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GEOLOGICAL SURVEY
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HAYDITE SHALE IN THE SUTTON AND KINGS RIVER AREAS OF THE MATANUSKA VALLEY, ALASKA

by

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ABSTRACT

Haydite raw materials have been found in two areas in the Matanuska Valley in south-central Alaska. One is located 67 miles northeast of Anchorage, along the Glenn Highway; the other is located along the Alaska Railroad (Sutton-Subdivision) near Sutton, 55 miles northeast of Anchorage.

Bloating tests indicate that shale from the Matanuska formation in the respective areas will yield a satisfactory lightweight product.

The principal aspects of the bloating phenomenon are presented. Several minerals are recognized as potential bloating agents, but the findings were generally inconclusive in that respect.

Both areas described in the report contain large, accessible reserves of haydite raw materials which are favorably located in regard to transportation, fuel and markets.

INTRODUCTION

The present large demand for construction materials and their high cost have emphasized the need for local supplies of lightweight aggregates in Alaska. The high cost of transportation precludes shipping such low-cost bulky products to Alaska. Likewise the development of suitable deposits of raw materials in Alaska that are not easily accessible to rail or highway transportation probably also would be uneconomical.

Several raw or processed materials, including haydite, pumice, perlite and diatomite, may be used as lightweight aggregates. Haydite is the commercial term applied to a vesicular, lightweight, expanded product, similar to coal cinders, which results from the controlled heating of suitable clays or argillaceous rocks in a rotary kiln to temperatures largely between 1,000 and 1,300 degrees Centigrade (see figure 11). The term is synonymous with the terms expanded shale and expanded clay.

From 1946 to 1949 pumice was mined on Augustine Island and shipped to Anchorage for the manufacture of lightweight building blocks. This material is at present being mined at Geographic Harbor in Katmai National Monument and shipped to Anchorage for the same purpose. As far as is known no other lightweight aggregates are being produced in Alaska.

Haydite produced in Alaska could be used to make lightweight concrete blocks. It might also be used as a high-strength, lightweight aggregate in structural concretes, the use of which in some structures in the United States has resulted in considerable savings in more expensive materials, particularly structural steel. Haydite has greater compressive strength, lower water absorption and better particle shape than pumice. For these reasons it would generally be a more favorable concrete aggregate. Concretes using pumice, however, usually have better insulation value than those using haydite (Housing and Home Finance Agency, 1949, pp. 21, 25). The choice of aggregate, therefore, would depend largely on the specifications of the concrete desired.

Two areas in which haydite raw materials have been found are described in this report. Both are located in the valley of the Matanuska River, a tributary of Knik Arm, in south-central Alaska (see figure 1). One area is situated near the mouth of Kings River, about 67 miles northeast of Anchorage via the Glenn Highway. The other is located between Sutton and Moose Creek, near mile 16 (measured from Matanuska) on the Sutton-Subdivision of the Alaska Railroad.

PREVIOUS INVESTIGATIONS

The areas here described are situated near the coal deposits in the Matanuska Valley. Considerable work has been done by the Geological Survey in this region, primarily in connection with coal investigations.

Mendenhall (1900, pp. 265-300) gave the first general geologic and geographic description of the valley after a traverse from Cook Inlet to the Tanana River in 1898.

In 1905, Martin (1906) made a reconnaissance study of the coal in part of the valley. Since that time, the area of coal deposition and adjacent regions have been studied by numerous workers (Capps, 1940, pp. 68-86).

The haydite potentiality of the shale in the Kings River area was first recognized by the Anchorage Sand and Gravel Company. Early in 1950, this company sent samples of the rock to Mr. W. G. Bauer, consulting engineer, Seattle, Washington for testing. Mr. Bauer reported the samples were suitable haydite raw material. A company called Basic Building Products, Inc. was then formed in Anchorage to undertake the development of the deposit.

In July 1950, G. O. Gates of the Geological Survey briefly investigated the geology of the areas here described. He recognized the similarity of the shale in the Sutton area to that in the Kings River area and recommended that the former be sampled and tested to determine its suitability for the manufacture of haydite.

Later in the summer 1950 the Bureau of Mines sampled the shale in the Kings River and Sutton areas and subsequently ran tests on these samples (Rutledge F. A., 1952). Results of the tests are included in this report.

PRESENT INVESTIGATION

During August 1951 a party of the Geological Survey examined the Kings River and Sutton areas to determine the distribution, structure, lithology, and accessibility of the argillaceous rocks in each locality. A detailed topographic and geologic map (see figure 2) of the Kings River area was made by plane table and alidade methods. The geology in the Sutton area was plotted on a base map compiled by the Topographic Division, Geological Survey (see figure 3).

GEOGRAPHY

The valley of the Matanuska River is about 5 miles wide and lies between roughly parallel, east-west trending, mountain fronts. The valley is bordered by the Talkeetna Mountains to the north and by the Chugach Mountains to the south. Within the valley are rounded hills, some of which attain altitudes of 3,500 feet above the level of the gravel flats in the floor of the valley. The Matanuska River is about 85 miles long and has a drainage basin of about 1,000 square miles (Martin and Katz, 1912, p. 10).

The Glenn Highway, extending from Anchorage to the Richardson Highway near Glenallen, follows the north side of the valley. The south side of the valley is largely inaccessible except on foot.

A spur line of the Alaska Railroad, called the Sutton-Subdivision, extends from the main line at Matanuska to Moose Creek and Jonesville, serving the valley's coal mining industry.

The Kings River area as referred to in this report includes an area of about one-fourth square mile at the confluence of the Matanuska and Kings Rivers. The latter, which heads in the Talkeetna Mountains, borders the area on the north whereas the Matanuska River forms the southern and western boundaries. To the east the area is bordered by low hills forming the divide between the two rivers. The principal topographic feature of the area is a small, northeast-southwest trending ridge, about three-fourths mile long and one-half mile wide, which attains an elevation of about 1,060 feet. A thin strip of gravel flats between the ridge and the rivers comprises the remainder of the area. The Glenn Highway parallels the Matanuska River in this locality and crosses the western and southern margins of the area.

The Sutton area as referred to in this report includes an area of about six-tenths square mile situated on a prominent bend in the Matanuska River about 3 miles west of Sutton. The river lies along the southern and most of the eastern boundary of the area. The area consists of a depression-marked bench with steep cliffs, up to 225 feet high, overlooking the river. On the south side of the area a gravel bench, locally 700 feet wide, lies between the cliff and the river. The Glenn Highway crosses the northern part of the area and the Alaska Railroad crosses the area parallel to the river, lying between the cliffs and the river.

Vegetation in both the Kings River and Sutton areas includes grasses, devil's club, alder, cottonwood, birch and a small amount of spruce.

Year-round quarrying operations in the Kings River and Sutton areas would be affected by the climate. The summers are mild and the winters moderate if compared with most of Alaska. Snowfall during the winter is not large but drifting, and low temperatures would probably hamper operations.

GEOLOGY

Folded and faulted Mesozoic and Tertiary sedimentary rocks comprise the major part of the bedrock in the Matanuska Valley. The sedimentary units are cut by numerous small intrusives of acidic and basic composition. On the north these units are bordered by the granitic rocks of the western Talkeetna Mountains and the Mesozoic sediments and volcanics of the eastern Talkeetna Mountains. On the south they are bordered by the metamorphic and granitic rocks of the Chugach Mountains. General structural trends within the valley are oriented in a northeasterly and easterly direction. Geologic boundaries of the valley are usually marked by zones of faulting.

Upper Cretaceous

Matanuska Formation

The argillaceous rocks and associated graywacke in the Sutton and Kings River areas are part of the Matanuska formation. This formation has a wide distribution in the Matanuska Valley (see figure 4), outcropping in irregular areas and belts extending from a few miles below the mouth of Moose Creek eastward to the headwaters of Caribou Creek (Capps, 1940, p. 77).

As described by Martin and Katz (1912, pp. 34-36) the Matanuska formation consists essentially of dark shale and greenish gray graywacke with a subordinate amount of conglomerate. On Granite Creek, where the most complete section known occurs, the formation has a thickness of at least 4,000 feet of which the lower half is almost all shale and the upper half consists of alternating graywacke and shale, the former predominating (Martin and Katz, 1912, pp. 34-35).

The base of the formation has not been observed, but it probably rests unconformably upon an erosion surface that truncates rocks ranging in age from Lower Jurassic to Lower Cretaceous. The Matanuska formation is unconformably overlain by Tertiary coal-bearing rocks.

