STATE OF ALASKA

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GEOLOGIC REPORT NO. 8

# Geology of the Paint River Area, Iliamna Quadrangle, Alaska

By

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TABLE OF CONTENTS


| | Page |
|---|---|
| Introduction | 1 |
| Geology | 2 |
| General Setting | 2 |
| Bedded Rocks | 3 |
| Sedimentary Rocks | 3 |
| Volcanic Rocks | 5 |
| Intrusive Rocks | 6 |
| Basic to Intermediate Dikes and Sills | 6 |
| Granodiorite | 7 |
| Intrusive Rocks of Unknown Affinity | 8 |
| Structure | 9 |
| Metamorphism | 10 |
| Tactite | 10 |
| Mineral Deposits | 13 |
| Magnetic Anomalies of Unknown Origin | 14 |
| Geochemical Anomalies | 15 |
| Summary and Conslusions | 15 |
| Suggestions for Exploration and Prospecting | 17 |
| References | 18 |

ILLUSTRATIONS


| | | Following Page |
|---|---|---|
| Figure 1 | Index Map | 1 |
| Figure 2 | Stereographic projections of poles of planar features | 3 |
| Figure 3 | Geologic sketch map of a part of the Paint River | 6 |
| Figure 4 | Geologic sketch map showing intricate flow structure in marble | 10 |
| Figure 5 | Geologic sketch map of Locality 6 | 11 |
| Figure 6 | Detailed geologic map and section of Locality 8 | 11 |
| Figure 7 | Map of part of the Paint River area showing spot magnetometer readings. | 14 |
| Figure 8 | Magnetic profiles in the Paint River area | 14 |
| Geologic Map of Paint River Area | | in pocket |

# GEOLOGY OF THE PAINT RIVER AREA,

# ILIAMNA QUADRANGLE, ALASKA

By

D.H. Richter & G. Herreid

## INTRODUCTION

The Paint River area as referred to in this report lies in the headwater region of the South and Middle Forks of the Paint River, a major stream draining the Alaska Peninsula south of Iliamna Lake (figure 1). The Paint River is approximately 20 miles long and flows easterly into Kamishak Bay at the mouth of Cook Inlet.

In 1911 C.H. McNeil located a number of mining claims for copper, gold, and silver along Crevice Creek1/, a main tributary of the Paint River. A few tons of ore were mined from the claims, but the spotty nature of the mineralization and the high cost of transportation eventually forced abandonment of the operation, and by about 1926 the claims were dropped. Interest was revived in 1953 when E. Sargent and associates relocated the Crevice Creek claims and initiated a vigorous prospecting program in the area. The claims and workings were examined by the Alaska Territorial Department of Mines in 1953 and 1955 (Jasper, 1953, 1956).

The geology of the upper Paint River country is poorly understood. Up to the time of this investigation, the only geologic information available has been from a brief reconnaissance conducted by K. Mather (1925) in 1923 as part of the U.S. Geological Survey's early petroleum investigations on the Alaska Peninsula. In 1951 the U.S. Geological Survey began to map the Iliamna quadrangle at a scale of 1 inch=4 miles, and a preliminary map, which does not include the Paint River area, has been

1/ Local usage favors referring to this stream as the Paint River and its large southerly flowing tributary as Crevice Creek. We have followed the nomenclature of the U.S. Geological Survey (Iliamna A-5 Quadrangle Map) which has named this straight, deeply incised stream Crevice Creek. In this report we refer to the tributary as Sargent Creek. (See geologic map)

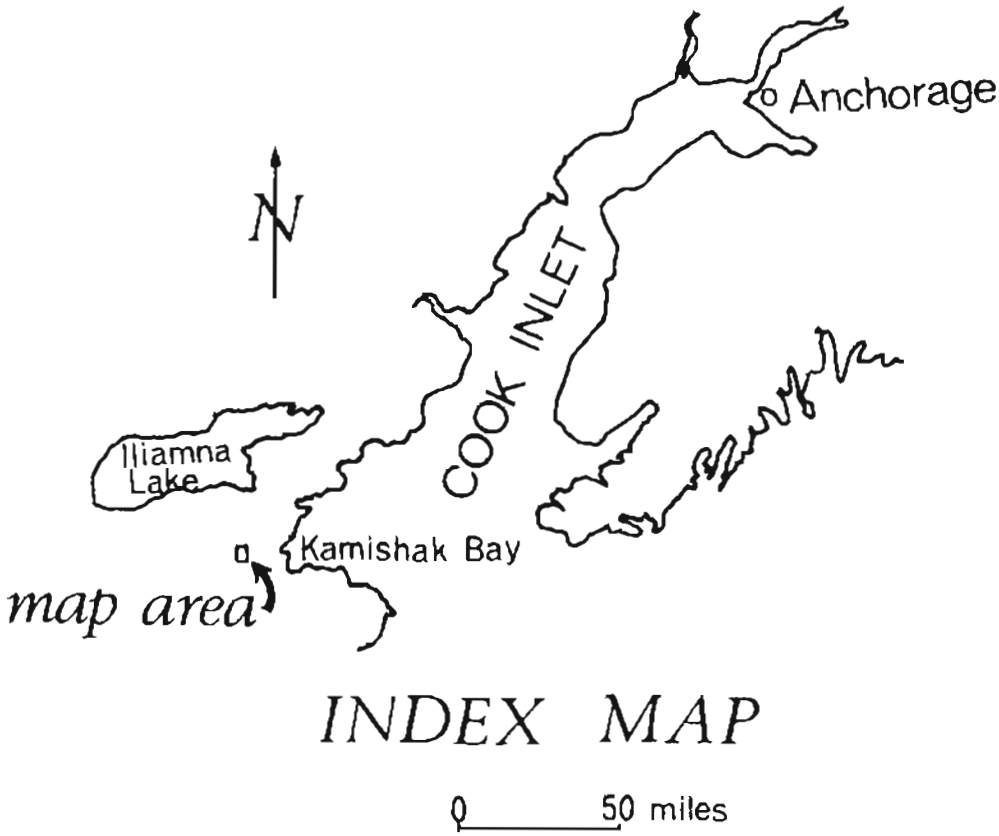


Figure 1. Map of a part of Southcentral Alaska showing location of Paint River area.

published (Detterman and Reed, 1964). This lack of geologic data in an area known to contain mineral deposits of possible economic significance prompted this present study by the State Division of Mines and Minerals.

