-	-	-	-	Too viscous.
37	70	30	42	2,950	45	11	-	-	Very coarse wool.
38	70	30	48	2,995	60	11	-	16	Coarse, brittle.
35	60	40	45	2,870	50	9.5	32	13	Slightly coarse.
36	60	40	44	2,900	46	15	-	-	Coarse.
31	50	50	44	2,700	34	9	36	11	Fair wool.
32	50	50	48	2,760	36	10	36	14	Coarse.
33	50	50	40	2,810	34	15	42	10.5	Good wool.
41	50	50	40	2,900	22	15	50	9	Do.
42	50	50	42	2,670	30	16	41	13	Somewhat coarse.
49	45	55	42	2,760	30	14	56	9	High shot.
50	45	55	40	2,800	20	17	46	9	Good wool.
51	45	55	32	2,850	27	13	42	8	Do.
39	40	60	45	2,700	33	17	52	11	High shot.
40	40	60	45	2,600	27	19	45	13	Slightly coarse.
47	40	60	40	2,690	29	20	47	8	Fair wool.
48	40	60	44	2,650	21	-	-	-	High shot.
43	35	65	42	2,750	24	-	-	-	Too basic.
44	35	65	42	2,700	25	-	-	-	Do.
45	35	65	42	2,830	-	-	-	-	Do.

CEMENT

Specifications

Portland cement is made by burning to a clinker a finely ground mixture of calcareous and argillaceous materials having an approximate composition of 70 to 75 percent $CaCO_3$; 20 percent SiO_2, Al_2O_3, and Fe_2O_3; and 5 percent or less MgO, alkalies, and other impurities. After cooling, the clinker is ground to 80 percent minus 325-mesh.

Most specifications require portland cement to meet standards set by the American Society for Testing Materials (ASTM). The ASTM classifications include five types of portland cement.[8] The most common is Type II, used in general concrete construction that will be exposed to moderate sulfate action or when moderate heat of hydration is required. In addition to ASTM standards, cement purchasers often specify other requirements in cement; the most common of these is a maximum allowable amount of Na_2O, K_2O, and MgO.

Limestone, or its equivalent, and clay or shale furnish the lime, silica, alumina, and iron required for cement. Sometimes small additions of silica sand and iron ore are necessary. Gypsum is added as a retarder in quantities of 2 to 3 percent and ground with the clinker. Only test results of the two major components of portland cement (limestone and shale) are described in this report. Should a cement plant be constructed in the railbelt area, a local source of high-silica material probably could be found; importing gypsum and a high-iron component might be necessary.

The suitability of limestone or shale for producing cement is partly dependent on the content of magnesia, alkalies, and alumina compounds. More than 5 percent magnesia is objectionable in cement (ASTM maximum allowable for Type II cement) because it may cause expansion as the concrete ages. The relative amount of magnesia present in the raw material constituents is increased in the finished cement by eliminating carbon dioxide, water, and organic matter during calcination. Therefore, to keep magnesia below the specified 5 percent, the raw mix should not exceed 3.2 percent MgO. Alkalies should not be present in excess of 1 percent because they may react with silicates, also resulting in expansion of the concrete.

Foggy Pass Limestone

A number of limestone and shale deposits were examined and sampled as part of the search to find materials suitable for portland cement. Results of studies conducted through 1950 were described in Report of Investigations 4932. Only one deposit was considered worth further study. It is known as the Foggy Pass limestone and is approximately 15 miles northwest of Cantwell, Alaska.

Investigations of shale deposits that might be used with Foggy Pass limestone to manufacture cement were confined to the immediate vicinity of the Foggy Pass-Cantwell area.

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[8] American Society for Testing Materials, 1958 Book of ASTM Standards: Philadelphia, Pa., pt. 4, pp. 1-5.

Location and Accessibility

The Foggy Pass limestone is located near the headwaters of the West Fork of Windy Creek within the Alaska Range (fig. 9). The deposit can be reached by a 15-mile tractor trail from the Alaska Railroad station at Cantwell. A road, following the general course of this tractor trail from Cantwell to a ranger cabin on Windy Creek, thence up Windy Creek to the deposit, could be built with relative ease. A railroad spur route probably would parallel Windy Creek from the present rail crossing of Windy Creek at Mile 323. Difference in elevation between the present railroad grade and the lowest limestone exposures along the West Fork of Windy Creek is about 800 feet. The deposit lies within Mount McKinley National Park. Unlike other national parks, prospecting and mining are permitted under certain conditions and regulations; these are best summarized by the following excerpts from a publication entitled Alaska Mining Laws:[9]

"Prospectors and miners may enter the Park and explore for mineral locations.