Inoceramus and other fossils have been collected from the shale and graywacke of the Matanuska formation. On the basis of these, the formation is definitely assigned to the Upper Cretaceous (Capps, 1927, pp. 37-40).

Kings River area--The Matanuska formation is believed to underlie the ridge and gravel flats comprising the Kings River area. Although exposures are not plentiful, outcrops examined indicate the ridge may be divided into two major units on the basis of lithology. One unit underlies the northern third of the ridge and consists largely of shale. The other underlies the remaining portion of the ridge and consists of interbedded graywacke and shale (see figure 2).

The shale occurs in an almost continuous exposure from the road cut, about 1,000 feet south of Kings River bridge, northeast along the Kings River. Along the south side of the river it is exposed in a steep cliff (see figures 5 and 6), but at the northeast end of the map area and beyond it is concealed by river gravel. A few small exposures suggest the shale underlies the vegetation and soil of the higher elevations in the northern part of the ridge.

The shale is black, fine grained, rather hard and massive jointing is common. Locally, the shale contains a few thin beds and pods of graywacke that are rarely more than a few feet thick. No graywacke, however, was observed in the shale exposed between the road cut and point Z (see figure 2) on the Kings River. Owing to the lack of bedding in this exposure the stratigraphic thickness of the grit-free portion of the unit is unknown. The stratigraphic thickness of the entire unit likewise could not be determined because of the lack of bedding, the large amount of shearing and faulting and the generally indefinite location of its contact with the graywacke to the south.

The stratigraphy of the Matanuska formation described by Martin and Katz (1912, pp. 34-35) suggests that the shale unit in the Kings River area is near the base of the formation, but no direct evidence of the stratigraphic sequence in this area was noted.

The petrographic character of the shale was studied in some detail as this material is of primary interest as a source of haydite. Thin sections prepared from specimens collected at the north end of the road cut show the rock consists of clay and very fine, subangular mineral fragments. The clay is probably illite. This identification is based on a comparison of stain test reactions of the clay with known clays and the results of differential thermal analyses. The mineral fragments are largely quartz and feldspars with subordinate amounts of muscovite, biotite, chlorite, epidote, pyrite and/or marcasite, amphibole and/or pyroxene and possibly opal. The presence of organic matter in the shale was determined by differential thermal analyses and the loss of color due to heating during the analyses. The feldspars include plagioclase and probably orthoclase. Calcite was identified in only one thin section. Its presence may be due either to calcite stringers that locally cut the shale or to small limy nodules in the rock. Such nodules occur in the rock at the northeast corner of the map area.

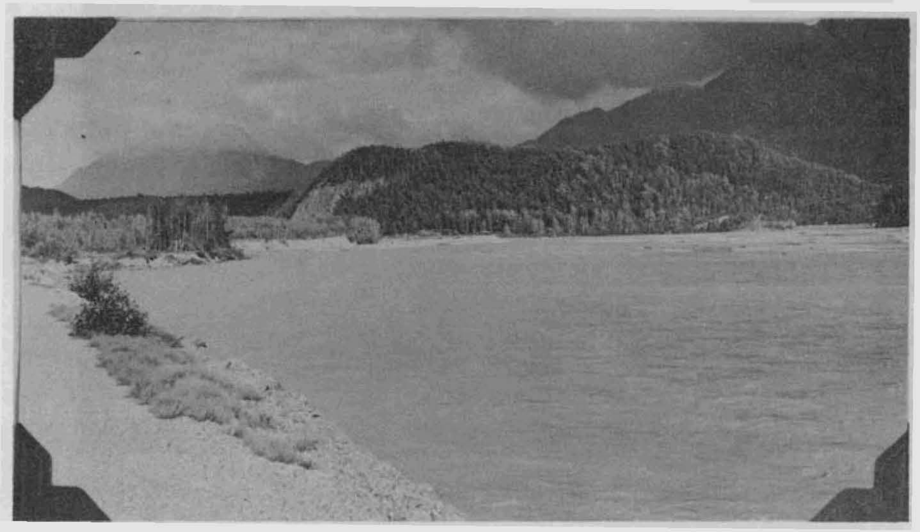

Figure 5 - View of Kings River haydite shale area from west along Glenn Highway. Cliff at north end of ridge overlooks Kings River and is largely black shale. The Matanuska River is shown in the foreground.

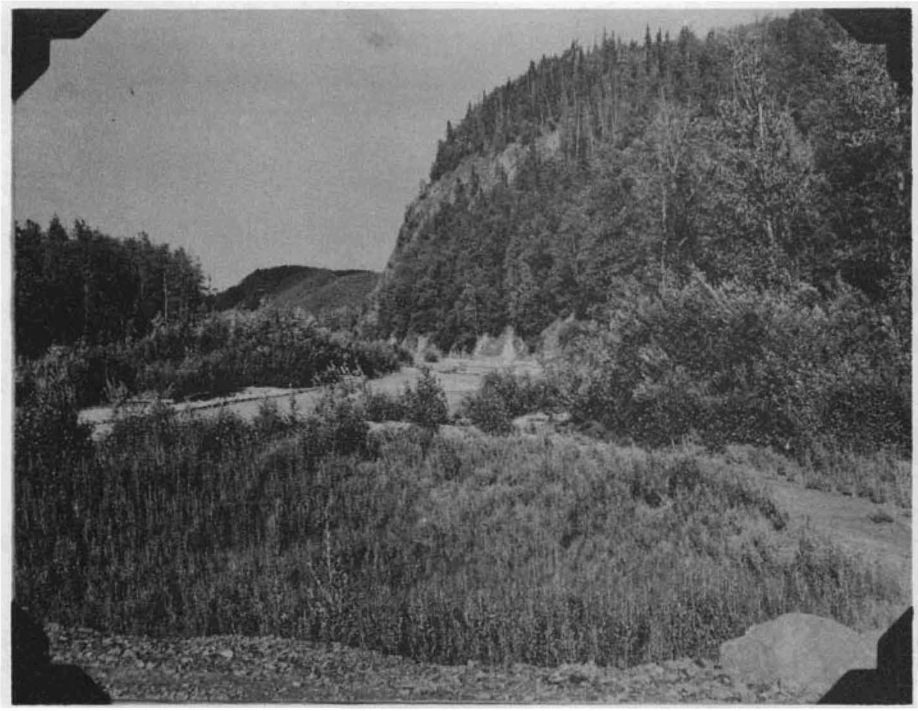

Figure 6 - Cliff overlooking Kings River. The exposed bedrock is largely black shale.

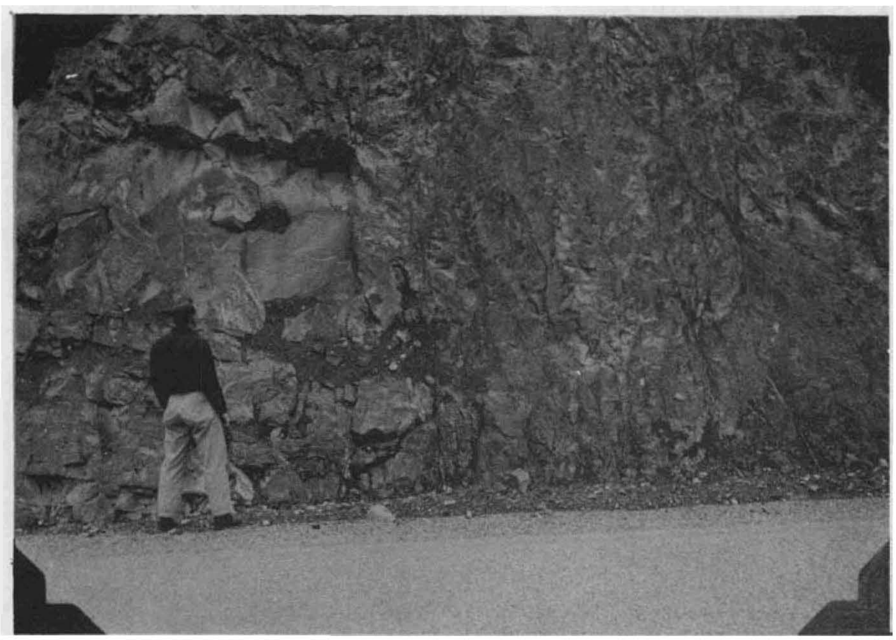

Figure 7 - West side of road cut at Kings River area. Vertical fault (center of picture) is contact between graywacke (left) and black shale (right).