Field work, consisting of geologic, geochemical, and magnetic studies, was carried out in the area between July 24 and August 7, 1963, by two geologists and one field assistant. Approximately 25 square miles were mapped in the vicinity of the Crevice Creek claims at a scale of 1 inch=1/2 mile, and the principal mineral showings were mapped in detail at a scale of 1 inch=200 feet. Geochemical heavy metal field tests were run on sediments from most of the streams in the area, and limited regional and detailed magnetometer surveys were conducted.

The area is readily accessible by air and is less than 18 miles from Kamishak Bay. Fixed-wing aircraft can land on Pilot Knob Lake in the northeast corner of the map area.

## GEOLOGY

### General Setting

Rocks in the Paint River area consist principally of a series of thin-bedded clastic and nonclastic sediments unconformably overlain by a thick assemblage of basic to intermediate greenstone volcanics, both intruded by large masses of granodiorite. Basic to intermediate dikes and minor sills that probably represent the feeding system for the volcanic flows are very numerous. Less common are dikes of quartz-feldspar porphyry and rhyodacite that appear to be related to the granodiorite. Glacial deposits mantle much of the bedrock in the broad upland basin of the Paint River so that exposures are limited mainly to stream cuts and mountainous areas.

Low grade contact metamorphism by the granodiorite intrusives has affected most of the bedded rocks in the area. Locally, contact metasomatism has produced irregular masses of epidote-garnet and magnetite-quartz tactite rock containing variable amounts of actinolite, calcite, and sulfides. Some of these tactite bodies occur along the granodiorite contact; others are scattered throughout the bedded rocks possibly indicating an underlying intrusive at shallow depths.

The mapped area lies along the southeastern side of the Talkeetna Mountains geanticline, a major arcuate structural element

that extends from the Alaska Peninsula to southeast Alaska. Ten miles east of the area, along the west shore of Cook Inlet, the northeasterly-trending Bruin Bay fault separates Paleozoic to Mesozoic sediments and volcanics of the Talkeetna Mountain geanticlinal belt from middle to late Mesozoic sediments of the Matanuska geosyncline. The coarse-grained granodiorite intrusives in the Paint River area represent the southern part of the large Mesozoic granitic batholith exposed over hundreds of square miles in the geanticline north of Iliamna Lake.

Mather's (1925) interpretation of the rock types and structure in the Paint River drainage could not be supported by this present study and its validity is questioned.

## Bedded Rocks

Sedimentary rocks: The oldest rocks in the map area are a series of thin-bedded chert, argillite, and limestone with minor siltstone and conglomerate. In general, the beds strike northeasterly and dip steeply to the northwest (figure 2). Although approximately 5,000 feet of sediments are exposed in the area, much of this thickness may be due to repetition of beds by folding. No primary features were observed for determining the direction of the tops of beds, but relatively abundant fracture cleavage in the argillites and argillaceous limestones indicate that at least some of the section may be overturned to the southeast. The sediments become progressively more calcareous and less sililic from northwest to southeast across the section. On the accompanying geologic map the following 3 units have been delineated: (1) chert, (2) limestone-argillite and (3) limestone. This distinction is based solely on a change in the predominant rock type; the contacts between the units are gradational and hence somewhat arbitrary.

The chert unit consists predominantly of cream, buff, and pale green dense, banded cherts, minor dark gray limestone and occasional beds of siltstone and pebble conglomerate. These rocks are well exposed in the deep gorges of Crevice Creek and the unnamed fork of the Paint River southeast of Crevice Creek. The subtle color bands in the cherty rocks range from less than one inch to more than one foot wide. Under the microscope the banding is seen to be due to variations in grain size of the microcrystalline quartz and variations in the amount of accessory minerals, principally actinolite and calcite, that are present. The tightly interlocked quartz grains, which may have undergone some recrystallization during metamorphism, range in size from 0.02 mm in the finest grained bands to 0.05 mm in the relatively coarse-grained bands.

