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UNITED STATES
DEPARTMENT OF THE INTERIOR
O. L. CHAPMAN, Secretary
GEOLOGICAL SURVEY
W. E. WRATHER, Director

GYPSIFEROUS DEPOSITS ON SHEEP MOUNTAIN, ALASKA

by

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1950

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INTRODUCTION

The gypsiferous deposits considered in this report are on the south side of Sheep Mountain, 112 miles northeast of Anchorage via the Glenn Highway. Sheep Mountain is an east west trending, high ridge, approximately 10 miles long and 3 miles wide. It is bordered on the west by Caribou Creek and on the east by Tahneta Pass. To the north it is isolated from the Talkeetna Mountains by the valley of Caribou and Squaw Creeks, and from the Chugach Mountains to the south by the valley of the Matanuska River.

Two creeks, Gypsum and Yellow Jacket, have incised V-shaped gulches, 1500 to 2000 feet deep, in the area of the gypsiferous deposits. The sides of the gulches are steep—30° to 45°. Outcrops within the area examined are plentiful although talus is common and locally very thick. In places where resistant rocks are exposed, sides of the gulches steepen to cliffs and many areas of outcrop are not accessible on foot. Routes of access over the area are largely confined to talus, areas of soft gypsiferous rock, and the bottoms of ravines.

Claims were filed by George H. Fennimore in 1946. Fourteen claims are presently (1949) held by the Alaska Gypsum Queen Corporation which consists of Mrs. George H. Fennimore, President, George H. Fennimore, and Leland Johnson, all of Anchorage, and Robert Clem of Palmer. The claims are leased by the Anchorage Gypsum Products Company which consists of Don Goodman, Edwin Johanson, and George Fennimore.

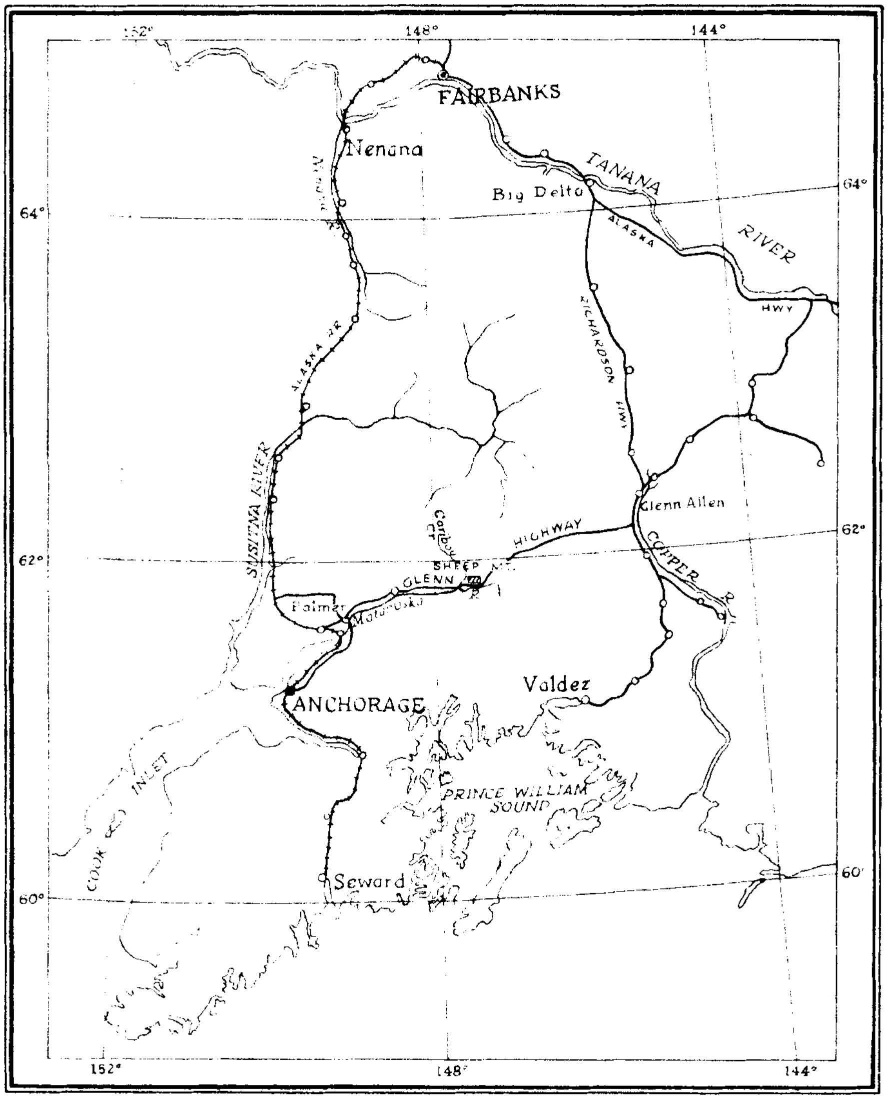

Figure 1.— Index map of south central Alaska showing location of Sheep Mountain

Development work includes two dirt roads from the Glenn Highway to the mouths of Gypsum and Yellow Jacket Gulches and a road to a proposed mill site at the base of the mountain. A small calcining plant (home-made) and two log cabins are located on the alluvial fan between the highway and the mountain. In 1947, 50 tons of calcined product were produced from the gypsiferous deposit at the mouth of Gypsum Gulch. In 1948, 50 tons of clay from a clay deposit at the mouth of Yellow Jacket Gulch were used by a brick plant in Anchorage in the manufacture of fire brick. Five tons of the clay were used in Palmer as boiler lining.

During part of the summer of 1949, an area about 1½ miles square was examined for gypsiferous deposits. Geologic features were plotted on a special topographic map prepared by the Topographic Division of the Geological Survey; scale 1:12,120 and contour interval 100 feet (see Figure 2). Detailed geologic and topographic maps, scale 1:1,200 and contour interval 20 feet, were compiled to include the six most promising areas of gypsiferous rock (see Figure 3). Control for the detailed maps was established by plane table and alidade traverse from Coast and Geodetic benchmarks along the Glenn Highway. Details were mapped by tape and compass. The detailed maps were made by R. A. Eckhart and C. Fenimore (field assistant) and checked in the field by G. O. Gates. The 1:12;120 scale map of the area was compiled by Gates and Eckhart.