"Under an act of Congress approved January 26, 1931, the Secretary of the Interior is given authority to prescribe regulations for the surface use of any mineral location in the Park, and he may require the registration of all prospectors and miners who enter the Park, but no resident of the United States who is qualified under the mining laws of the United States applicable to Alaska shall be denied entrance to the Park for the purpose of prospecting or mining."

Physical Features and Climate

The limestone deposit is near the head of the wide, glaciated, north-south valley containing the West Fork of Windy Creek. The West Fork of Windy Creek swings east near the entrance to Foggy Pass until it joins Windy Creek; below the confluence, Windy Creek flows southeastward to the Jack River.

Mountain slopes in the area are steep, with talus outwash fans at their bases. The slopes above the talus are generally bare; vegetation, where present, consists of low brush along water courses and moss and grass on the gentle slopes.

The Foggy Pass limestone deposit is cut at an angle nearly normal to its strike by the valley of the West Fork of Windy Creek. The deposit rises on either side of the valley to form part of north-south trending ridges paralleling the West Fork of Windy Creek.

Subzero temperatures are expected in the Foggy Pass area from November through April. Freezing temperatures may occur in any month of the year; temperatures range from minus 50° to 80° F.

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[9] Roden, Henry, Alaska Mining Laws: Jessens Print, Fairbanks, Alaska, Rev. 1935, p. 22.

Rain and fog are frequent during the summer months. The average annual precipitation is 20 inches. Snow may be expected between September and June.

General Geology

The Foggy Pass limestone deposit is the eastern end of a band of Middle Devonian limestone,[10] exposed from east of the West Fork of Windy Creek to the head of Bull River. The limestone is part of a series of sedimentary rocks composed of shale, argillite, conglomerate, limestone, quartzite, slate, and graywacke.

Description of Deposit

The deposit is a dense, fine-grained, dark-gray to blue-gray recrystallized limestone. The strate are folded locally and contorted, but the degree of shattering is slight. Networks of calcite veinlets are abundant. Dips and strikes of individual beds vary greatly but the deposit as a whole strikes east and west and stands nearly vertical. The intricate folding of individual beds has probably caused repetition of bedding so that the thickness of the deposit can only be roughly estimated;[11] indicated thickness, as sampled along the West Fork of Windy Creek, is 3,100 feet.

Sampling Procedures and Results

Chemical analyses of five preliminary samples of the Foggy Pass limestone deposit are shown in table 4. Alkali content of each sample in the table was less than 0.01 percent.

TABLE 4. - Chemical analyses of five preliminary samples of the Foggy Pass limestone deposit

Sample	Length, feet	Assay, percent				
		CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3
163..............	[1]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	.40	4.0	1.3	.50

[1]Talus sample.

Favorable analyses of preliminary samples led to extensive sampling of the Foggy Pass limestone during the 1951 field season. Representative samples (501 through 570) were taken from channels 50 feet in length, cut along the limit of the West Fork of Windy Creek across the deposit width.

[10]Capps, S. R., Geology of the Alaska Railroad Region: Geol. Survey Bull. 907, 1940, p. 102.

[11]Moxham, R. M., West, W. S., and Nelson, A. E., Cement Raw Materials Available to the Windy Creek Area, Alaska: Geol. Survey Mimeographed Rept., 1951, 38 pp.