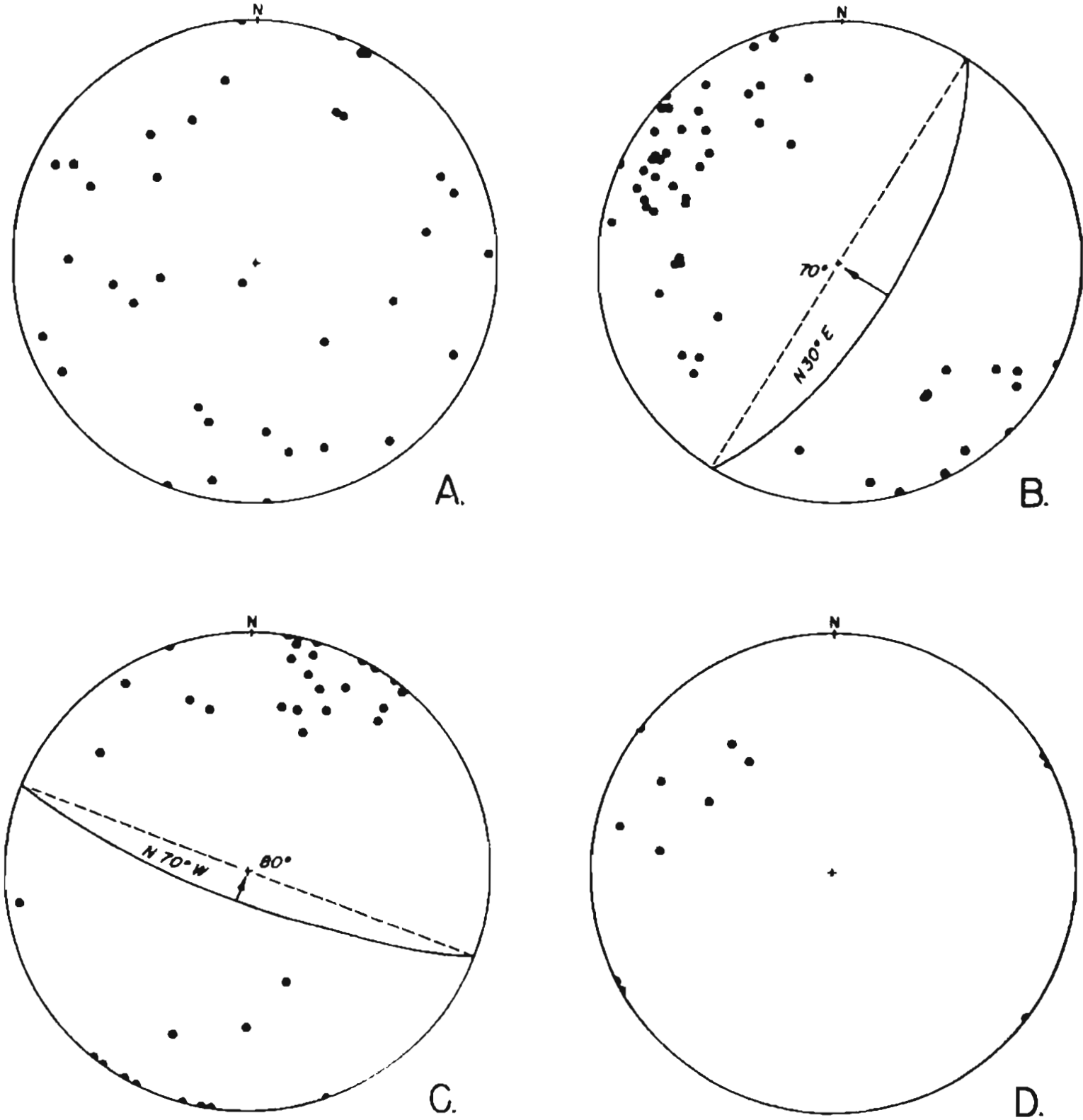


Figure 2. Upper hemisphere stereographic projections of poles of planar features in Paint River area. A, poles of bedding planes in intermediate to basic volcanic rocks; B, poles of bedding planes in sedimentary rocks; C, poles of intermediate to basic dikes; D, poles of rhyodacite (?) and quartz-feldspar porphyry and quartz porphyry dikes. Great circle plane in B and C portrays average attitude of the planar feature.

Minute ragged laths of actinolite, generally in association with calcite, constitute as much as 50 percent of some bands. Clinozoisite is scattered throughout the rock in small crystal clusters and veinlets, and garnet is occasionally observed in some of the limy strata. The actinolite-rich bands in the chert may represent original interbedded porcellanites or siliceous marls.

The limestone-argillite unit consists of alternating thin beds of fine-grained dark gray limestone, argillaceous limestone, argillite and minor chert and fine-grained clastic sediments. A well-developed fracture cleavage is generally present in the less competent beds with the cleavage planes commonly filled with veinlets of white crystalline calcite. These rocks are best exposed along Paint River from the junction of Crevice Creek south to near the South-Middle Fork junction and along the lower stretches of the unnamed fork of the Paint River. Near the head of the Middle Fork, conglomerate and grit beds are common in the section and overall the unit appears to be more clastic.

Massive, dark gray limestone of unit 3 is exposed along the Paint River and the Middle Fork of the Paint River. No chert or clastic sediments were observed interbedded with the limestone. The limestone consists of fine-grained pure calcite with occasional grains of quartz. Medium to coarse grained lenses and irregular masses of white calcite marble are present thoughout the limestone unit but appear to be more abundant in the vicinity of the diorite intrusive on the Middle Fork. The marble, and to some extent the limestone, exhibit spectacular flowage features (see figure 4).

The base of the sediments is not exposed in the area. Overlying the sediments, with a marked angular unconformity, are a series of intermediate to basic greenstone volcanics and minor interbedded sediments.

The chert-argillite-limestone sequence described above is tentatively correlated with the Kamishak Formation, of Upper Triassic age, described by Martin and Katz (1912). Their description of the Kamishak rocks exposed in Bruin Bay and at Ursus Cove in Kamishak Bay corresponds very well with the litholigic character of the rocks in the Paint River area. Mather's (1925) classification of these same rocks in the Paint River area, on the other hand, as gneiss, schist, quartzite and crystalline limestone bears no resemblance to fact and his assignment of an early Paleozoic or Precambrian age is untenable.

Volcanic rocks: Overlying the sediments with apparent marked angular unconformity are a thick series of intermediate to basic lava flows, fragmental volcanic rocks and minor intercalated thin-bedded graywacke and tuffaceous sediments. In the southeast part of the area, a narrow band or wedge of red-bed sediments occur in apparent conformity with the volcanics. The volcanics are typical low grade metamorphic greenstones containing relatively abundant quartz-epidote veinlets and locally, rosettes and veinlets of black tourmaline. No pillow structures were observed in any of the flows. Attitudes of the beds are only rarely discernible and exhibit no preferred orientation of strike, but generally dip steeper than 20° (figure 2). The presence of abundant fragmental rocks, lack of pillow structure and heterogeneity of strike suggests that the rocks were laid down on a subaerial volcanic pile.

Massive, fine-grained porphyritic and nonporphyritic flows are the predominant rocks in the volcanic series. Under the microscope the groundmass ranges from an indistinct turbid mass of relict feldspar, carbonate, and epidote with minor quartz, albite and chlorite to an intergranular texture with relatively fresh feldspar and hornblende after pyroxene (?). Phenocrysts and microphenocrysts of plagioclase feldspar ($An_{40-50}$) when present are largely replaced by albite and epidote. Massive, medium-grained pyroxene-bearing flows or sills are also common. In thin section these rocks consist largely of ophitic pigeonite commonly altered to serpentine, and feldspar ($An_{40-50}$) that has been locally albitized and partially replaced by epidote and carbonate.