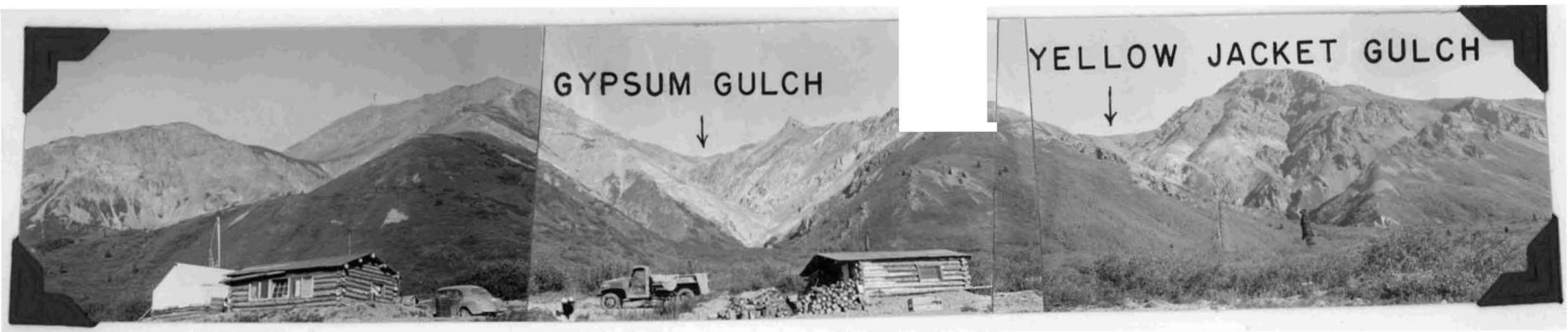

Figure - 4 Panorama of gypsiferous area on Sheep Mountain showing Gypsum and Yellow Jacket Gulches.

GEOLOGY

Sheep Mountain is made up of a thick section of layered volcanic rocks of Jurassic age. Within most of the area mapped these rocks have been intruded by a large number of mafic dikes and have undergone alteration to greenstone. Locally the greenstone has been altered to form irregular masses of gypsiferous rock and quartz-sericite rock. Along part of the south base of the mountain faulting has downthrown the sandstone and shale of the Upper Cretaceous Matanuska formation against the volcanics. The only younger rocks comprise patches of Pleistocene conglomerate that once partly filled the gulches of Gypsum and Yellow Jacket Creeks and the alluvial fans built by these creeks.

Talkeetna formation

The volcanic rocks comprising Sheep Mountain consist largely of interbedded tuffs, lavas, and volcanic breccias. Paige and Knopf[1]

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

have included these rocks in the Jurassic Talkeetna formation. This formation has a wide distribution in and adjacent to the upper Matanuska Valley. These authors mapped a quartz diorite boss in the area in which the gypsiferous deposits were later recognized. No evidence of the quartz diorite was found during the field work connected with the present report.

Within the mapped area the tuffs and breccias are light gray, gray, and greenish-gray in color. They are well bedded, with beds of tuff ranging from several inches to more than 20 feet thick and beds of breccia as much as tens of feet thick.

The tuffs are well consolidated, compact and in part, if not wholly, water layed. They consist of rock and mineral fragments embedded in an aphanitic matrix. The rock fragments are commonly andesite and diabase. The most common mineral constituents are quartz, plagioclase feldspar ranging in composition from andesine to labradorite, chlorite and serpentine minerals. The latter two minerals have replaced almost all the original ferromagnesian minerals and the aphanitic matrix. Some of the feldspar has been altered to an aggregate of albite, clinozoisite and prehnite. Thin seams of calcite, local secondary quartz and disseminated pyrote are not uncommon in these rocks.

A few thin beds of black carbonaceous shale and tuffaceous sandstone are locally intercalated with beds of tuff. A Unio from the shale was examined by Dr. Tang-Chien Yen. He reports that it is very similar to an undescribed species from the Morrison formation of northern Montana and is much more likely to be of Jurassic than of Cretaceous age.

Layers of breccia within the area are less abundant than layers of tuff and consist of angular fragments of porphyritic basalt and andesite fragments set in a fine-grained groundmass that is largely chloritic. The fragments vary in size from several inches to more than a foot in diameter.

The upper part of the layered volcanics in the mapped area consists of at least several hundred feet of fresh, greenish-gray to black basalts and andesites. Most of the flows are aphanitic. A few are porphyritic and some are amygdaloidal. The phenocrysts are usually labradorite and the amygdules consist of zeolites, calcite, and quartz.

The presence of secondary minerals such as chlorite, clinozoisite epidote, prehnite, and various serpentine minerals indicates the tuffs and breccias have undergone mild metamorphism and might be called greenstones. However in this report the term "greenstone" is restricted to phases of the volcanic rocks that have been more intensely altered to chlorite-albite-epidote rich rocks in the vicinity of the deposits.

Zone of alteration

The zone in which the volcanic rocks have been altered to greenstone, quartz-sericite rock, and gypsiferous rock lies within the drainage area of Gypsum and Yellow Jacket Creeks. It extends northward from the reverse fault near the south base of the mountain and crosses the crest of the mountain near the headwaters of the creeks. As seen from the air it is present on part of the north slope of the mountain. The brown, yellow, white, and red colors of the rocks and talus within the zone stand in striking contrast to the neutral hues of the tuffs, breccias and flows.

Greenstone

Greenstone comprises most of the rock in the zone of alteration. It is a light to dark greenish-gray, fine-grained rock which locally shows relic textures of the parent volcanics. In many places alteration has so obscured original textures that it is difficult or impossible to determine with certainty the nature of the original rock.