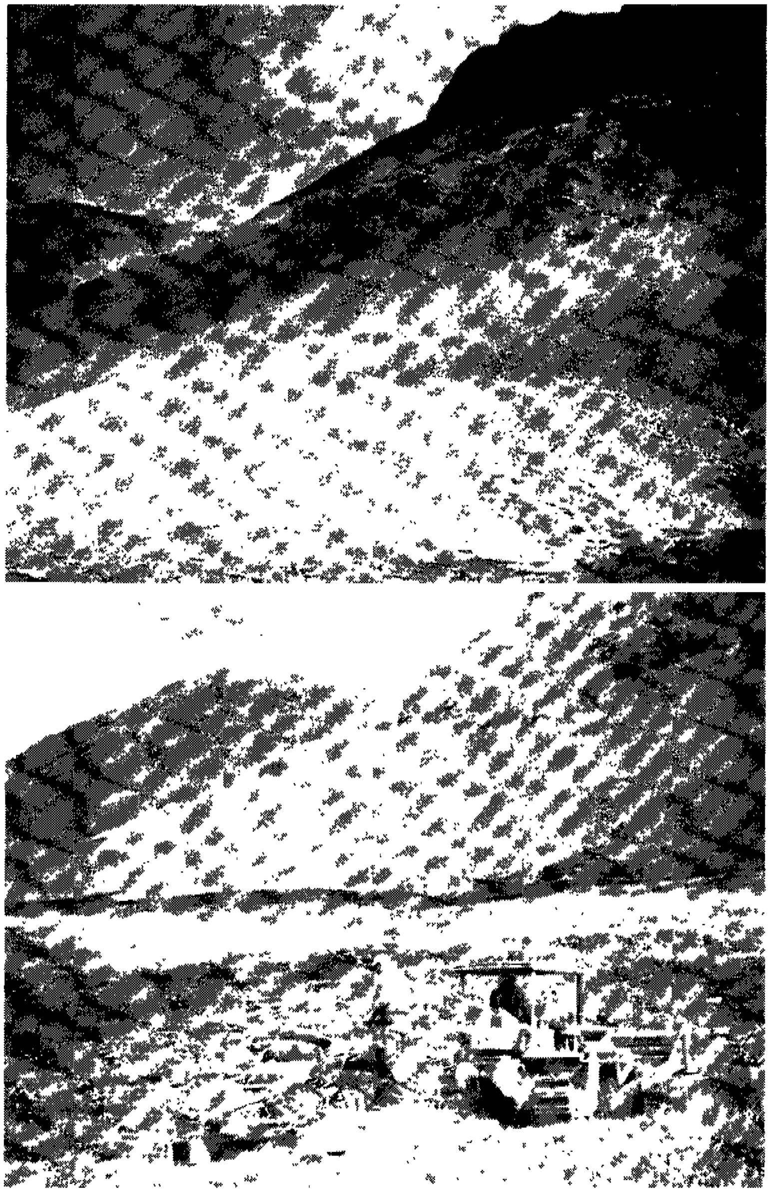

FIGURE 10. - Outcrop (Above) and Talus (Below) of Foggy Pass Limestone.

Large talus accumulations at the toe of the steeply rising deposit (fig. 10) afforded the opportunity to obtain representative samples both across the width and along the strike of material above the talus accumulation. Samples 571 through 603, each representing 100 feet of length, were collected from the talus accumulation. Other samples were 604, taken across an outcrop island, and 605, taken across a portion of talus accumulation on the west limit of the West Fork of Windy Creek Valley (fig. 9).

Samples were taken in large volume, mechanically crushed, and then split at the site to facilitate shipment to the Juneau Experiment Station. Chemical analyses of samples 501 through 605 are given in table 5.

Conclusions

The Foggy Pass limestone deposit is of suitable composition and of ample quantity to be used as the main constituent in portland cement. The limestone meets limits set for low-alkali cement, but some care would be necessary in mining to maintain low alkali in the final product. The talus accumulations are estimated to contain at least 14 million tons of already broken limestone. This amount would be sufficient to manufacture about 56 million barrels of cement (376 pounds of cement per barrel).

Shale Deposits, Cantwell-Windy-Foggy Pass Area

Numerous deposits of shale in the Cantwell-Windy-Foggy Pass area are of potential use in portland cement.