Fragmental volcanic rocks constitute an estimated 30 to 40% of the rocks in the volcanic unit. These are easily recognized in the field by their abundant rounded to angular inclusions up to a foot or more in size set in a fine-grained matrix. The inclusions are generally fragments of volcanic rocks, similar in texture and composition to the flow rocks in the area, but some crystalline rock inclusions and possibly a few of possible sedimentary origin were observed. Most of the fragmental rocks have a volcanic matrix similar to the turbid groundmass of the flow rocks and are apparently agglomerates and flow breccias. Some, however, contain abundant fine-grained quartz in uniform intergrowth with minor clinozoisite, chlorite, and amphibole, suggesting a mudflow-type origin.

The graywacke and tuffaceous sediments interbedded with the volcanics are thin and discontinuous. Rarely do they exceed more than a few tens of feet in thickness or more than a few

hundred feet in length. Graded bedding and scouring were observed in a few beds. The red beds in the southeast part of the area appear to be a unit and have been shown as such on the accompanying map. They range from coarse conglomerate to siltstone and are colored various shades of red, maroon and purple. A thin section of a purple sandstone shows abundant chert fragments and minor rounded grains of plagioclase, quartz and clinopyroxene in a brown cherty matrix. The red beds rest conformably on volcanics, contain a number of interbedded flows and are apparently conformably overlain by volcanics. The beds could not be traced northwest into the central part of the area, but from the abundance of float in the valley of the South Fork, they evidently extend out of the map area to the southeast.

Without much doubt these volcanic rocks are equivalent to the great thickness of Lower Jurassic volcanic rocks exposed in the Talkeetna geanticline in southcentral Alaska that are generally referred to as the Talkeetna Formation. Moreover, Detterman and Reed (1964) in their recent preliminary map show the Talkeetna Formation to be present not only northeast of the Paint River area but to the southwest as well.

## Intrusive Rocks

Basic to intermediate dikes and sills: The sediments and overlying volcanics have been intruded by hundreds of basic to intermediate dikes and some sills that probably represent the conduits for the volcanic flows. Because of the great number of these intrusives, and the relatively small scale of the mapping, no attempt has been made to show them on the accompanying geologic map. Some idea of their abundance can be gained, however, by inspection of the geologic sketch of a section of the Paint River in figure 3 and the detailed map and cross section of the Crevice Creek tactite area in figure 6. Along the 1,500 feet of Paint River shown in figure 3, at least 14 dikes and 2 sills are exposed. The dikes vary in thickness from a maximum of about 100 feet to less than a foot and average about 10 to 15 feet. Their trend is consistently near N70°W with an average dip of about 80°N (figure 2).

The intrusives are predominantly gray to dark greenish gray with an aphanitic or aphanitic-porphyritic texture. In the prophyritic varieties, phenocrysts of dull white to buff feldspar up to 1/2 inch long constitute as much as 50 percent of the rock. One prophyritic dike, east of the junction of the Middle and South Forks at an elevation of 2,000 feet, contains spectacular deep pink feldspar-phenocrysts up to 1 inch long. In thin section the rocks generally show the effects of strong alteration. The phenocrysts