The southern two-thirds of the ridge is underlain by interbedded graywacke and shale with graywacke predominating. Two distinct graywacke zones containing very little interbedded shale are exposed south of the main shale units. In the road cut a thin band of shale separates these zones and their contacts are marked by vertical or nearly vertical faults. Several exposures of graywacke near the highest elevation on the ridge suggest these zones may be continuous across the ridge. The outcrop on the southern end of the ridge (see figure 2) consists of intimately interbedded shale and graywacke, both rocks being present in about equal proportions.

The graywacke is dark greenish gray, fine grained and well-cemented. A thin section of a specimen collected at the road cut shows the rock is poorly sorted and sized and is composed of angular to subangular fragments. These fragments consist largely of quartz and feldspars with subordinate amounts of muscovite, calcite, chlorite, rock fragments, biotite, epidote, zoisite, clinozoisite and apatite in order of decreasing abundance. The feldspars include plagioclase, largely oligoclase, orthoclase, microcline, and perthite with the first two minerals being most abundant. Much of the orthoclase shows alteration to sericite and clay whereas the oligoclase is very fresh. Quartz fragments are fractured and strained. Rock fragments appear to represent andesite and/or basalt lavas or dike rocks.

Most of the calcite occurs as irregular masses filling the interstices between allogenic grains, but some of it may be detrital. A"paste" of sericite, clay, and chlorite is probably the principal bond between the constituent fragments of the graywacke although some of the calcite contributes to the cementation.

Locally small lenses of conglomerate occur in the graywacke. The conglomerate consists of well-rounded quartz, granite, chert, greenstone and quartzite cobbles, up to 4 inches across, set in a graywacke matrix. The matrix is shaly in some places. In the easternmost outcrop mapped along the highway, the conglomerate contains limestone fragments set in a calcareous graywacke matrix.

Individual beds of graywacke average about $2\frac{1}{2}$ to 3 feet in thickness with the thickest being about 5 feet. In most exposures, shale layers in the graywacke zones are a foot or less thick. This shale is black, fine grained, rather soft and thinly laminated. It occurs in beds up to several feet thick. Joints are generally lacking. Mineralogically the shale is similar to that described above.

The section along line A-A' in figure 3 represents the structure in the western part of the Kings River area where exposures are abundant enough to warrant an interpretation. The attitudes of the strata south of the main shale unit suggest an anticlinal structure whose axis

The section along line A-A' in figure 3 represents the structure in the western part of the Kings River area where exposures are abundant enough to warrant an interpretation. The attitudes of the strata south of the main shale unit suggest an anticlinal structure whose axis trends roughly northeast. Although this structure is not well exposed, it is believed to be faulted along or near its axis. This is suggested by the fact that what may be the westward extension of the same fold appears in the graywacke and shale which form the cliff on the west bank of the Matanuska River. As observed from the Glenn Highway the anticline exposed in the west bank appears to be faulted and sheared along its axis. No evidence was observed concerning movement along the fault. The strata on the north flank of this structure dip moderately north. The attitude of the shale along section A-A' is unknown as no bedding was observed. Farther east, along the Kings River (point Z in figure 2), several graywacke layers in the shale dip steeply southward, but the westward projection of this attitude would be subject to question.

A great amount of shearing and faulting has taken place in the graywacke and shale. Not all of the fault and shear zones are shown in figure 2. For the sake of simplicity shear zones are shown in figure 2 as faults. Slickensides and grooves are abundant along the faults, and their surfaces are locally coated with calcite. Movement along the zones is believed to be largely horizontal although at some places a vertical displacement of 2 or 3 feet was observed.

Slickensides and grooves on the vertical fault between the shale and graywacke in the road cut (see figure 7) indicate that movement has been horizontal, but no evidence was found as to the direction and amount of displacement. No evidence of the eastward extent of this fault was found.

A well defined jointing, striking northeast and dipping 40°-70° north was observed in the shale between the road cut and point Z along the Kings River. In shale exposures farther up the river, Martin and Katz (1912, p. 36) found that the jointing is perpendicular to the bedding and to a minor set of joints. They believe the minor joints are also perpendicular to the bedding.

Sutton area--The Matanuska formation is believed to comprise the bedrock of the Sutton area although exposures are found only in the cliffs along the railroad. The formation there consists of interbedded black shale and graywacke with individual beds ranging from less than a foot to about 4 feet in thickness. Both the shale and graywacke are about the same as that in the Kings River area. There are, however, horizons or zones in the formation in the Sutton area in which either shale or graywacke predominate. Because of the possible economic value of the shale it seemed desirable to map these horizons or zones as distinct units. The stratigraphic section in the Sutton area is, therefore, divided on the basis of lithology into ten units, arbitrarily designated as Units A through J in descending order (see figure 3).

Units A through F represent a normal stratigraphic sequence. Units G through J may include a portion of the overlying units, but the lack of marker beds and the presence of several faults with unknown displacements precludes such a correlation. Quaternary deposits unconformably overlie all of the units.

Unit A crops out at the north end of the cliff along the railroad. Its northern extent is concealed by unconsolidated Quaternary deposits. The unit is largely black shale with an estimated 10 percent of interbedded graywacke (see figure 8). A few thin layers of dark siltstone and gritty shale, less than 2 feet thick, also occur in the unit. The shale is finely laminated for the most part and rather soft. It is cut by numerous thin calcite stringers and locally contains subrounded calcareous nodules up to about 4 inches in diameter. Where these nodules occur the shale has a conglomeratic appearance from a distance. The unit has a stratigraphic thickness of more than 490 feet. The top of the unit is not exposed. It is conformably underlain on the south by Unit B.

Unit B is estimated to consist of about 50 percent black shale and 50 percent graywacke, the two rock types being interbedded in layers averaging 2 to 3 feet in thickness. The shale has the same appearance as that in Unit A; the graywacke contains numerous black shale fragments and streaks up to about 2 inches long. The unit has a stratigraphic thickness of 230 feet and is conformably underlain by Unit C.

Unit C consists of graywacke with an estimated 10 percent of interbedded black shale. Both rock types are similar to those in Units A and B. The unit has a stratigraphic thickness of 700 feet and is conformably underlain by Unit D.

Unit D is similar to Unit A as it consists of black shale with an estimated 10 percent of interbedded graywacke and siltstone (see figure 9). Some of the clastic material occurs in small irregular masses within the shale. The stratigraphic thickness of this unit is 230 feet. It is conformably underlain by Unit E.

Unit E is similar to Unit C as it consists of graywacke with an estimated 10 percent of interbedded black shale. This unit has a stratigraphic thickness of 160 feet and is conformably underlain by Unit F.

Unit F consists of black shale free of any interbedded graywacke or siltstone (see figure 10). The unit, however, contains numerous thin, impure limestone layers, less than a foot thick, which form resistant layers in the shale.

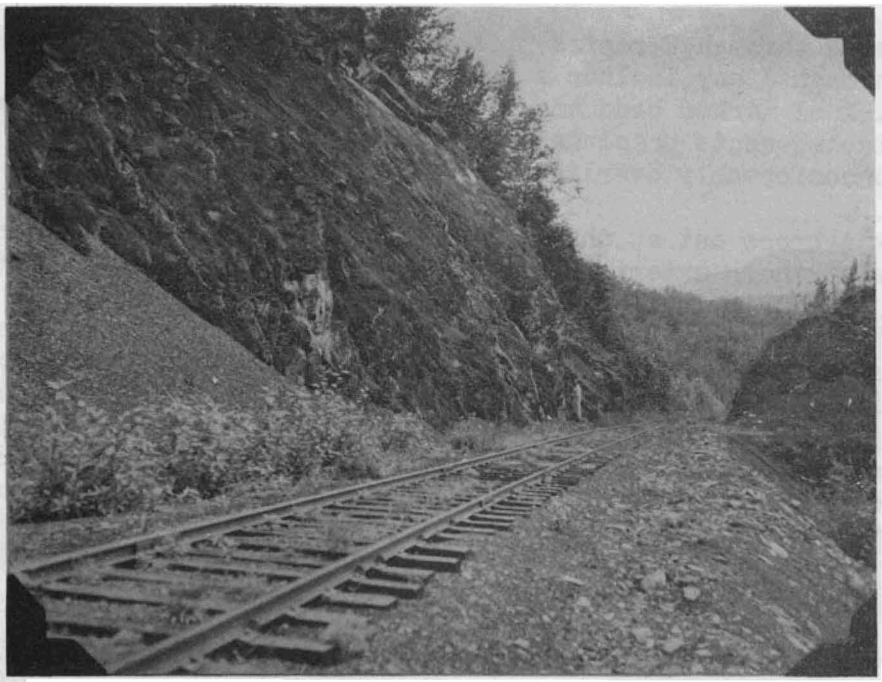

Figure 8 - Black shale of Unit A at Sutton area.