TABLE 5. - Chemical analyses of Foggy Pass limestone, percent

Sample	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Ignition loss	CO_2[1]	SO_3	P_2O_5	NaCl + KCl[2]	K_2O[2]	Na_2O[2]
501.......	43.8	1.1	9.24	3.8	1.9	36.6	36.0	1.02	0.04	0.18	-	-
502.......	31.0	2.0	24.0	7.1	4.4	26.6	25.4	1.26	.07	.80	-	-
503.......	47.8	1.45	6.4	2.1	1.1	39.2	38.8	.52	.018	.10	-	-
504.......	47.6	1.5	6.4	2.0	1.1	39.4	39.0	.54	.016	.04	-	-
505.......	51.4	1.8	1.86	1.15	.58	42.2	42.2	.22	.007	.16	-	-
506.......	52.2	1.45	1.14	1.0	.58	42.8	42.4	.20	.014	.10	-	-
507.......	52.2	1.3	1.74	1.0	.58	42.6	41.7	.30	.018	.70	-	-
508.......	52.6	1.4	1.24	.72	.58	42.6	42.1	.32	.019	.80	-	-
509.......	52.4	1.65	3.26	1.0	.58	42.7	41.7	.26	.03	.52	-	-
510.......	21.6	1.3	21.3	14.6	11.4	21.9	17.4	7.24	.25	.62	-	-
511.......	50.8	1.6	2.72	1.38	1.02	41.7	40.8	.74	.03	.58	-	-
512.......	50.6	2.0	2.20	1.47	.73	42.6	41.8	.30	.016	.41	-	-
513.......	50.6	1.65	2.40	1.57	.73	42.6	41.4	.28	.018	.62	-	-
514.......	50.2	2.45	4.00	2.07	.73	41.3	40.5	.42	.025	.18	-	-
515.......	50.0	2.0	3.50	2.33	.87	41.6	40.8	.48	.023	.14	-	-
516.......	48.4	1.8	4.8	2.55	.95	40.5	40.0	.50	.02	.40	-	-
517.......	48.3	1.7	5.3	2.78	1.02	40.2	39.4	.54	.025	.90	-	-
518.......	48.0	1.65	5.5	2.98	1.02	40.2	39.5	.56	.03	1.34	-	-
519.......	47.0	1.55	7.4	3.11	1.09	38.8	38.1	.62	.04	1.00	-	-
520.......	47.4	1.4	7.1	3.73	1.17	38.8	38.1	.66	.02	.86	-	-
521.......	46.4	1.45	8.4	3.95	1.45	37.6	37.6	.14	.013	.82	-	-
522.......	42.7	2.25	10.1	4.90	1.60	36.1	36.1	.22	.015	-	0.32	0.30
523.......	46.8	2.1	6.4	3.23	.89	39.2	39.0	.07	.023	-	.33	.26
524.......	49.4	1.8	5.0	3.05	.95	42.4	41.8	.06	.03	-	.23	.32
525.......	49.2	2.0	5.9	2.63	.87	41.1	41.1	.06	.035	-	.31	.41
526.......	49.5	1.8	4.7	2.93	.87	40.4	40.3	.07	.03	-	.38	.38
527.......	51.0	1.5	3.4	2.57	.73	41.2	40.9	.05	.019	.24	-	-
528.......	50.0	1.7	3.6	2.45	.95	40.8	40.4	.06	.020	.36	-	-
529.......	48.5	2.2	4.6	3.03	.87	40.6	40.6	.07	.020	.62	-	-
530.......	48.0	2.3	5.5	3.03	.87	40.4	39.8	.07	.020	.14	-	-
531.......	48.6	2.5	5.4	3.15	.75	40.3	40.0	.06	.025	<.01	-	-
532.......	47.0	1.8	7.8	3.05	.96	38.3	38.0	.08	.030	<.01	-	-
533.......	44.2	1.8	10.0	4.05	1.45	36.8	36.6	.11	.032	<.01	-	-
534.......	47.1	1.4	8.0	3.3	1.0	38.4	38.3	.06	.029	.16	-	-
535.......	49.6	1.9	4.4	2.3	.60	41.2	40.8	.03	.016	<.01	-	-
536.......	40.1	2.4	14.0	5.85	1.45	34.3	33.8	.12	.046	.44	-	-
537.......	46.6	1.7	6.9	3.75	.65	38.8	38.6	.06	.035	.92	-	-
538.......	49.0	1.5	5.5	3.60	.50	39.4	39.2	.06	.032	.88	-	-
539.......	46.8	1.9	6.1	3.7	.90	38.8	38.8	.06	.030	.90	-	-
540.......	50.4	1.4	5.4	2.15	.65	41.2	41.1	.01	.023	1.2	-	-
541.......	49.0	1.8	4.8	3.05	.95	40.2	39.8	.51	.025	.74	-	-
542.......	49.4	1.7	3.6	2.3	.60	40.6	39.9	.42	.020	.92	-	-
543.......	49.6	2.9	2.6	1.75	.65	41.9	41.7	.31	.020	1.2	-	-
544.......	49.5	2.0	3.6	2.50	.60	41.6	41.4	.36	.019	.46	-	-
545.......	46.9	2.3	6.1	4.25	.75	39.6	38.8	.62	.018	<.01	-	-

See footnotes at end of table.

TABLE 5. - Chemical analyses of Foggy Pass limestone, percent (Con.)