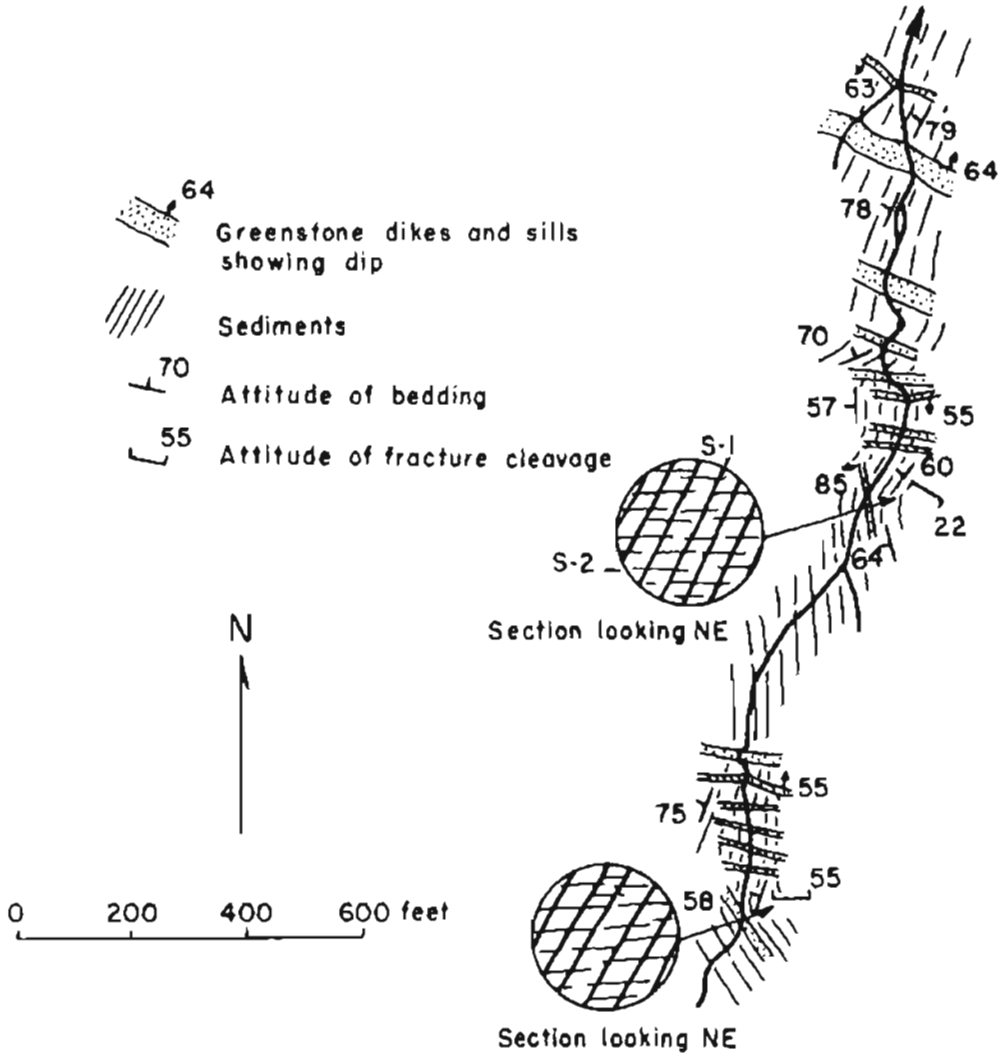


Figure 3. Geologic sketch map of a part of the Paint River south of the junction of the unnamed fork, showing abundance of intermediate to basic (greenstone) dikes. In sections S-1 (heavy line) denotes bedding plane and S-2 (light line) fracture cleavage.

of feldspar are indistinct under the microscope and consist of an intimate mixture of clinozoisite, carbonate and possibly secondary albite. The groundmass is usally a mass of fine-grained altered feldspar, ragged amphibole, and minor chlorite with scattered clusters of clinozoisite and carbonate. Sphene, altered in part to leucoxene, is fairly common. No quartz was observed in any of the dike rocks.

Granodiorite: Three large bodies of granodiorite, each with slightly different textural and mineralogical features, extend into the Paint River area from the northeast, northwest and south. All are phases of the large quartz diorite-granodiorite batholith that forms the backbone of the Alaska Peninsula. The rocks are characteristically holocrystalline and medium- to coarse-grained with colors ranging from light buff to gray. Mafic minerals are sparse. Modal analyses of the granodiorite from each body are given in Table 1.

The granodiorites have a subhedral-granular texture and consist of quartz, plagioclase and orthoclase with minor and varying amounts of biotite, hornblende, chlorite, epidote, sphene, and opaques. Average grain size ranges from 4-5 mm in the Pilot Knob body to less than 2 mm in the body at the head of Crevice Creek. Least altered of the granodiorites is apparently the body west of Pilot Knob Lake (sample 442) which contains subhedral, strongly zoned plagioclase ($An_{35-28}$), anhedral quartz and orthoclase, minor fresh biotite, and poikilitic, low iron, common hornblende. The feldspars are fresh and chlorite is absent. The mafic minerals, together with some sphene and opaque minerals, are generally concentrated in clots as large as 10mm in diameter. Some of the biotite appears to have replaced hornblende but most shows no evidence of any such genetic relationship. A few large phenocryst like plagioclase crystals with only weak zoning and a core of $An_{46}$ are present. The rock contains fairly abundant xenolithic inclusions of dark fine-grained hornblende-plagioclase rock that apparently represent unassimilated fragments of the volcanic country rock.

The granodiorite body at Pilot Knob has undergone greater alteration (sample 33) than the granodiorite of the other two bodies and as a result is lighter colored. Plagioclase, zoned $An_{35-18}$, in this granodiorite shows a pronounced fine-grained argillic alteration with minor sericite and zoisite. Interlayered biotite-chlorite is the principal mafic mineral; hornblende being present in trace amounts only. Chlorite and biotite also occur as separate phases, often in association with the interlayered biotite-chlorite.

The contact between the granodiorite and volcanics is exceptionally well exposed on Pilot Knob. Although the contact is sharp, fine bands and segregations of granodiorite extends as far as 100 feet into the volcanics from the contact, and septa of volcanics are present an equal distance in the granodiorite. Neither at Pilot Knob or elsewhere in the area is there any evidence to indicate that the granodiorites were intruded forcefully.

Radiometric age dates of 156 and 159 million years (Detterman and Reed, 1964) for the Peninsula batholith elsewhere in the Iliamna quadrangle are consistent with the Lower or Middle Jurrassic age advocated earlier by Martin and Katz (1912). However, the batholith was probably emplaced in pulses, much like the Sierra Nevada rocks, over periods of millions of years. Detterman and Reed (1964) show quartz diorite rocks to be predominant north of Paint River, whereas south of the mapped area in the vicinity of Battle Lake, the intrusive is almost entirely granodiorite. A suggestion of this major change in rock type may possibly be manifested in the Paint River rocks. The northernmost intrusive body, the Pilot Knob granodiorite, is coarse-grained with definite quartz-diorite tendencies (low modal orthoclase) while the two more southerly intrusives are finer-grained and normal granodiorites.

Intrusive rocks of unknown affinity: Throughout the mapped area a number of intrusive rocks of diverse chemical and physical characteristics are present whose origin is not well understood. From the probable oldest to youngest these rocks are: (1) an irregular body or bodies of diorite, (2) rhyodacite (?), quartz-feldspar porphyry and quartz porphyry dikes and (3) a basic dike in the Pilot Knob granodiorite.

The diorite is a holocrystalline, medium-grained, gray rock that is exposed in the valley of the Middle Fork, at the junction of the Middle and South Fork, and along the unnamed fork of the Paint River.(see geologic map). A fourth body of lighter-colored and finer-grained diorite is exposed on Crevice Creek above the junction of Sargent Creek. On the Middle Fork the diorite is intrusive into the limestone unit of the sedimentary rock series and contains abundant (1-5%) disseminated pyrite. The geochemical anomaly on the left limit of the Middle Fork is probably caused by the high content of trace elements associated with the pyrite in this intrusive.