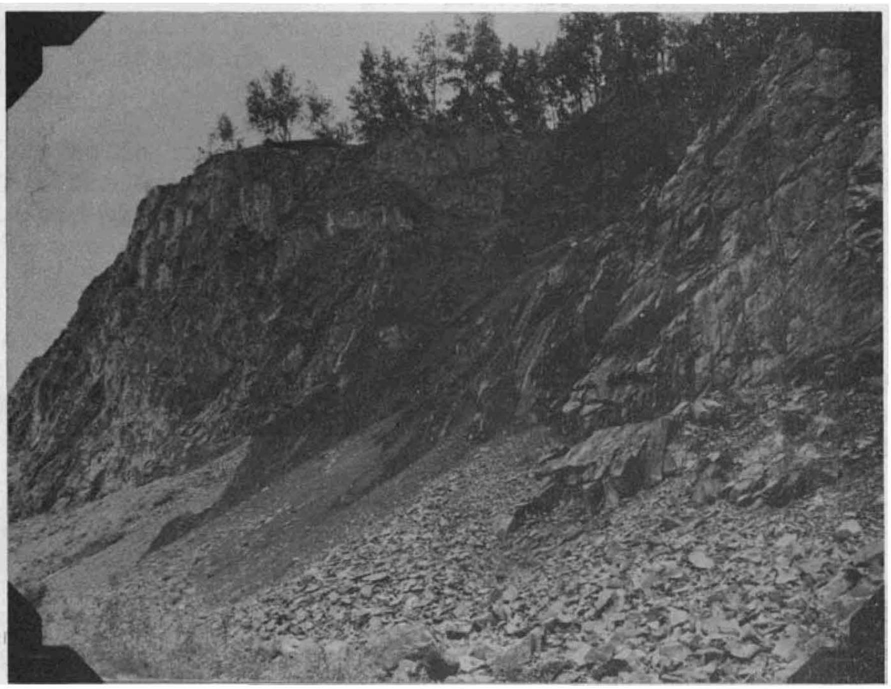

Figure 9 - Black shale of Unit D (center) in cliff along railroad at Sutton area.

The calcareous beds are estimated to comprise less than 10 percent of the unit. The limestone has a fine grained texture and is blue-black in color, weathering to a dark brown. Impurities in it include small angular fragments of quartz, chert, feldspar, micas, chlorite, clinozoisite, and apatite. A thin section shows forms having circular cross-sections that may be radiolaria. Unit F has a stratigraphic thickness of more than 360 feet. The base of the unit is not exposed.

Unit G consists of interbedded black shale and graywacke, each being present in about equal amounts. Layers of each rock type average 3 to 4 feet in thickness. The stratigraphic position and thickness of the unit are unknown as neither the base nor the top of the unit is exposed. Its lateral extent is believed to be limited to the east and west by faulting.

Unit H consists of graywacke and appears to be free of black shale. The graywacke is similar to that in the units described above. Neither the base nor the top of the unit is exposed. The lateral extent of the unit is limited by faulting.

Unit I is similar to Units A and D as it consists of black shale with an estimated 10 percent of interbedded graywacke. The eastern extent of the unit is limited by a fault which according to F. F. Barnes (oral communication) has displaced this unit and Unit J southward. Unit I may be the stratigraphic equivalent of Unit D. Unit I has a stratigraphic thickness of more than 240 feet, and is conformably underlain by Unit J. The top of the unit is not exposed.

Unit J consists of graywacke with an estimated 10 percent of black shale. This unit is similar lithologically to Units C and E, and it may be that the sequence formed by Units I and J is the stratigraphic equivalent of the sequence formed by Units D and E. Unit J has a stratigraphic thickness of more than 240 feet. The base of the unit was not observed.

The section along line A-A' in figure 2 shows the Sutton area is underlain by a homoclinal succession of steeply north-dipping strata. Beds in this structure strike north 80 to 85 degrees east and dip from 78° to 88° north. Bedding is very distinct although locally it is slightly contorted.

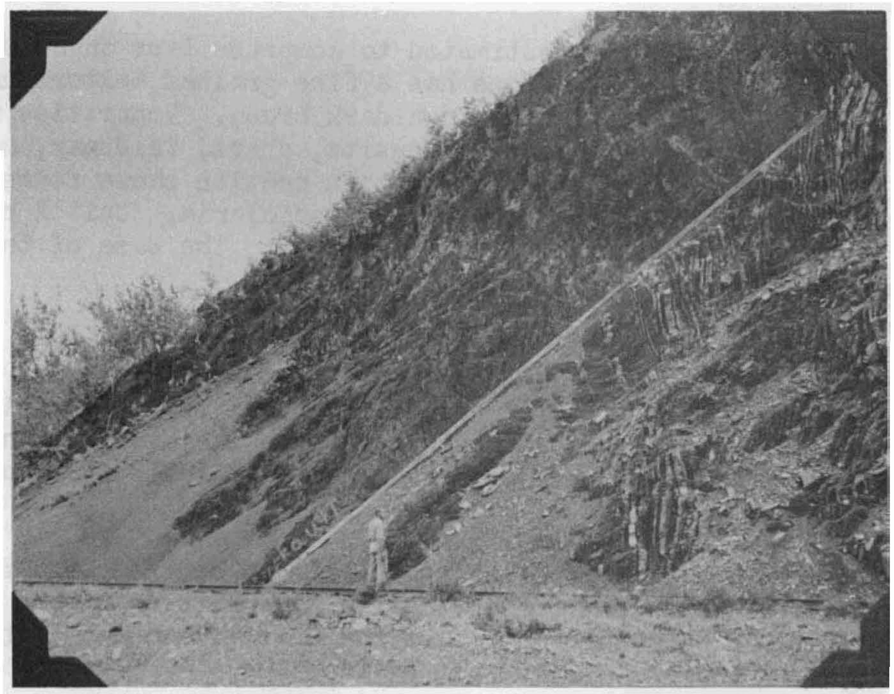

Figure 10 - Black shale of Unit F (center and left) at Sutton area. Note fault and offset of beds.

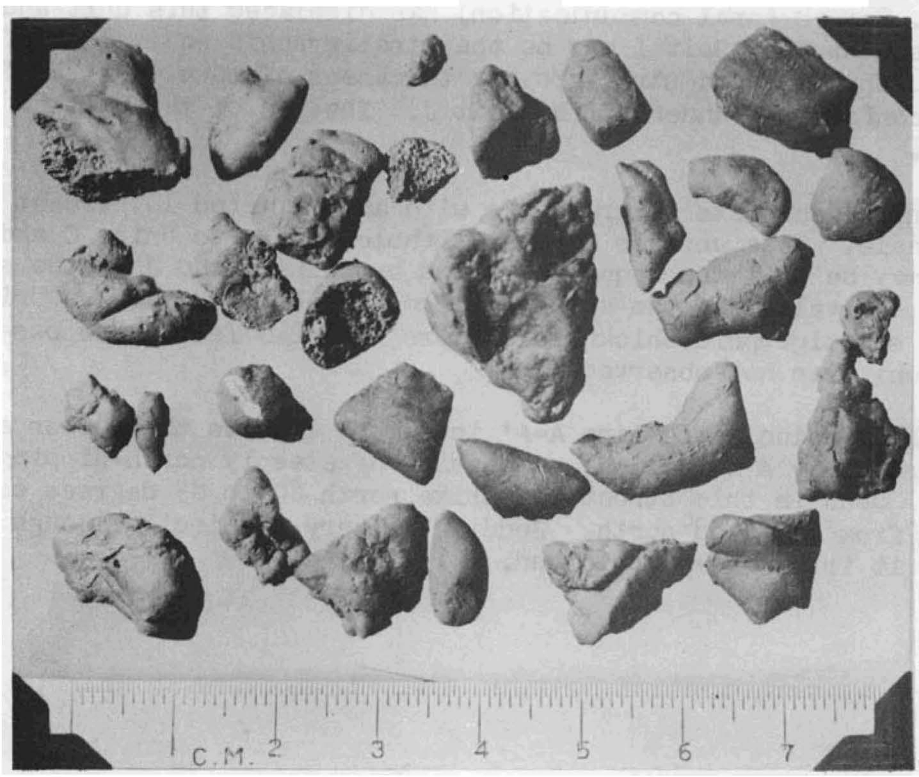

Figure 11 - Haydite made from a shale sample from the Kings River area. Bloating temperature of 1052 degrees Centigrade.