Saussuritization and chloritization were the principle processes by which the greenstone was formed. A microscopic examination of several thin-sections of greenstone reveals that epidote, clinozoisite, albite, and prehnite have formed at the expense of original plagioclase feldspar. Chlorite commonly comprises a large part of the fine-grained matrix in which fragments of the minerals produced by saussuritization and locally badly altered and fractured original labradorite are embedded. Pyroxene crystals have been largely altered to chlorite. Commonly the matrix between mineral grains and composite fragments is a finely crystalloblastic, semi-opaque mass, composed essentially of epidote, leucoxene, some iron oxide and probably some fine quartz and/or feldspar. Where developed sphene is commonly in the form of semi-opaque clusters which are coated by leucoxene. Several specimens illustrate the partial or complete replacement of olivine phenocrysts by serpentine minerals. The field and petrographic evidence strongly suggests these rocks were originally flows of olivine basalt.

Numerous small pods and stringers of gypsum intricately cut much of the greenstone and, locally, calcite and quartz stringers are present. Many of the stringers follow joints and shears which, along with a great amount of slickensiding and fracturing, are prominent features of the greenstone. Weathered surfaces of the rock are stained with light to dark brown limonite.

Dikes

A large number of mafic dikes cut the greenstone. Most of the dikes were observed along Yellow Jacket and Gypsum Creeks. The full extent of the dikes was rarely traced but it is believed that many of them are continuous across the divide that separates the two creeks. At least several dikes cross the gypsiferous deposits while others, in part, border the deposits.

The dikes trend northeast and dip 30° to 65° to the north. A few dikes dip to the south. Most of the dikes in Gypsum and Yellow Jacket Gulches are less than 30 feet thick but they range from several feet to more than 160 feet in thickness. Locally they are so closely spaced as to constitute dike swarms as much as 300 feet wide.

The dikes are usually greenish-gray to black and of basaltic composition. Fairly fresh phenocrysts of labradorite and in lesser amount pyroxene and olivine are commonly set in a fine-grained chloritic groundmass. Locally the dikes contain abundant secondary quartz. Most of the phenocrysts, though usually well preserved, are badly fractured. Locally, some of the labradorite is altered to clinozoisite and an undetermined carbonate mineral. Some pyroxene phenocrysts are replaced by chlorite and rarely epidote. Locally pyrite is present in abundance. Small amounts of magnetite and apatite are also present in part of the dike rock.

Quartz-sericite rock

A quartz-sericite rock is one of the alteration products of the volcanic rocks. It is intimately mixed with gypsum in the gypsum deposits. In places the volcanic rocks are altered mainly to quartz-sericite rock

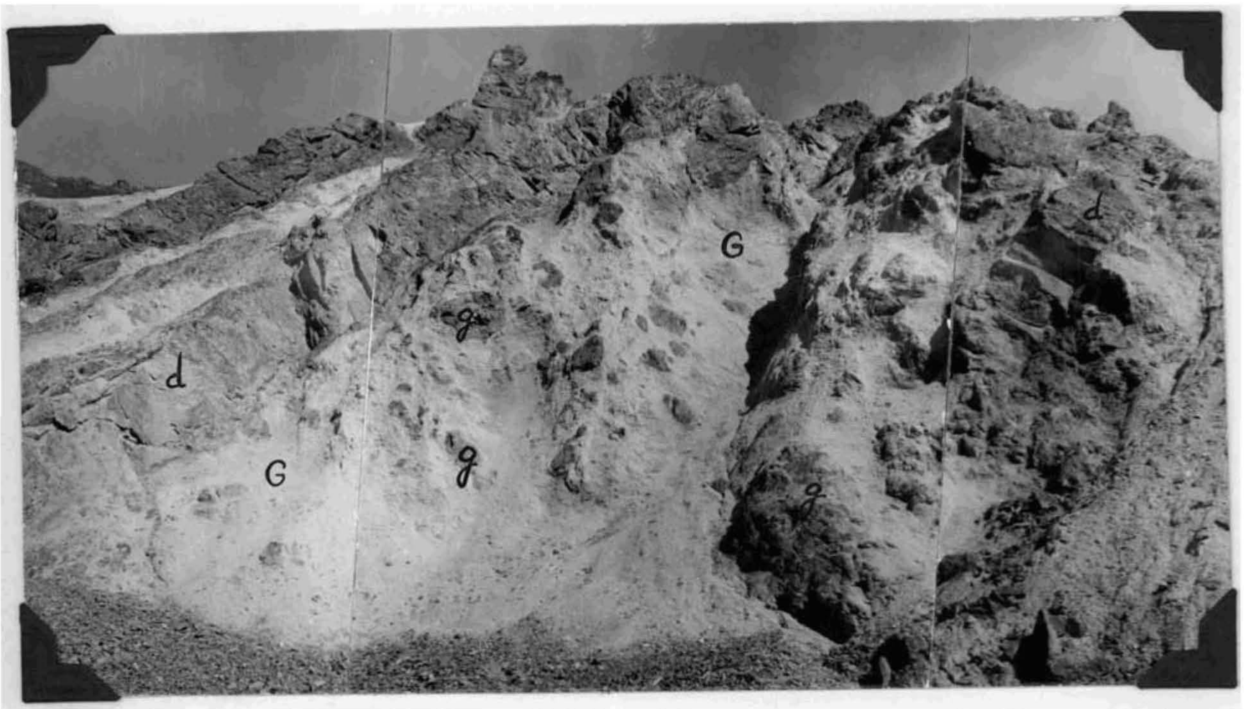

FIGURE - 5 Photograph showing dikes, gypsiferous rock, and greenstone in Gypsum Gulch. d - dike, G - gypsiferous rock, g - greenstone to form irregular bodies ranging in diameter from a few feet to several hundred feet. One of the largest of these bodies forms a narrow ridge jutting out beneath Deposit 2 on the east side of Yellow Jacket Gulch. This is shown in Figure 3.

The quartz-sericite rock is white to light gray, fine-grained, and platy. Much of it shows relic porphyritic, clastic, or trachytic textures. Its mineralogy is variable, but quartz and sericite are its most common and abundant constituents. With the possible exception of some of the quartz, none of the original constituents of the volcanics remain. The groundmass has been silicified and the original feldspars have been altered to sericite and rarely gypsum and clinozoisite. The small amounts of mafic minerals present in the original rock have been replaced by chlorite and epidote. Hematite and a clay mineral comprise a small percentage of the rock. The presence of varying amounts of gypsum and other soft minerals gives the rock a hardness ranging from 4 to more than 6.