Sample	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Ignition loss	CO_2[1]	SO_3	P_2O_5	NaCl + KCl[2]	K_2O[2]	Na_2O[2]
546.......	48.7	2.4	4.0	2.05	0.95	40.5	40.2	0.75	0.019	0.56	-	-
547.......	48.1	2.9	5.2	3.0	.80	39.8	39.6	.45	.026	.20	-	-
548.......	47.4	1.1	6.8	3.7	.90	38.0	37.4	.67	.027	.14	-	-
550.......	47.6	1.6	6.0	3.25	.95	39.9	39.4	.73	.027	.76	-	-
551.......	47.8	1.95	8.8	3.85	1.15	37.6	37.1	1.1	.039	.50	-	-
552.......	47.8	1.9	7.0	3.55	1.15	39.2	38.8	1.0	.030	.70	-	-
553.......	47.8	1.65	7.4	3.05	.85	39.8	38.4	.95	.030	.24	-	-
554.......	48.1	2.4	6.2	2.95	.85	39.5	38.7	.69	.030	.08	-	-
555.......	48.6	1.25	3.5	2.55	.85	40.8	40.6	.45	.023	.10	-	-
556.......	48.9	.85	3.6	2.35	.85	40.7	40.6	.42	.017	.44	-	-
557.......	42.2	2.3	4.1	2.95	1.45	40.2	40.2	.60	.021	.84	-	-
558.......	45.1	2.4	5.8	3.85	1.15	39.7	39.3	.67	.023	.70	-	-
559.......	48.6	1.45	3.9	2.95	.85	40.7	40.4	.53	.025	<.01	-	-
560.......	49.1	1.9	5.2	2.8	1.0	39.8	39.6	.68	.019	1.0	-	-
561.......	43.5	2.7	5.4	4.0	1.4	39.8	39.5	1.0	.021	.86	-	-
562.......	46.3	2.0	4.4	4.3	1.1	39.9	39.8	.64	.022	.80	-	-
563.......	47.1	2.3	4.6	4.2	1.0	40.6	40.2	.65	.026	.50	-	-
564.......	47.4	1.9	5.0	3.7	.90	40.5	40.2	.76	.032	.62	-	-
565.......	50.0	1.5	4.9	2.65	.65	40.1	39.8	.72	.028	.42	-	-
566.......	52.3	1.5	4.7	2.55	.75	40.8	40.2	.67	.030	.24	-	-
567.......	48.4	1.5	11.3	3.2	.80	40.2	39.8	1.1	.041	.52	-	-
568.......	48.0	2.0	8.4	3.1	1.0	39.9	39.6	.80	.028	.48	-	-
569.......	49.7	1.8	5.0	2.45	.75	40.6	40.2	.57	.016	.22	-	-
570.......	48.3	1.3	5.0	3.05	.85	40.6	40.2	.35	.018	<.01	-	-
571.......	51.6	1.43	2.8	1.77	.43	42.2	41.8	.11	.014	.62	-	-
572.......	51.4	.73	2.8	1.55	.35	42.1	42.0	.06	.020	.30	-	-
573.......	50.8	1.48	2.4	1.6	.50	42.0	41.8	.15	.015	.82	-	-
574.......	49.7	2.75	3.3	1.92	.78	41.8	41.6	.22	.028	1.0	-	-
575.......	51.0	1.05	2.4	1.85	.35	42.2	42.0	.13	.023	.40	-	-
576.......	50.0	1.23	3.3	2.2	.50	42.1	41.8	.07	.025	.46	-	-
577.......	49.5	1.23	2.8	2.77	.43	41.8	41.4	.15	.025	.56	-	-
578.......	49.8	1.60	3.5	2.5	.50	40.9	41.6	.21	.023	.14	-	-
579.......	51.4	1.23	2.4	1.62	.28	42.8	42.6	.12	.020	1.1	-	-
580.......	51.4	1.43	2.4	1.77	.43	42.4	42.1	.08	.023	1.1	-	-
581.......	48.8	1.77	4.8	3.03	.57	40.1	39.9	.21	.028	1.1	-	-
582.......	48.5	1.81	5.1	2.69	.71	40.4	40.3	.20	.041	.40	-	-
583.......	48.4	1.45	4.7	2.9	.50	39.1	37.6	.22	.039	.96	-	-
584.......	49.6	1.41	3.8	2.77	.43	40.8	40.6	.18	.030	.48	-	-
585.......	50.6	1.35	3.2	2.02	.28	41.4	41.1	.15	.037	.06	-	-
586.......	49.2	1.20	4.5	2.45	.35	40.6	40.2	.38	.028	1.1	-	-
587.......	43.0	2.18	5.8	4.25	1.15	37.7	36.5	.18	.025	.66	-	-
588.......	46.2	2.02	7.1	3.32	.78	39.2	38.4	.62	.023	<.01	-	-
589.......	44.4	1.78	9.3	4.2	1.0	37.8	36.8	.37	.020	.70	-	-
590.......	43.0	1.45	9.9	4.4	1.0	37.6	36.0	.47	.025	.64	-	-
591.......	43.8	1.65	10.5	5.1	1.3	37.6	35.9	.24	.025	.10	-	-
592.......	47.0	1.9	6.2	3.7	1.1	39.4	38.8	.25	.028	.70	-	-

See footnotes at end of table.

TABLE 5. - Chemical analyses of Foggy Pass limestone, percent (Con.)

Sample	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Ignition loss	CO_2[1]	SO_3	P_2O_5	NaCl + KCl[2]	K_2O[2]	Na_2O[2]
593.......	47.0	1.6	6.3	4.2	1.1	39.0	38.0	0.33	0.035	0.70	-	-
594.......	47.4	1.5	4.7	3.55	.95	39.8	39.2	.26	.037	.24	-	-
595.......	45.8	1.35	4.7	2.97	.73	40.4	40.0	.16	.028	.44	-	-
596.......	46.8	1.9	4.7	2.97	.73	40.4	39.8	.15	.025	.50	-	-
597.......	40.8	1.65	3.6	2.85	.65	41.1	40.7	.12	.028	.74	-	-
598.......	48.6	1.5	4.2	3.47	.73	41.0	40.8	.12	.023	.54	-	-
599.......	49.2	1.65	2.8	2.27	.73	41.6	41.4	.14	.023	.40	-	-
600.......	48.0	1.9	3.5	2.37	.73	41.0	40.8	.17	.020	.68	-	-
601.......	46.2	1.9	3.7	2.47	.73	41.6	41.1	.07	.020	.62	-	-
602.......	48.1	1.9	3.4	2.67	.73	41.6	40.7	.09	.018	.62	-	-
603.......	48.1	1.5	3.9	3.2	.80	40.8	40.2	.08	.032	.26	-	-
604.......	46.9	1.65	3.0	2.47	.73	41.4	41.3	.06	.030	.64	-	-
605.......	46.9	1.3	6.5	3.6	1.0	39.4	39.1	.08	.016	.08	-	-