The homoclinal structure is cut by numerous faults and shears. The surfaces along which movement has taken place are usually coated with calcite. Not all of the faults and shears observed are shown in figure 2. The most noticeable fault is a small thrust which is exposed in the cliff along the east side of the area. The fault strikes roughly east-west, dips about 10 degrees south and has a horizontal displacement of about 6 feet.

Two sets of joints occur in the black shale of Unit A. These strike about N. 15° E. and dip about 75° NW. and 40° SE.

Quaternary

Gravels of the Matanuska and Kings Rivers comprise the Quaternary deposits of the Kings River area. The gravels rest unconformably upon the Matanuska formation. They include silt, sand, cobbles and boulders from most of the various rock types found in the Matanuska Valley.

Quaternary deposits consisting largely of river gravels and loess unconformably overlie the Matanuska formation in the Sutton area. Locally, the loess is up to 10 feet thick. At several places the alluvium may be of glacial origin.

FACTORS AFFECTING DEVELOPMENT

Properties of lightweight aggregate--Standard specifications for lightweight aggregates for concrete, including haydite, have been adopted by the American Society for Testing Materials (1950, pp. 720-722). Both chemical and physical tests are necessary to determine the suitability of a particular material. In the absence of such tests, some of the generally desirable properties of lightweight aggregates (Conley, Wilson, Klinefelter and others, 1948, pp. 7-8) that should be sought are listed below. These may serve as a guide to evaluate the argillaceous material in the Sutton and Kings River areas. The properties pertain to the use of an aggregate in concrete, but most of them also would apply to building blocks.

1. Lightweight The aggregate should not weigh more than half as much as the standard aggregate it replaces. Because rock or gravel aggregates have a bulk density of approximately 100 pounds per cubic foot, the ideal light aggregate should be less than 50 pounds per cubic foot.

2. Strength The individual particles of the aggregate should be as strong as possible. A concrete using a strong aggregate will require less cement than one using a weaker aggregate, thus resulting in savings of cost and weight.

3. Particle shape The ideal aggregate should have well-rounded, preferably spherical surfaces. This quality promotes good workability.

4. Low water absorption The individual particles should have closed pores, otherwise water from the concrete mix will fill the pores. This dehydrates the concrete and gives a poor set. This quality may be compensated to some extent by pre-soaking the aggregate.

5. Uniform particle-size gradation The aggregate must be composed of a range of sizes, including a sufficient quantity of fines. This promotes workability.

6. Chemical inertness Compounds of the aggregate that would tend to react with the cement and affect its setting should be absent.

7. Low production cost The production cost of the lightweight aggregate is the ultimate factor that determines its acceptability for the aggregate must compete with heavy aggregates (sand, gravel, et cetera) and other lightweight aggregates. This means the raw material must be easily mined, located near a source of fuel and markets, and must be processed with a minimum of technological difficulty. Although their production costs are higher, lightweight aggregates may favorably compete with heavy aggregates if the initial extra production costs are offset by saving in weight that permits elimination of some reinforcing steel, use of lighter weight forms and reduction of labor costs or the attainment of better thermal and sound insulation qualities.

Bloating tests--The conditions and results of tests by the U. S. Bureau of Mines on samples of argillaceous material collected by the Bureau from the Kings River and Sutton areas are shown in Tables 1, 2, and 3. The tests were run at the Bureau of Mines' Electro-technical Laboratory, Norris, Tennessee.

For the stationary kiln tests, the samples were crushed to pass an 8 mesh sieve and small briquettes, approximately ½" x 1" x 2", were formed by hand tamping dampened particles into a mold. The briquettes were artificially dried for about 12 hours at 100 degrees Centigrade or air dried for several days before firing.

A laboratory kiln was heated to 1,150 degrees Centigrade and a series of samples inserted on a silicon carbide slab. Sufficient time was allowed for the kiln to come to equilibrium, after loading, and the samples were held at the maximum temperature 15 minutes before removing for visual inspection. The kiln temperature was then adjusted upward and downward, in steps of 50 degrees Centigrade, as indicated by the condition of the specimens. A sufficient number of heats were run to indicate the bloating range and optimum bloating temperature of the material.

Table 1 -- Results of stationary kiln bloating tests on samples from the Kings River area.

	Temperature	Bloating Results			
Sample No.	(Centigrade)	Poor	Fair	Good	Remarks*
3	1100		x		Temperature too low
	1150			x	
	1200		x		Temperature too high
4	1100		x		Temperature too low
	1150			x	
	1200		x		Temperature too high
5	1100		x		Temperature too low
	1150			x	
	1200		x		Temperature too high
6	1100		x		Temperature too low
	1150			x	
	1200		x		Temperature too high
7	1100	x			
	1150	x			
	1200	x			
8	1100	x			
	1150	x			
	1200	x			
9	1100	x			
	1150		x		
	1200		x		Outer surface glazed

*See figure 2 for locations of samples 3 through 8. Location of sample 9 is described on page 38.

Table 2 -- Results of stationary kiln bloating tests on shale samples from Sutton area

Sample No.	Temperature (Centigrade)	Bloating Results Poor	Fair	Good	Remarks	Sample Location **
53	1100	x				Sample length 80 feet. Cut normal
	1150			x		to strike and dip of beds adjacent
	1200	x			Bloated*	to railroad.
54	1100	x				Sample length 50 feet. Cut approx.
	1150			x		normal to strike and dip of beds
	1200	x			Bloated*	near upper contact adjacent to railroad.

*Large cellular structural bubbles 1/8 to 1/4 inch in diameter.

**Channel samples spaced 400 feet apart along strike of beds in Unit F.

Table 3 -- Results of rotary kiln test of combined samples 3, 4, 5, and 6 from Kings River area

			fine	coarse
Particle size	1" to 4 mesh	Bulk specific gr.	0.89	0.84
Total weight of feed	280 lbs.	Bulk sp. gr. sat. surface, dry basis	1.29	1.12
Weight cu. ft.	94-1/2 lbs.	Apparent sp. gr.	1.66	1.16
Product, total weight	215 lbs.	Absorption	33.2%	44.5%
Weight cu. ft. minus 3/8"	43 lbs.			

Kiln Operation Conditions

Time	Temperature °C.	Remarks
10:10 a.m.		Start fire
10:40 a.m.	1190	Off to load
10:45 a.m.		Loaded and fired
11:20 a.m.	1200	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" 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

Mr. A. F. Waldron, president, Basic Building Products, Inc., has been kind enough to make a report of tests on Kings River shale samples by W. G. Bauer available to the author (letter dated October 23, 1951). After preliminary tests on the samples, Mr. Bauer made five follow-up firings on one of the samples to determine optimum heating rates, temperatures, kiln atmospheric conditions, bloating range, glaze coating, heat spalling, and sticking tendencies. All firings were made in a gas-fired rotary kiln. Firing schedules were held to those employed in commercial-size kilns using similar raw material. The kiln was correlated in commercial-size kilns using similar raw material. The kiln was correlated to a large rotary kiln used in a commercial plant and, therefore, Mr. Bauer believes the test results can be duplicated on a commercial scale.

The tests showed the maximum temperature required for bloating is 1980° F. (1100° C.). The weight of the product was judged to be about 42 pounds per cubic foot when the full range of required sizes is obtained. It was necessary to crush the kiln product in order to obtain the required fines.

Summarizing the results of his tests, Mr. Bauer states "the shale forms a good ceramic glaze or coating which is harder than steel at a temperature of 1870° F. and which takes place just prior to bloating. The bloating range is not wide, although the pores become too large if the material is held at the maximum temperature too long. Some sticking occurs in the kiln, especially when particle size range of the feed is large and much fine material is present. There are operational and equipment design techniques, however, to overcome this to a large extent".

Mr. Bauer concludes that the shale sample produces "a haydite-equivalent product and there are no special processing difficulties. There are definite indications that considerable further improvement in uniformity, strength, and absorption can be achieved in a correctly designed commercial installation."