Locally, small cubes of pyrite are disseminated in the quartz-sericite rock. In some outcrops surfaces of the rock are pitted. The pits are cube-shaped and apparently formed by the leaching of pyrite.

Outcrops of the rock exhibit a poorly developed platy structure which is also shown though more poorly developed, in some outcrops of weathered greenstone.

The similarity of textures and platy structure of the quartz-sericite rock to those of the greenstone indicates the quartz-sericite rock is also the result of the alteration of the tuffs, breccias, and flows.

Gypsiferous rock

Gypsiferous rock comprises the bulk of the areas mapped as ore deposits. It also occurs as smaller, scattered masses in the greenstone. The composition of the gypsiferous rock is complex and variable. Quartz and gypsum are its most abundant mineral constituents. Clay minerals of the kaolinite group and alunite are usually present. Limonite and an unidentified yellow-green coating stain local areas of gypsiferous rock. The platy structure of the quartz-sericite rock is also evident in some outcrops of the gypsiferous rock.

At the surface the gypsiferous rock is porous and fragmental or granular. Beneath the surface it is more compact. The rock consists largely of two intimately mixed components, white fine-grained gypsum and, for lack of a better term, altered rock. The gypsum occurs as blebs and irregular stringers cutting and cementing together fragments of altered rock. It is soft, massive and usually contains fine-grained admixed quartz and larger siliceous fragments. Good cross fiber vein structure is rare. Alunite and cubes of pyrite, up to 1/8 of an inch in diameter, are occasionally present.

For descriptive purposes the altered rock component may be divided into light gray or tan variety and a dark gray variety. These colors combined with the white (rarely pink) gypsum and brown and yellow-green stains give the ore a mottled appearance.

The light gray or tan altered rock is similar in appearance to the quartz-sericite rock, but is usually softer and different in mineralogy. This variety of the altered rock is largely mixtures of fine-grained quartz and gypsum. Alunite and a clay mineral are commonly present. Antigorite and/or chrysotile comprise a large part of the matrix of some specimens. Sericite rarely is present as an alteration product of feldspars. In one specimen, talc appears to have replaced orthorhombic pyroxene crystals. In some of the light gray or tan variety of altered rock pyrite is present as disseminated cubes or its former presence is indicated by cube-shaped pits. The hardness of this variety ranges from 3 to more than 6 depending on the relative amounts of quartz and soft minerals present. Usually it is less than 5 in hardness.

The light gray or tan altered rock is commonly aphanitic but some of it exhibits relict porphyritic textures in which the original feldspar phenocrysts have been replaced by gypsum. Small irregular masses of gypsum in some of the light gray or tan altered rock suggest a relict clastic texture and may indicate replacement of tuff.

The dark gray portion is hard, consisting almost entirely of quartz. Most of it is aphanitic but relict porphyritic textures are seen in some of it. Rarely, alunite is present. It may form a considerable part of the rock, however. One sample contained as much as 35 percent of alunite.

The exact effect of ground water on the ore has not been ascertained. Locally, the ore at the surface appears to have been enriched with gypsum while in other places leaching appears to have taken place. Gypsum and Yellow Jacket Creeks are highly charged with mineral matter. Table 1 summarizes water analyses of these creeks by R. T. Kiser of the U. S. Geological Survey.

Table 1. Water analyses of Gypsum and Yellow Jacket Creeks

(Parts per million)

	Gypsum Creek	Yellow Jacket Creek
Silica (SiO_2)	73	78
Iron (Fe)	0.54	3.7
ppt Fe	--	54
Calcium (Ca)	378	372
Magnesium (Mg)	268	253
Sulfate (SO_4)	2820	2860
Chloride (Cl)	5.5	3.0
Specific conductance ($Kx10_6$ at 25C.)	3410	3810
pH	3.5	2.8

*In addition to the constituents reported there appears to be a considerable amount of aluminum in both creeks. No determinations were made for sodium or potassium.

Clay

Clay, also a product of alteration of the volcanic rocks, is mixed in variable amounts with the gypsiferous rock and the quartz-sericite rock in most of the deposits. It is white to yellow, sticky, plastic, and is commonly veined by stringers of white, fine-grained gypsum. A deposit at the mouth of the gulch of Yellow Jacket Creek consists in considerable part and perhaps largely of clay.

Matanuska formation

The Matanuska formation of Upper Cretaceous age is exposed along part of the south base of Sheep Mountain. In the area mapped this formation consists of sandstone and shale and has been faulted down against the volcanic rocks on the north.

The sandstone is greenish-gray, fine-grained, and well bedded. Individual layers are several inches to a few feet in thickness. They contain numerous Inoceramus which R. W. Imlay, U. S. Geological Survey, has determined as probably of early Upper Cretaceous age.

Black shale is exposed in a very small area just north of the proposed mill site at the base of the mountain. It is massive and overlies the sandstone.

Conglomerate

Erosional remnants of a reddish-brown conglomerate of Pleistocene (?) age are present in the lower parts of Gypsum and Yellow Jacket Gulches. The conglomerate is composed largely of subangular greenstone and some gypsiferous rock fragments ranging from less than an inch to a foot or more in diameter; 3 to 4 inches being about average. It is coarser in its lower portion, and near its top several layers of fine-grained, red sandstone are present. For the most part the conglomerate is horizontally bedded, but beds dipping 25° to 40° south are also present.

The conglomerate is believed to have been deposited when Gypsum and Yellow Jacket Creeks were dammed by a glacier in the Matanuska Valley. The dipping beds apparently represent deltaic deposition. The sediments were later cemented with gypsum and iron oxide that were carried in solution by the creeks.

Structure

In general, the volcanic rocks comprising Sheep Mountain strike a few degrees east or west of north and have a fairly uniform dip of about 30° to 50° to the east. Layering is obscure and attitudes are difficult to determine within the area of greenstone. There is some evidence however for local reversal in dip west of Gypsum Creek so that this creek follows approximately the crest of an anticline.

The large reverse fault shown in Figure 2 cuts the entire area mapped. It trends approximately parallel to the front of the mountain and dips steeply northward. The southern side is downthrown. Comparison of the sequences of rocks north and south of the fault suggests a minimum vertical displacement of about 1500 feet.