[1]400° to 1,000° C., direct combustion.
[2]Determined by gravimetric methods.

Location and Accessibility

All shales sampled are in the vicinity of the Foggy Pass limestone deposit and would be accessible from the West Fork of Windy Creek. Locations of outcrops and samples are shown on figure 9.

General Geology

The shales lie within a belt of rocks about 5 miles in width tentatively assigned to the Jurassic age.[12] This belt, estimated to exceed 5,000 feet in stratigraphic thickness, is comprised chiefly of shale and conglomerate with lesser amounts of argillite and graywacke, all of which have been closely folded, crushed, and faulted. They are bounded on the north and are in fault contact with rocks of Devonian age.

Sampling Procedures and Results

Bureau of Mines engineers obtained channel samples from a number of shale outcrops in the Cantwell-Windy-Foggy Pass area. These samples were all preliminary to determine which shales would be suitable for use in portland cement. No attempt was made to determine the uniformity or size of the various deposits; each deposit or part of a deposit was represented by one sample. Since the shale deposits in the area are extensive, quality of the shale probably would be important in determining mining location.

All of the shale samples taken during the investigation contained less than the maximum permissible limit of magnesia, but some samples contained more than the maximum limit of alkalies permissible for low-alkali cement. The chemical analyses of all shale samples are presented in table 6.

[12]Capps, S. R., The Eastern Portion of Mount McKinley National Park: Geol. Survey Bull. 836 (d), 1932, p. 263.

TABLE 6. - Chemical analyses of shale samples, percent

Sample	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Ignition loss	SO_3	P_2O_5	NaCl+KCl[1]	K_2O[1]	Na_2O[1]
606......	<0.05	1.95	66.5	15.2	6.4	3.8	0.19	0.28	-	0.44	0.42
607......	<.05	2.1	59.4	15.95	5.95	3.8	.17	.47	-	.90	.51
608......	<.05	1.65	63.8	17.9	6.4	4.6	.21	.30	-	.72	.38
609......	<.05	1.95	64.7	17.0	6.55	4.4	.28	.34	-	.62	.33
610......	<.05	2.0	64.0	17.15	6.55	3.8	.19	.28	-	.47	.25
611......	<.05	1.9	64.0	16.9	7.3	3.8	.14	.34	-	.45	.24
612......	<.05	1.9	64.4	17.45	6.75	3.8	.17	.27	-	.51	.27
613......	<.05	1.95	63.4	16.2	7.5	4.4	.24	.40	-	.57	.30
614......	<.05	2.1	63.0	16.0	7.3	4.1	.28	.27	-	.35	.18
615......	1.2	.13	59.8	16.8	8.05	4.3	.24	.37	0.86	-	-
616......	.8	.14	59.3	17.0	8.45	4.3	.28	.41	.93	-	-
617......	1.2	.09	59.4	18.1	8.05	4.2	.24	.32	.66	-	-
618......	1.8	.12	58.8	16.9	8.8	4.1	.62	.35	.60	-	-
619......	.4	.15	57.5	16.8	7.75	3.9	.26	.32	.61	-	-
620......	.2	.21	59.7	21.2	8.65	4.1	.19	.16	.58	-	-
621......	.6	.19	63.8	14.1	8.8	4.6	.24	.15	.53	-	-
623......	1.0	.13	57.1	16.5	8.05	4.0	.32	.21	.50	-	-
624......	1.2	.13	57.9	14.0	8.1	4.1	.34	.26	.48	-	-
625......	1.4	.07	60.0	13.4	8.45	4.5	.41	.23	-	.46	.38
626......	1.8	.11	56.6	12.9	8.0	3.9	.29	.35	-	.60	.36
627......	.6	.11	57.6	14.0	7.5	3.8	.24	.35	-	.58	.43
628......	.8	.06	59.6	16.5	9.8	4.1	.20	.37	-	.60	.50
629......	.4	.07	60.0	15.1	9.0	4.3	.21	.32	-	.66	.40
630......	.6	.07	61.5	14.0	8.8	4.4	.28	.28	-	.98	.20
631......	1.4	.11	57.5	14.1	8.1	4.0	.28	.23	-	.61	.60
632......	1.6	.12	61.6	15.0	8.05	4.0	.18	.30	-	.53	.36
633......	1.0	.11	68.2	11.2	8.0	4.0	.17	.32	-	.60	.61
634......	1.2	.14	57.2	20.0	7.8	3.8	.15	.34	-	.62	.61
635......	1.54	2.1	57.1	20.0	6.8	6.42	.25	.32	-	.49	.43
636......	.52	1.8	55.3	23.4	7.6	6.94	.19	.32	-	.36	.40
637......	.20	1.2	70.3	19.0	6.0	4.08	.21	.32	-	.38	.41
638......	.48	.9	62.1	18.3	6.0	4.20	.27	.28	-	.60	.58
638-A....	.40	.3	60.2	18.0	6.0	4.54	.29	.28	-	.63	.49
639......	.48	.5	59.0	21.0	6.8	4.64	.20	.34	-	.60	.39
640......	.72	2.2	57.5	18.7	6.0	4.58	.22	.39	-	.40	.36
641......	7.52	.5	70.4	12.8	3.8	6.90	.17	.40	.92	-	-
642......	.80	.6	57.8	22.7	7.0	5.36	.20	.34	1.0	-	-
643......	1.02	.3	57.6	18.1	6.6	5.22	.18	.28	.74	-	-
644......	1.10	.04	58.5	19.3	6.8	5.40	.28	.37	.82	-	-
645......	3.86	.4	55.6	14.2	4.0	5.84	.41	.28	.86	-	-
646......	.96	.3	66.6	15.2	5.0	3.00	.22	.28	1.0	-	-
647......	.76	.4	55.7	21.4	6.8	4.38	.14	.32	.56	-	-
648......	1.14	.09	59.4	22.1	7.2	4.40	.18	.32	.72	-	-
649......	1.14	.2	68.5	13.4	4.4	5.34	.07	.34	.90	-	-
650......	1.60	.6	65.1	16.1	5.4	4.14	.25	.28	.38	-	-
651......	.64	1.5	59.2	19.5	7.0	5.24	.24	.30	.46	-	-