<u>Discussion of bloating</u>--Grim and Bradley (1940); Austin, Nunes and Sullivan (1942); Conley, Wilson, Klinefelter and others (1948); Riley (1951) and other investigators have done valuable work on the bloating properties of clays and shales. The following discussion is based largely on the works cited above.

The mechanisms by which some clays and shales bloat when heated is not fully understood. There appears to be no direct correlation between chemical composition and bloating properties. It is probable that the mineralogical composition governing the chemical combinations present in the raw material is of basic importance. It is known, however, that the following two conditions must be fulfilled to produce a bloat (Conley, Wilson, Klinefelter and others 1948, p. 10):

1. The material, when heated sufficiently, must produce a pyroplastic or glassy phase which is developed by fluxes to the point of incipient fusion. The viscosity of the phase must be great enough to trap a gas.

2. Some constituent or constituents of the material must evolve a gas at or slightly above the temperature at which the pyroplastic phase is produced. The gas is then trapped by the viscous melt and produces a cellular structure. The gas must not be readily soluble in the melt.

By plotting a large number of chemical analyses of bloating and non-bloating clays, Riley (1951), was able to define the limits of bloating on a composition diagram. He states, "The 'area of bloating' on this diagram showed desirable compositions of clays which satisfy the first necessary condition for bloating. As a test of the area of bloating, silica and alumina were added to non-bloating clays to give them compositions conforming to points within this area. When fired these mixtures bloated." It should be emphasized that the bloating would not have taken place if the second condition for bloating was not satisfied; that is, if gas-producing constituents were not present.

The impurities of some clays and shales are potential sources of gases for bloating. Some of these are: carbonaceous matter, various iron compounds, carbonates and sulfates. Conley, Wilson, Klinefelter and others (1948, p. 98) state that, "these need be present only in small proportions (1 to 2 percent) to effect extensive bloating." Riley (1951, p. 121) in a study of a Minnesota shale demonstrated that hematite, pyrite and dolomite are the only accessory minerals which dissociated and produced a gas at the proper temperature.

Conley, Wilson, Klinefelter and others (1948, p. 30) concluded from their studies that if the combined impurities of a clay or shale are less than 5 percent, the rock is almost certainly a non-bloater. However, Grim and Bradley (1940) bloated purified samples of illite and montmorillonite clays. Riley (1951, p. 124) also bloated a purified sample of illite.

Many non-bloating clays and shales may be made to bloat by using admixtures such as sulfur, carbon, hydrocarbons, and sulfates; some clays and shales which are non-bloating at normal temperatures will bloat at temperatures higher than those now employed commercially (1,000° to 1,300° C.). The use of admixtures or higher kiln temperatures, however, increases production costs.

Table 4 shows the chemical composition of shale sample collected at the north end of the road cut at the Kings River area. It is interesting to note that this composition falls within the "area of bloating" on Riley's composition diagram (see page 29). The analysis shows no sulfur in the sample, but pyrite and/or marcasite (both are iron sulfides) were observed in a thin section of the same sample and identified by microchemical tests. This suggests that pyrite and/or marcasite are sparsely disseminated in the shale but were not present in the portion of the sample analyzed.

Precise quantitative mineralogical analyses of the Kings River and Sutton haydite raw materials are not available, but the Kings River shale is estimated to have the following mineral composition from the chemical analysis, thin section studies, and stain tests: 50-60 percent quartz and feldspars, 10-15 percent illite, 15-20 percent micas, 5-10 percent calcite, opal, chlorite, epidote and other ferromagnesium minerals, 1 percent or less pyrite and/or marcasite and organic matter. The shale of Unit F at the Sutton area is believed to have roughly the same chemical and mineral composition.

The bloated shale from the Kings River area has a cellular structure with a sealed outer surface (see figures 11 and 13). A thin section shows the cell walls consist of glass with many embedded fragments of unaltered quartz and feldspars. Within the cells are a few small fragments of quartz, feldspars and an unidentified mineral. The latter occurs in isotropic and anisotropic grains and has a negative relief. Refractive indices of this mineral are unknown as specimens of the bloated shale are not available. It is possibly a glass, but it is unlike the glass comprising the cell walls.

From the thin section study it appears that quartz and feldspars are the only minerals in the shale that survive the bloating process and that glass and an unidentified mineral, which may also be glass or an artificial mineral, are the only new substances formed in the kiln.

Table 4 - Chemical analysis of shale sample from Kings River area.*

SiO_2	60.17
Al_2O_3	16.02
Fe_2O_3	1.29
FeO	5.14
MgO	3.17
CaO	2.33
Na_2O	2.22
K_2O	2.72
H_2O-	0.64
H_2O+	3.78
TiO_2	0.73
CO_2	0.77
P_2O_5	0.29
S	0.00
MnO	0.15

TOTAL	99.42**

* Analysis by H. M. Hyman, U. S. Geological Survey

** Contains organic matter.

The quartz and feldspars apparently play no part in the bloating process. The other constituents of the shale behave as follows: some melt to a glassy phase; others are dissolved in the glassy phase once it has formed, as the temperature increases; still others evolve a gas or gases which vesiculate the glass. Which minerals participate in each of these functions is unknown, but the physical and chemical characteristics of some of the minerals present are at least suggestive.

Purified samples of illite were bloated experimentally by Grim and Bradley (1940, pp. 8-10). They found that at a temperature of 850° C. illite has lost all of its water; from 850° to 1,300° C. a spinel forms from illite; at 1,100° C. mullite forms from illite. No attempt was made to explain the bloating phenomenon. It is possible, however, that a dissociation of Fe_2O_3 in the spinel takes place, providing oxygen as the gas for bloating. Hydrogen and water vapor could not be responsible for the bloating because water is lost at a temperature much lower than that needed to produce the pyroplastic phase. The Kings River shale and the shale comprising Unit F in the Sutton area are estimated to contain 10-15 percent illite, but no mullite or spinel were observed in the haydite from the Kings River area. It is probable that the reaction of illite with the other ingredients of this rock does not yield mullite or a spinel and, therefore, whether or not the illite could be responsible for the bloating gas is not known.

A biotite when heated to temperatures around 1,200° C. yielded leucite, Fe_2O_3 and a spinel (Grim and Bradley, 1940, p. 9). As in the case of illite, a dissociation of the Fe_2O_3 and the spinel might produce oxygen. The argillaceous rocks in the Kings River and Sutton areas contain biotite but, as stated above, the haydite does not contain spinel and no leucite was identified. Therefore, it is not known whether or not biotite could be responsible for the bloating gas. Biotite also contains water, but all of it would probably be driven off by the time the bloating temperature is reached.

It has been demonstrated that pyrite will evolve a gas, probably sulfur dioxide, at a temperature within the bloating range. Marcasite should do the same. The shale in the areas here described probably contains less than 1 percent iron sulfide minerals. If gas-producing constituents must be present in the amount of 1 to 2 percent, it is considered unlikely that iron sulfide minerals are of major significance in the production of gas in these rocks during bloating. This conclusion is based on the lack of sulfur in the chemical analysis shown in Table 4. More analyses are needed, however, to support this conclusion.

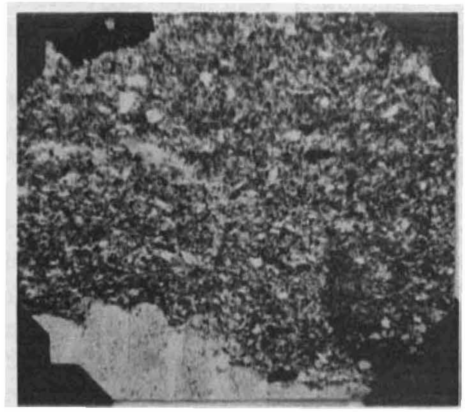

Figure 12 - Photomicrograph (ordinary light, x97) of shale from the Kings River area. Small white fragments are largely quartz, feldspars, and micas. Black area in upper left corner is pyrite and/or marcasite. Light area in lower part is a calcite stringer.