The fault is best exposed on the east side of Yellow Jacket Gulch. There it strikes N. 60° E. and dips 72° north, forming a steep scarp as much as 100 feet high. (See Figures 8 and 9.) Near the fault the volcanic rocks on the downthrown side are overturned to the north. Greenstone, containing the gypsiferous deposits, comprises the upthrown side. A band of white clay, several feet wide, borders this side of the fault.

South of this fault a normal fault has downthrown the sandstone and shale of the Matanuska formation against the volcanic rocks to the north.

Locally, the greenstone is broken by shear zones as much as four feet wide. These shear zones trend northeast more or less parallel with the dikes. Along the shears gypsiferous and limonitic alteration has usually taken place.

GYPSIFEROUS DEPOSITS

Description of Deposits

What are believed to be the largest and most promising deposits of gypsiferous rock are the six mapped in detail. Their locations are shown in Figure 2.

The deposits are closely associated with dikes and although their shapes are irregular, at least to some degree, shape is controlled by the attitude of the dikes and the enclosing greenstone. Masses of quartz-sericite rock and greenstone, ranging from less than a foot to tens of feet in size, are found within the deposits. Their presence is unpredictable. These masses are intricately cut by stringers and small pods of gypsum. Pyrite is abundant in many of the greenstone masses. The change from greenstone to relatively high grade gypsiferous rock may be abrupt and take place within a few inches. A narrow limonitic zone usually separates the greenstone and the gypsiferous rock. The change from greenstone to gypsiferous rock may also be gradational through a zone of quartz-sericite rock.

Much of the gypsiferous rock of the deposits lies beneath talus several feet to 10 or more feet thick. Where the talus is several feet thick it consists largely of small angular greenstone fragments in its upper part and layers of vari-colored clay and gypsiferous rock fragments, that are often banded in texture and color, in its lower part. The lack of greenstone fragments in the lower part suggests the layers formed by fragmentation of underlying gypsiferous rock and movement downslope. Thin, narrow spaced stone stripes are not uncommon on the surface of the talus.

Permafrost was reached 7½ feet vertically below ground surface in the face of the open-cut on Deposit 2 and 6½ feet vertically below ground surface in the face of the open-cut on the east slope of Deposit 1.

No. 1

This deposit is on the crest of the ridge between Gypsum and Yellow Jacket Creeks, largely between 4400 and 4600 feet in elevation. The deposit is completely enclosed by greenstone.

The northwestern part of the deposit was mapped as gypsiferous rock containing small greenstone masses. These masses are estimated to comprise 50 to 60 percent of this area and 10 of the remainder of the deposit. Figure 6 shows typical greenstone pods in the northern part of the deposit.

An irregular mass of quartz-sericite rock, about 100 feet long and 35 feet wide, lies between the gypsiferous rock and the surrounding greenstone at the south side of the deposit.

Figure - 6 Photograph showing greenstone pods in northern part of Deposit No. 1. G - gypsiferous rock, g - greenstone.

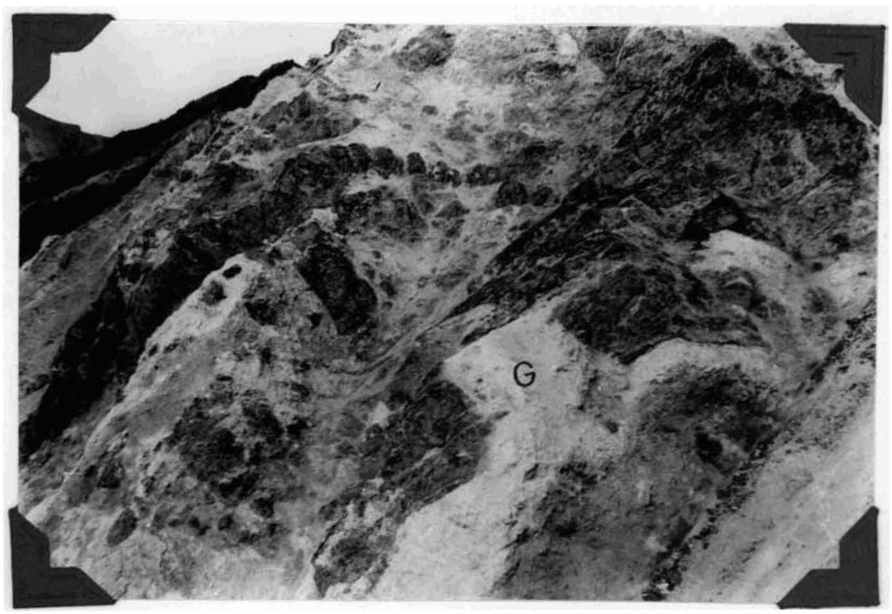

Figure - 7 Photograph showing dike cutting gypsiferous rock and pods of greenstone in Deposit No. 1. d - dike, g - greenstone, G - gypsiferous rock

One of the dikes cutting the enclosing greenstone was traceable into and through most of the deposit. The dike also cuts several greenstone pods within the deposit. It is badly weathered and limonitic stained at the surface. The contact between it and the gypsiferous rock is very sharp. Figure 7 shows the relationships of the dike.

The contact between the ore and the greenstone at the north end of the deposit is concealed by thick talus. It is possible that the deposit extends some distance northward under this cover. However, a short distance north of the mapped contact greenstone is known to underlie the talus.

No. 2

Deposits 2, 3, 4, and 5 (Figures 3 and 8) comprise a discontinuous zone of ore roughly 2400 feet long and 700 feet wide on the east side of Yellow Jacket Gulch.

Deposit 2 is near the northwest end of this zone. It crosses a spur between elevations of about 4500 feet and 4640 feet. In outcrop it is about 300 feet long and 100 to 200 feet wide. Parts of the deposit are covered with talus and soil creep as much as 8 feet thick. The nature of the bedrock and the positions of contacts were determined by digging pits.