The rhyodacites (?), quartz-feldspar porphyry and quartz porphyry dikes are younger than the volcanic rocks in the area and may be genetically related to the granodiorites. The

TABLE 1

Modal Analyses of Granodiorite
from Paint River area

| | 33<br>Pilot Knob<br>Lake | 426<br>Head of Crevice<br>Creek | 442<br>1 Mile West<br>Pilot Knob Lake |
|---|---|---|---|
| Quartz | 39 | 27 | 34 |
| Plagioclase | 43 ($An_{35-18}$) | 46 ($An_{40-?}$) | 45 ($An_{35-28}$) |
| Orthoclase | 11 | 18 | 16 |
| Biotite | 1 | -- | 2 |
| Hornblende | -- | 2 | 3 |
| Chlorite | 5 | 6 | -- |
| Epidote | tr | tr | -- |
| Sphene | -- | -- | tr |
| Opaques | 1 | 1 | tr |
| C.I. | 7 | 9 | 5 |

rhyodacite (?) intrusives are light-colored, sinuous, branching bodies (see figure 5) that are relatively common in the volcanic rocks north of Crevice Creek. Megascopically the rock is light buff to light greenish-gray and fine-grained. Under the microscope it is seen to consist of a mass of plagioclase (50%), quartz (10%), and orthoclase (10%) with scattered phenocrysts of plagioclase (5%) and minor rounded quartz. The remainder of the rock consists of clots of crystalline yellow epidote and some chlorite. Most of the feldspar is altered to epidote and other indistinct fine-grained secondary minerals, but where freshest, it appears to be sodic andesine.

The prophyry dikes are relatively rare. A quartz-feldspar porphyry dike is exposed in the canyon of Sargent Creek and in the large tactite body to the northeast (see figure 6), and another is present near the small tactite body between Crevice Creek and Paint River. The only quartz porphyry dike observed is in the valley of the Middle Fork near the diorite intrusive (see figure 4). The rock is generally light colored and may contain as much as 50% plagioclase feldspar or quartz phenocrysts set in a fine-grained matrix.

A thin dark green dike, 4 to 5 feet wide, is exposed along the trail from Pilot Knob Lake to the Crevice Creek claims. This minor intrusive, which represents the only rock definitely younger than the granodiorite observed in the area, may be Tertiary in age.

## Structure

Within the map area only the bedded sedimentary rocks have been strongly folded. These rocks, as shown on the equal area stereographic plot of bedding plane poles in figure 2B, strike consistently northeast and generally dip steeply to the northwest. Locally, prominent fracture cleavage indicates that at least some of the beds are overturned (figure 3), but, on the whole, the data are not sufficient to determine the nature of the folding. The younger volcanic flows, agglomerates, and minor interbedded sediments exhibit no such preferred orientation (figure 2A) and overlie the sedimentary rocks with marked angular unconformity.

Highly contorted flowage folds are common in the marbleized limestone, especially near intrusive rocks (figure 4). These features, although spectacular, are due solely to local stress and thermal effects and apparently do not reflect any major structures.

No major faults were recognized in the area. A few minor faults have been observed in the volcanic rocks, and two have been mapped in the large tactite body along Crevice Creek (see figure 6). The fracture cleavage present in many of the steeply dipping sedimentary rock exposures commonly offsets the bedding from a few tenths of an inch to as much as 3 or 4 inches. In every case where movement along the fracture cleavage has been observed, the sense has been right lateral.

## Metamorphism

Most of the sedimentary and volcanic rocks in the area contain variable amounts of secondary quartz, epidote, actinolite, albite, chlorite, and muscovite. These minerals and the assemblages they form are typical of either the greenschist facies of regional metamorphism or the albite-epidote-hornfels facies of contact metamorphism. The proximity of the large granodiorite bodies and absence of metamorphic minerals in some of the rocks farthest removed from the intrusives, however, indicates a local rather than regional source of metamorphism.

An aureole of marbleization and epidotization about a mile wide borders the Upper Crevice Creek granodiorite body in the southern part of the map area. The rocks in this area are strongly epidotized and underwent a kneading action while in a plastic state. As a result, the relatively competent rocks, such as the greenstone dikes and sills, have been disrupted allowing the marble to flow in and around the broken blocks (figure 4).

The finer-grained clastic rocks are usually slaty and some of the volcanic rocks are semi-schistose, but in general the rocks exhibit no foliation and have retained most of their primary textures.

Common mineral assemblages are: quartz-actinolite-epidote-calcite in the cherty rocks, quartz-muscovite in the slates, and quartz-albite-chlorite-epidote in the volcanics. The limestone and marble are generally pure calcite, but may contain minor quartz and epidote.

## Tactite

Tactites in the Paint River area consist of relatively small and discontinuous bodies of epidote-garnet rock and