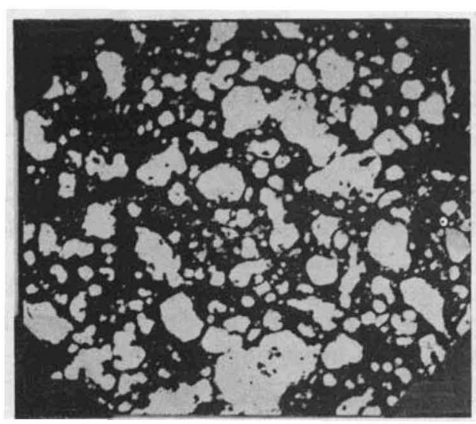

Figure 13 - Photomicrograph (ordinary light, x20) showing the internal structure of bloated shale from Kings River area. Black spots within vesicles are grinding compound.

A small amount of calcite occurs in the Sutton and Kings River haydite raw materials. This mineral may be responsible, at least in part, for the bloating. It dissociates at temperatures below those at which bloating takes place, but Riley (1951, p. 127) believes that calcite may react with other ingredients to form compounds which dissociate at temperatures high enough for bloating. He suggests cancrinite and potassium carbonate as possible intermediate compounds. Part of the calcite may also act as a flux in the formation of the glassy phase.

It is possible that no single mineral constituent of the argillaceous rocks in the Kings River and Sutton areas is the sole gas-producing agent, but, rather, the pyroplastic phase and bloating gas or gases are the result of reactions largely among illite, micas, ferromagnesium minerals, and calcite.

Intensive laboratory study would be needed to fully explain the bloating of the shale. One valuable contribution would be quantitative analyses of the gas or gases evolved during bloating.

Properties desired of haydite raw material--The following properties are some of those listed by Conley, Wilson, Klinefelter and others (1948, pp. 76, 81-82) as desirable in a raw material that will bloat in a rotary kiln. These properties have been briefly applied to the shale unit in the Kings River area and Unit F in the Sutton area. It is assumed that all of the material in these units bloats under the same conditions and with the same results as obtained in bloating tests on samples.

1. Short bloating time.--Fast-bloating material requires less time in the kiln and, therefore, the kiln may be operated at a greater capacity. Tests by the Bureau of Mines (table 3) and Mr. Bauer indicate the Kings River shale possesses this property. Samples of the Sutton shale were not tested in the rotary kiln.

2. Wide range between temperature of bloating and temperature of agglomerating.--Materials which agglomerate at temperatures near those at which they bloat cause serious kiln operating difficulties. Not only does this cause the material to stick to the kiln lining and to form "logs", but it impedes the movement of the feed through the kiln and may prevent part of the feed from receiving the proper amount of heat. Generally, the finer particle size of the feed, the greater the tendency to agglomerate. There are, however, remedies for this problem. Both the Bureau of Mines and Mr. Bauer observed that the Kings River shale showed some tendency to agglomerate. They do not, however, consider this tendency to be serious. As the Sutton shale was not tested in the rotary kiln it is not known whether or not the shale possesses this property.

3. Low bloating temperature.—Because of fuel costs, a material that bloats at temperatures above about 1,300° C. in the rotary kiln is generally considered undesirable as a raw material unless there are other strong factors in its favor. Tests indicate the Kings River shale bloats in the rotary kiln at temperatures less than 1,200° C. and that the Sutton shale also bloats below that temperature in a stationary kiln. It is believed that the Sutton shale would bloat at 1,200° C. or less in a rotary kiln.

4. Presence of free carbon.—A substantial amount of free carbon is desirable. The exthermal reaction of its combination with oxygen reduces the amount of fuel required for bloating. Differential thermal analyses indicate an exothermic reaction in the Kings River shale up to about 400° C.

Other economic factors—Coal from the mine at Jonesville is a potential source of fuel for a haydite plant using shale from either the Kings River area or the Sutton area.

The part of the Kings River shale unit exposed from the road cut to point Z along the Kings River appears free of graywacke and, therefore, is considered the best source of haydite raw material in the Kings River area. The remainder of the exposed part of the unit contains 10 percent or less graywacke. The effect this impurity would have on the bloating of the shale is unknown. It occurs in beds up to several feet thick and, therefore, much of it might be excluded from the raw material in quarrying. If included in the feed and passed through the kiln the graywacke would not bloat and probably would only add weight to the product.

The interbedded graywacke and shale unit in the Kings River area is not considered a potential source of haydite material for samples of the shale (samples 7 and 8 in table 1) did not bloat satisfactorily in stationary kiln tests. A shale sample (sample 9 in table 1) from the easternmost outcrop along the highway (see figure 2) also did not bloat satisfactorily (Rutledge, 1952). The large proportion of graywacke and the fact that none of the shale horizons observed are thick enough for mining are other factors that rule out this unit as a source of haydite material.

The King River shale is easily accessible from the Glenn Highway and enough "working room" exists for quarrying operations (see figure 2). Much of the shale unit is free of overburden and where present the overburden probably does not exceed 3 feet in thickness. Locally considerable brush and timber would have to be stripped before quarrying.

Unit F is considered the best potential source of haydite raw material in the Sutton area. The limestone that occurs in thin beds within the unit is apparently not a contaminating constituent for it undoubtedly made up parts of the samples collected and successfully bloated by the Bureau of Mines (see location column in table 3).

Unit F is easily accessible from the railroad and enough "working room" is available for quarrying operations (see figure 3). Very little soil and brush cover the western part of the unit on the side of the bench. At the top of the bench, Quaternary material, up to 10 feet thick covers the shale, but this comprises only a small area which is not included in the reserves.

Units D and I are other possible sources of haydite shale in the Sutton area but the lack of "working room" for quarrying between these units and the railroad (see figures 8 and 9) is a disadvantage. Their graywacke content is also an undesirable feature. According to F. A. Rutledge (oral communication) a sample of Unit A tested by the Bureau of Mines did not bloat satisfactorily.

Reserves--All calculations of reserves are based on the assumption that the specific gravity of the black shale is 2.65, that is, 12 cubic feet of ore weights one short ton.

Reserves--All calculations of reserves are based on the assumption that the specific gravity of the black shale is 2.65, that is, 12 cubic feet of ore weighs one short ton.

Reserves in the Kings River area were calculated only for the main shale unit. Calculations were made by constructing five vertical sections across the unit oriented S. 35° E. An altitude of 560 feet was assumed as the bottom of each section as this is the approximate elevation of the base of the cliff along the Kings River and, therefore, probably the lowest practical working limit in quarrying. The south contact of the shale is assumed to be vertical. Graywacke layers in the shale are included in the reserves. These probably comprise less than 10 percent of the unit.

Inferred reserves - - - - 34,900,000 short tons.

Reserves of the graywacke-free shale exposed from the road cut to point Z along the Kings River-are estimated to comprise 20 percent of the total reserves of the unit, or 7,980,000 short tons.

Reserves in the Sutton area were calculated only for Unit F. Calculations were made by constructing 4 vertical sections across the unit oriented N. 40° W. An altitude of 425 feet was assumed as the bottom of each section. The part of the unit which underlies Quaternary material at the top of the bench is not included in the reserves. The reserves are considered to be indicated.

Indicated reserves - - - - 24,900,000 short tons.

MINING CLAIMS

Several mining claims are held by A. F. Waldron and Jack Harrison of Anchorage on part of the shale unit in the Kings River area. The claim marker shown in figure 2 represents the northwest corner of Discovery No. 1 claim held by these men. No other claims are known to be staked on this unit.

According to the Bureau of Land Management, no mining claims had been staked on or near the bedrock exposures in the Sutton area as of August 1951.

OTHER SOURCES OF POTENTIAL HAYDITE RAW MATERIALS

Other potential sources of haydite shale in the Matanuska formation are suggested by extensive exposures along the highway between Kings River and Chickaloon and along the highway between Hicks and Caribou Creeks. The latter locality, however, has the disadvantage of being a considerable distance from a market and a source of fuel. The former area might compare favorably with the Kings River area. A sample of shale collected from this area at Mile 71.5 yielded a satisfactory bloat in stationary kiln tests by the Bureau of Mines (Rutledge, 1952).

A sample of shale of the Matanuska formation exposed near the north abutment of the Matanuska River bridge (near Palmer, see figure 4) was collected and tested in a stationary kiln by the Bureau of Mines (Rutledge, 1952). The sample did not bloat satisfactorily.

CONCLUSIONS

The graywacke-free portion of the shale unit in the Kings River area and Unit F in the Sutton area appear to be the best sources of haydite raw material considered in this report.

These units have relatively large accessible reserves and, if all of the shale bloats as successfully as tests on samples indicate, a large tonnage of raw material is available. Both localities are favorably located with respect to year around rail and truck transportation, source of fuel, and a market.