At the east side and at the west side of Deposit 2 the gypsiferous rock grades into quartz-sericite rock which contains some gypsum. The relation between the traces of the contacts between the gypsiferous rock and the quartz-sericite rock and the attitude of layered volcanic rocks a few hundred feet north, suggests that quartz-sericite rock in part

Figure - 8 Photograph showing location of Deposits Nos. 2, 3(in part), 4, and 5 on east side of Yellow Jacket Gulch.

forms the bottom and the roof of Deposit 2. A basalt dike which dips to the north forms the southeastern boundary. The deposit is bounded on the north and south by greenstone.

Deposit 2 appears to contain the least number of pods and blocks of greenstone. A body of porphyritic basalt 50 feet long and 20 feet wide is exposed near the center of the deposit. The basalt shows little evidence of alteration although it is veined by several stringers of gypsum. Its contact with gypsiferous rock is sharp and marked by a thin band of clay and gypsum.

No. 3

Deposit 3 is southeast of Deposit 2; the two deposits being separated by a large area of thick talus. Apparently, the geology beneath the talus is similar to that on either side of it.

In calculating tonnage, the deposit was divided into four parts, a, b, c, and d. These are shown in Figure 3. All four parts are covered with talus, part (a) being separated from the remainder of the deposit by a fairly large area of thick talus. The talus over the remainder of the deposit averages about three feet in thickness and by persistent trenching the underlying geology was mapped. However, it should be pointed out that due to this talus the deposit, in part, could not be mapped as accurately as Deposits 1 and 2.

Greenstone masses within the deposit consist largely of altered tuffs. Clay and quartz-sericite rock are major constituents of the deposit.

Between parts (b) and (c) the quartz-sericite rock is so abundant that the area was mapped as a mixture of quartz-sericite rock and gypsiferous rock.

To the south the deposit is limited by greenstone that is believed to be an altered tuff and, in part, a breccia. To the north a layered sequence of tuffs strikes into the deposit. Quartz-sericite rock is abundant at the contact and a few stringers of gypsum extend a short distance into the layered sequence. There appears to be a rough transition from the gypsiferous rock through a narrow zone of quartz-sericite rock to the well bedded, mildly altered tuffs. The transition takes place within tens of feet. Several small shears occur in the tuffs near the deposit but none show mineralization.

No. 4

Deposit 4 is southeast of Deposit 3, across a gulch incised by a tributary of Yellow Jacket Creek. Figure 9 affords a close-up view of this deposit. The face of Deposit 4 is barren of talus and is very steep with slopes exceeding 40°. A large part of the deposit is not readily accessible on foot. Greenstone pods comprise at least 10 percent of the deposit and quartz-sericite rock is locally very abundant.

No. 5

Deposit 5 is at the southeast end of the discontinuous zone of gypsiferous rock on the east side of Yellow Jacket Gulch. About one hundred feet south of Deposit 5 this zone is terminated by the reverse fault previously described.

Figure 9 Photograph showing Deposits 4 and 5. The white areas within the deposits are gypsiferous rock. g - greenstone pod in Deposit 4.

The east and west sides of the deposit are covered by thick talus. Its north and south sides are bordered by greenstone. The greenstone to the north consists of a green, fine-grained, pyritiferous altered tuff.

For description the deposit is divided into an upper and lower part. The lower part contains numerous pods of greenstone and quartz-sericite rock. The upper part of the deposit is covered with a thin talus and the underlying gypsiferous rock is different from that observed elsewhere. It appears to contain considerable clay and small amounts of quartz and alunite, but the dark gray siliceous fragments in the gypsiferous rock of the other deposits is absent.

No. 6

Deposit 6 is the smallest deposit mapped in detail but it is the most accessible of the six deposits. The deposit forms approximately a 45° slope on the east side of the mouth of Gypsum Gulch. The bed of Gypsum Creek forms the western boundary of the deposit as gypsiferous rock is not present across the creek. The north and south sides of the deposit are bounded by greenstone and its eastern exposure is limited by thick talus composed largely of greenstone fragments.

For the calculation of tonnage, the deposit was assumed to extend horizontally into the side of the gulch.

Origin

Relict textures and structures in the greenstone demonstrate that it was formed by local alteration of the volcanic rocks of the Talkeetna formation. In some places the alteration continued beyond the stage of greenstone to form deposits of gypsiferous rock and deposits of quartz-sericite rock. This is shown by the following:

(1) Deposits of gypsiferous rock and deposits of quartz-sericite rock are restricted to the zone of greenstone.

(2) Relict textures and structures in the gypsiferous rock and quartz-sericite rock can be traced into greenstone.

(3) All gradations are present between greenstone cut by short, scattered, irregular veinlets of gypsum and gypsiferous rock and quartz-sericite rock which contain residual pods of greenstone.

The alteration of the volcanics to greenstone, gypsiferous rock and quartz-sericite rock probably was accomplished by hydrothermal solutions.

Dikes are largely restricted to the zone of greenstone. There is no evidence that they are younger than the gypsiferous rock and the presence of secondary quartz in many of the dikes suggests they are older.

The intrusion of the dikes and the hydrothermal activity probably are related to a single phase of igneous intrusion.

Grade

A total of 60 gypsiferous rock samples were collected from Deposits 1 through 5. They include continuous chip samples, spaced chip samples (approximately one foot spacing), samples from pits and trenches dug through talus, and grab samples from outcrops. The locations of pits, trenches, and lines of samples on outcrops are shown in Figure 3. Two grab samples were taken from the ore pile at the calcining plant. All this material was mined from Deposit 6.

Pits through talus covering the deposits ranged from one foot to 8½ feet in depth, and averaged about 3 feet. Samples were usually taken from the bottoms of the pits. Most of the chip samples were taken from trenches 3 inches to one foot deep.

Five samples were analyzed in laboratories of the U. S. Geological Survey by W. J. Blake, Jr., and Leonard Shapiro. The determinations were made according to testing methods described in A.S.T.M. Designation C 26-33, A.S.T.M. Standards, Part 2, 1933, modified to take into account the possible presence of alunite and pyrite. Table 2 gives the results of these analyses.

Through the courtesy of the Department of Mineral Sciences of Stanford University in making available their laboratory and equipment, a simple acid soluble test was made by the author to determine the approximate amount of gypsum in 56 of the ore samples, excluding the samples shown in Table 2. Table 3 summarizes the results of this test.