See footnote at end of table.

TABLE 6. - Chemical analyses of shale samples, percent (Con.)

Sample	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Ignition loss	SO_3	P_2O_5	NaCl+KCl[1]	K_2O[1]	Na_2O[1]
652......	0.92	0.8	61.0	19.5	7.0	4.84	0.22	0.32	0.52	-	-
653......	.24	1.2	60.4	20.6	7.0	4.96	.20	.32	.58	-	-
654......	1.8	.29	62.6	22.7	7.5	5.2	.17	.30	.82	-	-
655......	2.2	.41	61.2	17.0	6.2	6.2	.28	.26	.92	-	-
656......	4.0	.21	70.2	12.9	4.9	4.4	.20	.28	.82	-	-
657......	1.6	.36	76.2	12.2	4.0	4.8	.21	.26	.76	-	-
660......	1.4	.14	68.0	16.6	6.0	3.8	.22	.28	.26	-	-
661......	1.0	.22	57.2	24.0	7.6	4.0	.24	.27	.32	-	-
662......	.8	.43	69.0	16.6	6.0	4.2	.21	.16	.34	-	-
663......	2.0	.36	72.2	12.4	4.2	6.4	.28	.13	.40	-	-
664......	1.4	.29	70.8	11.3	4.3	5.2	.18	.28	.46	-	-
665......	.8	.43	69.8	16.2	5.0	4.6	.20	.32	.58	-	-
666......	.6	.58	70.0	15.0	4.8	4.8	.21	.39	.70	-	-
667......	1.0	.21	74.4	13.9	4.9	3.8	.21	.30	.84	-	-
668......	1.2	.15	63.0	20.9	6.9	3.6	.19	.28	1.0	-	-
669......	.8	.07	70.0	17.2	5.0	4.0	.21	.28	.68	-	-
670......	1.4	.21	72.0	14.0	4.8	5.2	.22	.28	.58	-	-

[1]Determined by gravimetric methods.

Table 7 briefly describes visual observations made of the various shale outcrops and the samples taken.

TABLE 7. - Log of shale samples, Cantwell-Windy-Foggy Pass area

Sample	Sample length, feet	Individual sample description	Group description
606...	100		
607...	100		
608...	100		
609...	100		
610...	100	....	Shale samples taken along a small tributary to the West Fork of Windy Creek near Foggy Pass (fig. 9). This deposit is within a very short distance and easily reached from the probable road route to the Foggy Pass limestone deposit.
611...	100		
612...	100		
613...	100		
614...	100		
615...	100		
616...	50		
617...	50	....	A shale outcropping along Windy Creek located adjacent to the second tractor trail crossing downstream from the ranger cabin (fig. 9). The shale is black in color and grades from thin-bedded to massive badly fractured zones. A few pyrite crystals were observed.
618...	50		
619...	90		

TABLE 7. - Log of shale samples, Cantwell-Windy-Foggy Pass area (Con.)