In view of the limited exposures at each locality, additional exploration such as trenching or drilling and sampling is needed to firm up the reserves of shale in the Kings River area and the Sutton area suitable for the manufacture of haydite.

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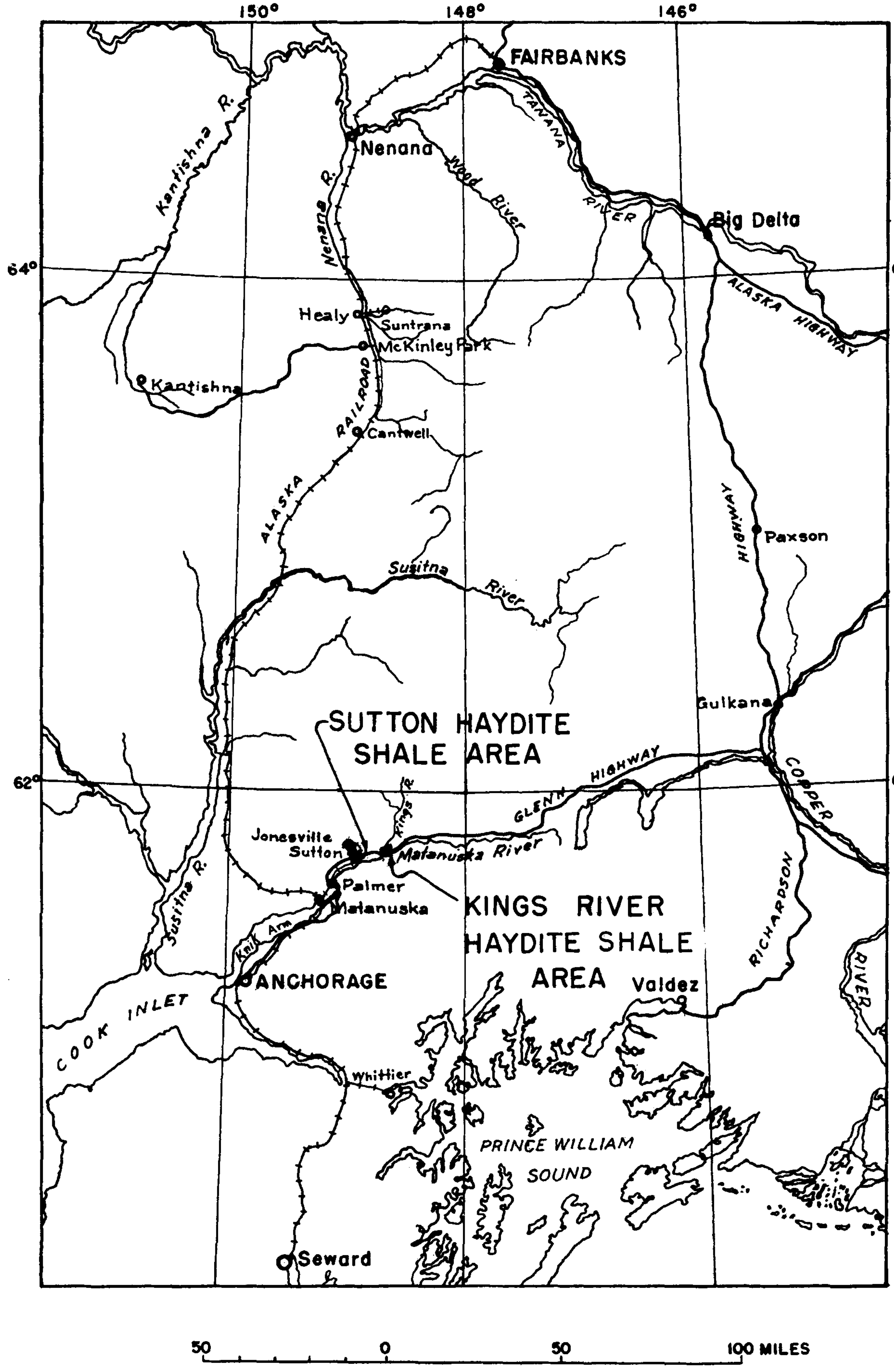
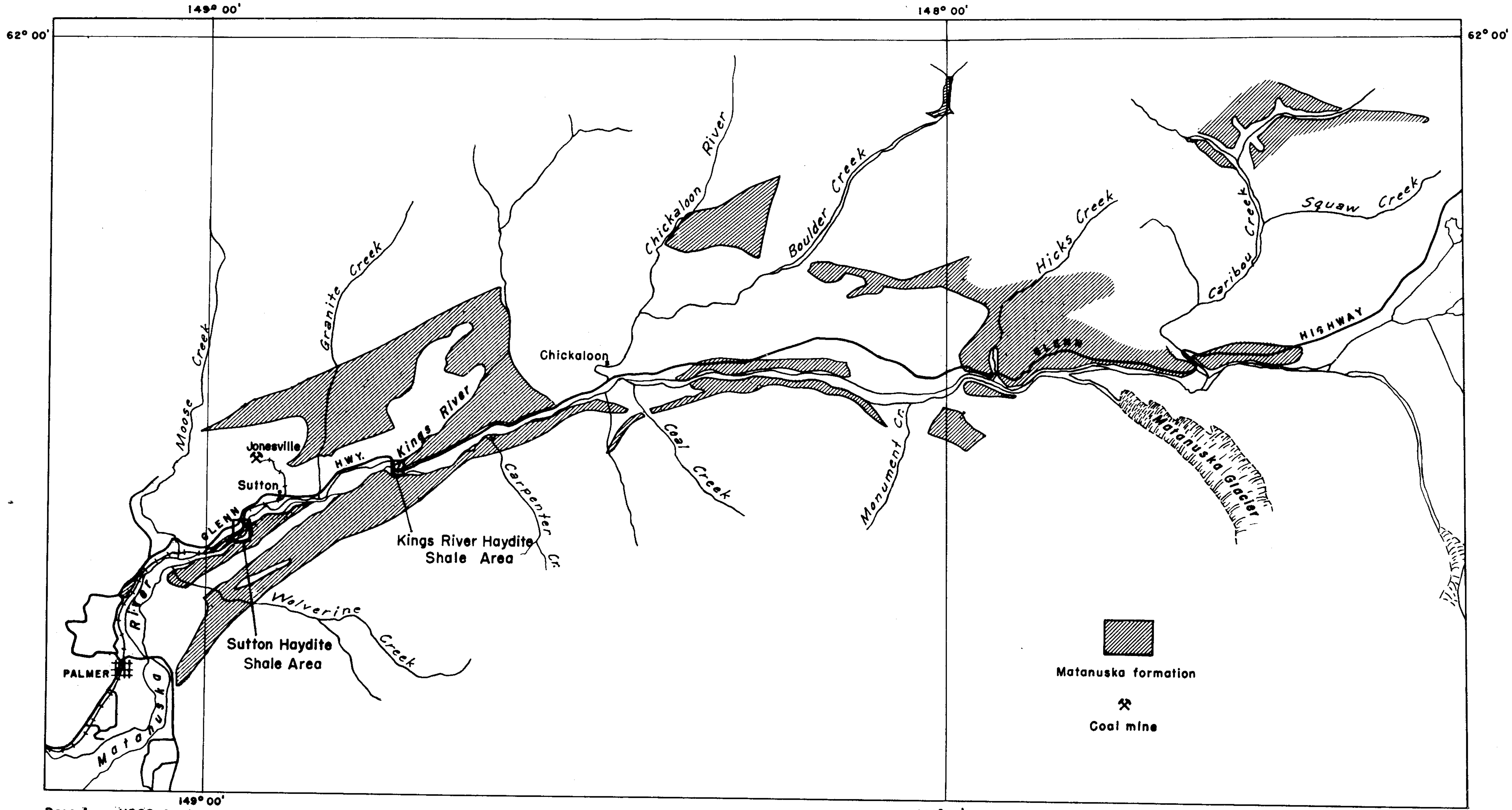


Figure I: Index map of south central Alaska showing locations of haydite shale areas

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

FIGURE 4



Base from USGS Anchorage Quadrangle, 1951.

Geology adapted from USGS Bull. 907, Pl. 2 by S. R. Capps, 1940.

GEOLOGIC MAP SHOWING DISTRIBUTION OF MATANUSKA FORMATION IN THE MATANUSKA VALLEY, ALASKA

5 0 5 10 MILES

Magnetic declination varies from 27° to 28° east