Table 2

Sample No.	D1-10	D2-14	D2-17	D2-19A	D2-19E
SiO_2 + Insol.	55.64	44.70	70.24	62.50	63.75
Fe_2O_3 (Total)	1.48	1.35	1.69	2.65	1.47
Al_2O_3 (Total)	14.27	9.31	15.59	14.24	12.29
TiO_2 (Total)	0.53	0.53	0.53	0.60	0.60
CaO (Total)	9.90	17.54	8.46	7.42	10.65
MgO (Total)	0.09	0.11	0.04	1.57	0.09
SO_3 (Acid sol.)	14.14	25.43	11.45	11.13	15.67
SO_3 (Acid insol.)	11.08	nil.	0.37	9.19	0.60
K_2O*	0.80	0.04	0.08	1.10	0.04
Na_2O*	1.48	0.14	0.30	1.20	0.10
CO_2	trace	trace	trace	0.10	0.11
Loss on Ign.	21.09	13.98	10.00	18.82	11.45
H_2O (220°C)	5.91	10.94	5.21	4.42	6.92
Gypsum (calc. from sol. SO_3)	30.41	54.70	24.63	23.94	33.71
Alunite (calc. from insol. SO_3)	28.71	nil.	0.96	23.81	1.55
K alunite (calc. from K_2O)	7.02	nil.	0.70	9.65	0.35
Na alunite (Total alunite-K alunite)	21.69	nil.	0.26	14.16	1.20

*Alkalies with flame photometer by S. M. Berthold.

D1-10 continuous chip sample from face of upper 6 feet of Pit 56, Deposit 1.

D2-14 continuous chip sample along Trench 6, Deposit 2. Trench 6 was about 4 inches deep.

D2-17 from Pit 23, 18 inches deep, Deposit 2.

D2-19A continuous chip sample of the bottom 1 foot of the face of Pit 27, Deposit 2. Pit 27 was 8½ feet deep.

D2-19E continuous chip sample 1 foot long near top of face of Pit 27.

Table 3. Approximate analyses of samples of gypsiferous rock.

*Sample No.	Percent gypsum	**T-trench, P-pit	Depth of trench or pit in feet. (length of sample trench)	Remarks
Deposit 1:				
D1-1	31	P54	3.5	
D1-3	17	P55	2.5	
D1-4	36	T7	.33 (42)	Spaced chip samples. D1-5
D1-5	36	T7	.33 (45)	up slope from D1-4.
D1-6	37	T8	.33 (28)	Spaced chip sample.
D1-8	34	P56	7	Open-cut - top of perma-frost 6$\frac{1}{2}$ feet vertically below ground surface.
D1-11	40	P57	5	Continuous chip sample along face of pit.
D1-12	38	P58	.5	
D1-14	32	P59	7	
D1-15	40	P59	7	Continuous chip sample of middle 4.5 feet of face of pit.

*Location in Figure 3.

**Unless otherwise noted sample was taken from bottom of pit.

Table 3. (Continued)

*Sample No.	Percent gypsum	**T-trench, P-pit	Depth of trench or pit in feet. (Length of sample trench)	Remarks
Deposit 2:				
D2-1	39	P1	7	Talus 6 feet thick.
D2-2	26	T3	.5 to 1 (3.5)	Continuous chip samples taken consecutively up slope. Above D2-2, 7 feet of trench was not sampled.
D2-3	25	T3	.5 to 1 (9)	
D2-4	31	T3	.5 to 1 (16.7)	
D2-5	34	T3	.5 to 1 (22)	
D2-6	33	T4	.33 to .5 (30.5)	Continuous chip samples taken consecutively up slope.
D2-7	32	T4	.5 (15.5)	
D2-8	19	P6	4	
D2-9	28	P7	3.5	
D2-10	25	T5	.5 to .75 (22)	Continuous chip samples taken consecutively up slope.
D2-11	29	T5	.5 (24)	
D2-12	51	T5	.5 (19)	
D2-13	32	T6	.33 (14)	
D2-15	32	P9	5	
D2-18	11	P26	5	
D2-19B	61	P27	8.5	Continuous chip samples up face of pit. Permafrost in bottom of pit.
D2-19C	30	P27	8.5	
D2-19D	31	P27	8.5	
D2-19F	32	P27	8.5	

Table 3. (Continued)

*Sample No.	Percent gypsum	**T-trench, P-pit	Depth of trench or pit in feet. (length of sample trench)	Remarks
Deposit 3:				
D3-1	37	P28	2.5	
D3-2	37	P28	2.5	Continuous chip sample up face of pit.
D3-3	26	P29	1	
D3-4	34			Grab sample from outcrop 15 feet east of P29.
D3-6	27	P32	7	
D3-7	27	P33	7.5	
D3-8	3	P35	3	
D3-10	28	P44	2.5	
D3-11	18	P47	3	
D3-12	46	P48	2	
D3-13	23			Grab sample from outcrop north of P48.
D3-14	27			Grab sample from small outcrop in part (d) of the deposit.
D3-15	12			Grab sample from outcrop south of part (d).
D3-17	23			Grab sample from outcrop south of part (d).
D3-18	25			Grab sample from outcrop in part (c) - south of P48.
D3-19	19	P49	2.5	

Table 3. (Continued)

*Sample No.	Percent gypsum	**T-trench, P-pit	Depth of trench or pit in feet. (length of sample trench)	Remarks
Deposit 4:				
D4-1	23	T9	1 (25)	
D4-2	17	T9	1 (15)	Continuous chip samples taken consecutively up slope.
D4-3	29	T9	1 (15)	
D4-4	19	T9	1 (20)	
Deposit 5:				
D5-1	30	T10	.33 (15)	Continuous chip sample.
D5-2	29	T11	.33 to .5 (12)	Continuous chip sample.
D5-3	30	T12	.33 to .5 (18)	Continuous chip sample.
D5-4	33	P51	4	
D5-5	22	P50	3	
D5-6	28	P52	3.5	
Deposit 6:				
D6-1	26			Composite grab sample from ore pile at kiln.