Sample	Sample length, feet	Individual sample description	Group description
620...	50	A 50-foot bed of shale located between the third and fourth tractor trail crossing of Windy Creek, downstream from the ranger cabin (fig. 9).	
621...	500	A shale outcrop 500 feet in width along the south limit of Windy Creek, just downstream from the point at which the tractor trail leaves Windy Creek to enter the valley of a small tributary (fig. 9).	
623...	100	Black sheared shale, calcite on slickensides.	Shale samples taken along the cut of the Alaska Railroad between Mile 321 and 322 (fig. 9).
624...	100	do.	
625...	100	do.	
626...	50	do.	
627...	50	Bands of limy shale with some grading almost to limestone.	
628...	100	Dark-brown to black shale, exposure poor.	
629...	100	Dark shale.	
630...	100	do.	
631...	50	do.	
632...	50	Graywacke.	
633...	100	do.	
634...	100	Black, thin-bedded shale.	
635...	100	do.	
636...	43	do.	
637...	100	Black, thin-bedded shale grading to a more sandy phase.	
638...	100	Black thin-bedded shale.	
638A..	100	Black shale with some igneous intrusion.	
639...	100	Black shale.	
640...	100	do.	
641...	85	do.	
642...	54	A black, thin-bedded shale 65 feet in width along Little Windy Creek just above its confluence with Windy Creek (fig. 9).	

TABLE 7. - Log of shale samples, Cantwell-Windy-Foggy Pass area (Con.)

Sample	Sample length, feet	Individual sample description	Group description
643...	100		A thin-bedded, sheared black shale and graywacke that strikes N. 65° E. and dips S. The deposit is exposed along the limit of Little Windy Creek, approximately 500 feet upstream from sample 642. The samples represent a section 195 feet in width, ending on the hanging-wall side at the contact with an intrusive dike (fig. 9).
644...	95		
645...	150	Interbedded graywacke and shale 150 feet in width exposed along the limit of Little Windy Creek immediately upstream from the intrusive dike ending sample 644 (fig. 9).	
646...	100	Interbedded graywacke and shale. Contains one 18-inch dike of foreign materials.	These samples were taken along a small gully 0.5 mile NE. of Alaska Railroad crossing (fig. 9).
647...	100	Black sheared shale with a small amount of graywacke.	
648...	100	Interbedded black shale and purple graywacke stained yellow in places by limonite.	
649...	200	Thin-bedded gray-to-black shale which weathers yellow to brown and shows some scattered pyrite grains. The deposit strikes N. 60° to 70° E. and dips 70° S.	Samples 649 through 654 represent shale deposits exposed along the lower portion of Windy Creek (fig. 9).
650...	150	Interbedded black shale and graywacke, sheared and contorted, thin-bedded, contain a 2.0-foot igneous dike. The strike ranges from N. 60° to 65° E., and the dip ranges from 75° N. to 75° S.	
651...	100	Thin-bedded black shale.	
652...	80	Black sheared and contorted shale.	
653...	100	do.	
654...	80	do.	

TABLE 7. - Log of shale samples, Cantwell-Windy-Foggy Pass area (Con.)

Sample	Sample length, feet	Individual sample description	Group description
655...	100	Black, thin-bedded, contorted shale.	This sample was obtained along the south limit of Windy Creek immediately above its junction with Little Windy Creek (fig. 9).
656...	75	Gray-to-black shale interbedded with purple-gray graywacke.	These samples were taken along the limit of upper Little Windy Creek (fig. 9). Sample cutting commenced adjacent to an igneous dike. The deposit strikes about N. 80° E. and dips 55° S.
657...	100	do.	
660...	50	Black shale, strike N. 63° E.	Samples taken along the Cantwell to McKinley Park roadcut, just south of the first Nenana River road crossing from Cantwell (fig. 9).
661...	50	Black shale.	
662...	50	Black shale, strike N. 65° E., dip 60° S.	
663...	50	Black shale.	
664...	50	do.	
665...	50	Black shale, strike N. 65° E., dip 80° N.	
666...	50	Black shale.	
667...	50	Black shale.	A group of samples taken from a shale exposure along the roadcut of the Cantwell to McKinley Park highway. This exposure is located about 600 feet upstream from the confluence of the Jack River and Windy Creek; the Jack River approximately parallels the highway at this location (fig. 9).
668...	50	do.	
669...	50	do.	
670...	50	do.	