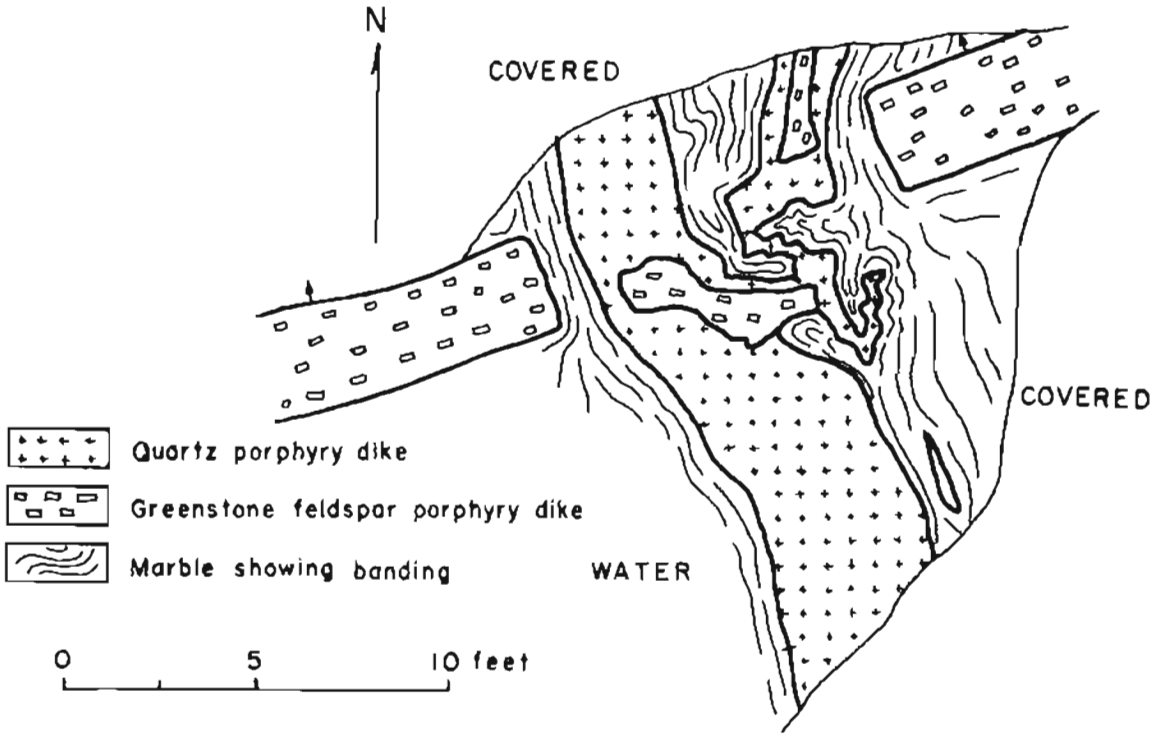


Figure 4. Geologic sketch map showing intricate flow structure in marble that has been intruded by greenstone feldspar porphyry dike and later by a quartz porphyry dike.

magnetite-quartz rock. Variable amounts of actinolite, calcite, quartz, magnetite, and sulfide minerals may or may not be present in the epidote-garnet tactite but are generally absent from the magnetite-quartz tactite. All but 2 of the known tactite bodies are concentrated within a square mile area around the southwest nose of the Pilot Knob granodiorite body (see geologic map). These bodies occur both along the contact between the volcanic rocks and granodiorite and in the volcanic rocks as far as 3/4 mile from the contact. None are known to occur in close proximity to either of the other two granodiorite bodies exposed in the area. Size of the tactites varies from pods a foot thick and less than 10 feet long to masses as much as 200 feet wide and 2,500 feet long.

In general, the tactite bodies close to or at the granodiorite contact are mineralogically more complex than those away from the contact. Most of the simple epidote-garnet tactites are exposed in the valley and drainage basin of Sargent Creek; one is present in the valley of the South Fork about 1/2 mile south of the Middle Fork junction. These tactites are fine- to coarse-grained crystalline rocks consisting usually of a mixture of green epidote and reddish to yellowish-brown garnet. Locally within the same body, the two constituent minerals may be concentrated in irregular masses or in diffuse to distinct bands. The simple magnetite-quartz tactites have been observed only at one locality (locality 6, geologic map and figure 5) in the upper drainage of Sargent Creek. These bodies range in composition and texture from pure coarsely crystalline magnetite to banded magnetite and quartz. Most of the magnetite-quartz tactites occur as isolated bodies in the volcanic rocks, but some are associated with epidote-garnet tactite.

The largest of the complex epidote-garnet tactites, which has been vigorously prospected for its copper content, lies along the unconformable volcanic-sedimentary rock contact immediately north of Crevice Creek and on both sides of Sargent Creek (locality 8, geologic map and figure 6). Although heavy brush and locally thick talus cover much of the area, the tactite is probably continuous over a length of about 2,500 feet. Besides the massive epidote-garnet rock, the tactite contains abundant actinolite and lesser amounts of calcite, quartz, pyrite, and chalcopyrite. The actinolite is especially spectacular, occurring as large radiating crystal clusters, up to 2 feet in diameter, with the space between individual crystal laths generally filled with massive calcite and minor sulfides. Large dodecahedral garnet crystals, as much