The acid soluble test is based on the relative solubilities of alunite and gypsum in dilute hydrochloric acid. The following procedure was used. The sample was ground to minus 100 mesh, quartered and weighed. The weighed portion was added to hydrochloric acid of 0.5 normality using the ratio of 30 milliliters of acid per gram of ore. The mixture was then heated for half an hour, decanted, fresh acid of the same normality added, and heated again for half an hour. Care was taken not to boil the mixture during heating. After the second heating the mixture was filtered and the insoluble residue dried in an oven at a temperature of 100° to 120° C. The difference between the weight of the sample and the weight of the residue was taken to equal approximately the weight of the gypsum present in the sample.

Microscopic examinations of the residue of each sample tested usually failed to indicate the presence of gypsum. Rarely, one or two small grains of gypsum were identified under the microscope.

Mr. Leonard Shapiro also analyzed for gypsum the samples in Table 2 using the acid soluble test. Table 4 compares his results with the results obtained by using modified A.S.T.M. methods (Table 2).

Table 4

Sample No.		D1-10	D2-14	D2-17	D2-19A	D2-19B
Percent gypsum	Acid soluble test	30.2	54.6	26.4	23.7	33.1
	Modified ASTM methods	30.41	54.7	24.63	23.94	33.71

The quartz-sericite rock intimately associated with the gypsiferous rock, and the quartz, alunite and alteration minerals present in the gypsiferous rock are contaminating constituents of the ore. A sample representing Deposit 6, analyzed by the Bureau of Mines, contained 28.2 percent alunite. Estimates of the percent of alunite in the 60 ore samples collected from Deposits 1 through 5 were made by inspection of immersion mounts of the ore. Nineteen of the samples contained alunite in amounts ranging from an estimated 2 to 65 percent. Seven of these 19 samples were estimated to contain 20 percent or more alunite. Residues of the acid soluble test on samples in which no alunite was identified in immersion mounts of the ore, commonly, but not always, contained a little alunite when examined under the microscope.

As seen in the material of the ore pile at the kiln, the gypsiferous rock of Deposit 6 contains abundant disseminated small grains of pyrite. Very little pyrite was seen in the gypsiferous rock of Deposits 1, 2, 3, 4, and 5. Some of the fragments of quartz-sericite rock in the ore, however, are marked by small cube-shaped pits. These pits probably formed by the leaching of pyrite. Heavy mineral separations of samples D1-10, D2-14, D2-17, D2-19A, and D2-19B were examined by Theodore Woodward, U. S. Geological Survey, and the samples were found to contain only a negligible amount of pyrite and traces of magnetite.

Reserves

All calculations of reserves are based on the assumption that the specific gravity of the gypsiferous rock is 2.4 or 13 cubic feet of ore weighs one short ton. This specific gravity is slightly higher than that of gypsum (2.32), but was assumed to account at least in part for the heavier impurities in the ore, such as quartz (2.65) and alunite (2.6 to 2.8).

Deposit 1:

The northwestern part of this deposit contains 50 to 60 percent greenstone and is not included in the reserve calculations. It is estimated that the reserves calculated include as much as 10 percent greenstone, present as small masses throughout the gypsiferous rock.

Reserves were calculated by constructing five vertical sections 50 feet apart across the deposit at a bearing of N. 65° E. On each vertical section the gypsiferous rock was assumed to bottom at a line connecting the intersection of the vertical section and the lower limit of gypsiferous rock on each side of the ridge. The reserves are considered to be indicated.

Indicated reserves --------- 206,000 tons.

Deposit 2:

Both indicated and inferred reserves were calculated for this deposit. The small masses of greenstone present in the deposit are included in the reserves.

For the indicated reserves it was assumed that the gypsiferous rock extends horizontally into the spur to straight horizontal lines connecting the points of intersection of contours with the mapped boundaries of the gypsiferous rock. For calculating reserves, the deposit is divided into horizontal blocks. The top and bottom of each block is determined by a horizontal plane through each contour.

For inferred reserves it was assumed that for each horizontal section the area of gypsiferous rock extending into the spur beyond the horizontal line connecting the points of intersection of each contour with the mapped boundaries of the gypsiferous rock is equal to that used in calculating indicated reserves.

Indicated reserves ---------- 92,000 tons

Inferred reserves ---------- 92,000 tons

Deposit 3:

As previously stated, this deposit consists of four parts, a, b, c, and d. Part (d) contains abundant greenstone masses and is not included in the reserves. An area between parts (b) and (c), mapped as a mixture of gypsiferous rock and quartz-sericite rock, is also not included in the reserves.

It is inferred that parts (a), (b), and (c) contain 100,000 tons of ore, much of which is quartz-sericite rock containing some gypsum. The actual reserves may be larger as parts (a) and (b) may be continuous across the thick talus area between them.

Deposit 4:

To calculate the reserves, five vertical sections 30 feet apart, striking N. 75° E., were constructed across the deposit. This strike is approximately at right angles to the strike of well-stratified, tuffaceous beds 600 feet to the north. It was assumed that the ore body dips 30°—about the same as the tuffaceous beds. For each section it was further assumed that gypsiferous rock extends down dip onethird of the length of the section.

Greenstone masses are estimated to comprise 10 percent of the deposit. These are included in the reserves which are considered to be inferred.

Inferred reserves -------- 73,000 tons

Deposit 5:

Reserves for this deposit were calculated by the same method as for Deposit 4 and are based on the same assumptions.

Inferred reserves -------- 83,000 tons

Deposit 6:

Ten percent of this deposit is estimated to be greenstone. This is included in the reserves. The deposit is assumed to extend horizontally into the hillside.

The reserves are considered to be indicated. They were calculated by constructing four vertical sections 50 feet apart, and one vertical section 20 feet from the last of the above four sections. These cross the deposit at a bearing of N. 75° E. On each vertical section the gypsiferous rock was assumed to be bottomed by a horizontal line drawn through the intersection of the vertical section with the lowest exposed limit of ore and by the intersection of this line and a perpendicular dropped from the intersection of the vertical section and the highest limit of ore.

Indicated reserves -------- 12,800 tons

Table 5. Summary of Reserves

	Indicated (tons)	Inferred (tons)
Deposit 1	206,000	
Deposit 2	92,000	92,000
Deposit 3		100,000
Deposit 4		73,000
Deposit 5		83,000
Deposit 6	12,800	
Total	310,800	348,000