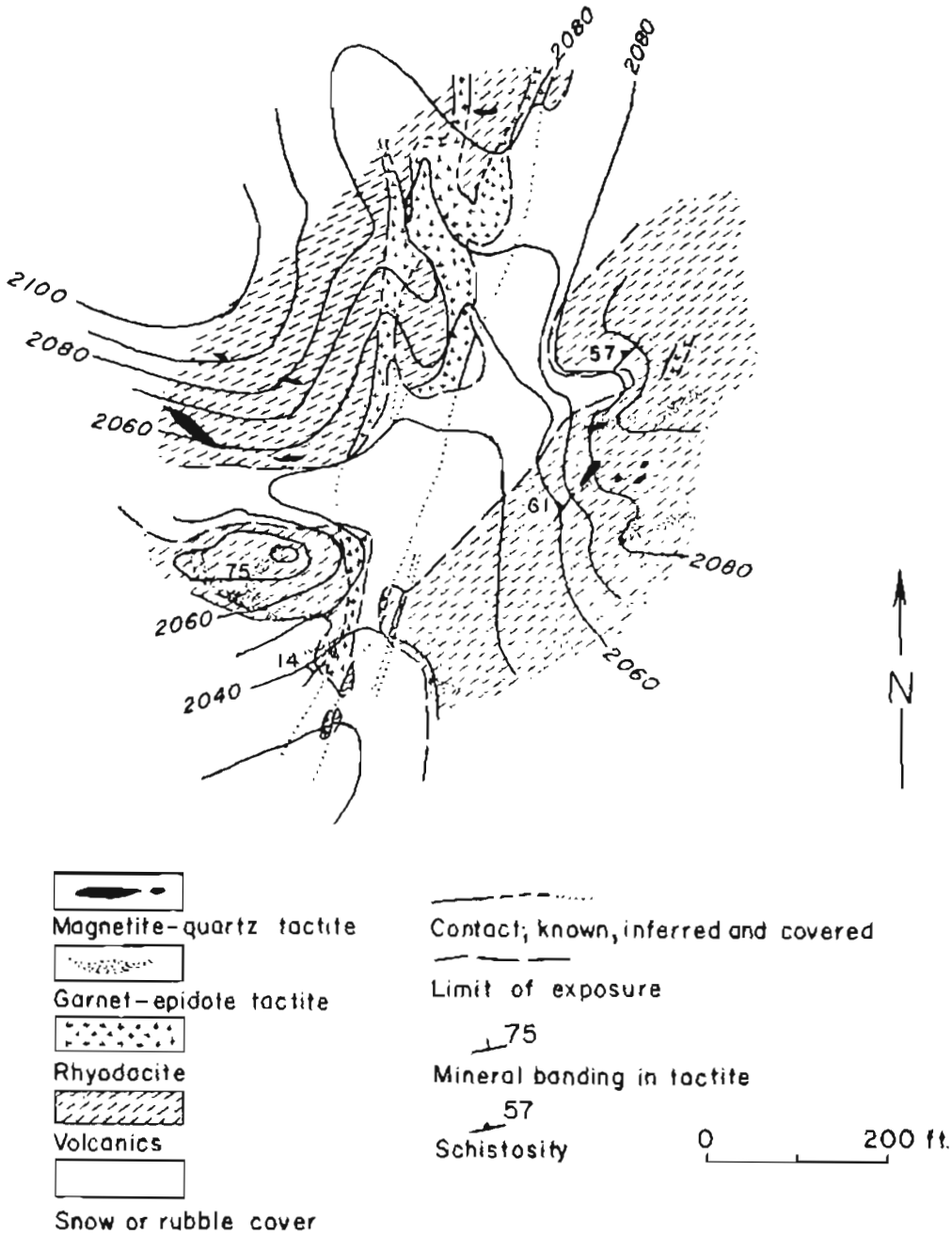


Figure 5. Geologic sketch map of locality 6 showing distribution of magnetite-quartz and garnet-epidote tactite rock. Note the irregular, sinuous nature of rhyodacite (?) dike.

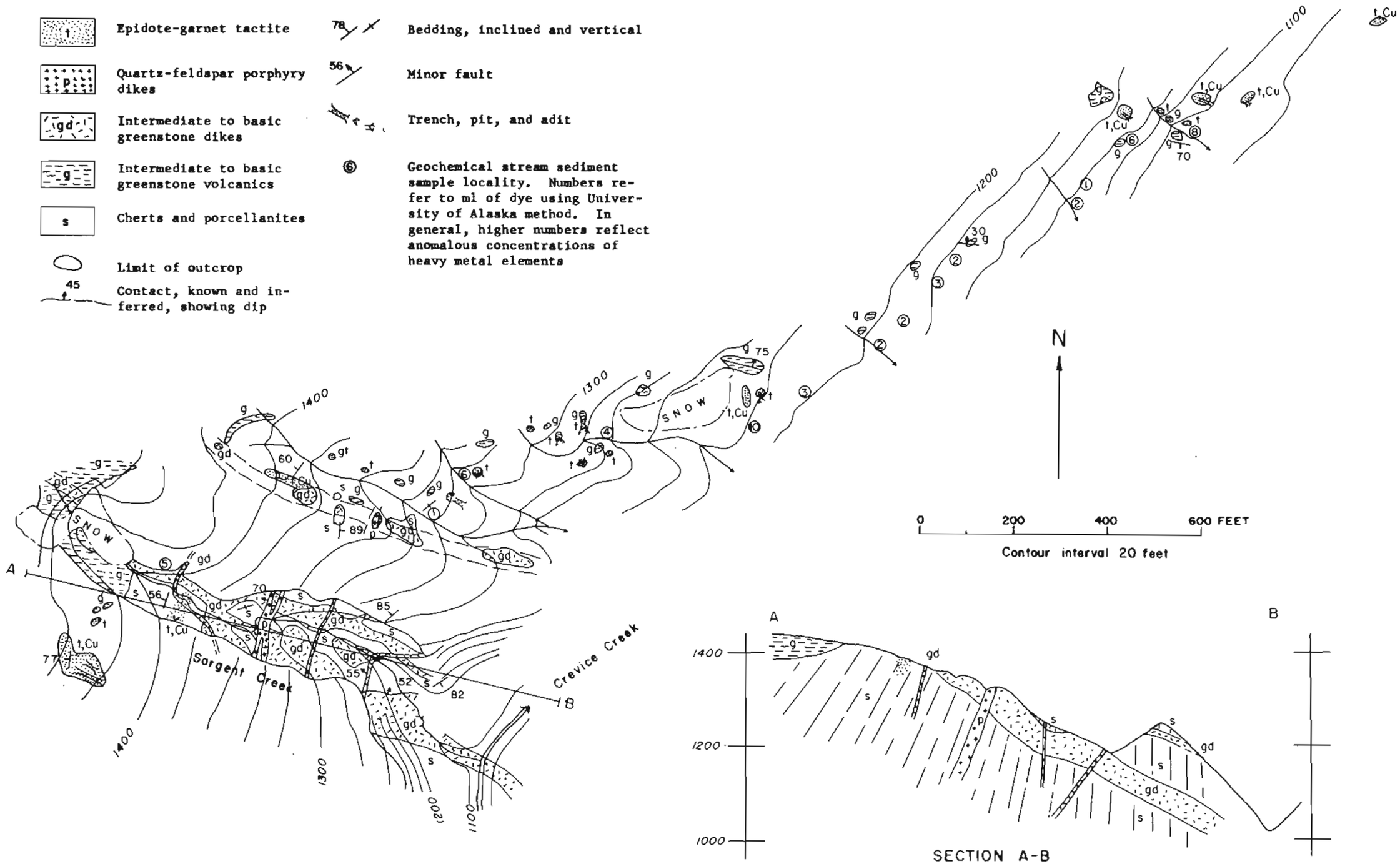


Figure 6. Detailed geologic map and section of locality 8 (Crevice Creek claim area).

as 2 inches in diameter, are common in the garnet-rich zones throughout the tactite. Many of the large garnets are conspicuously zoned yellow and dark red, but both color phases appear to have similar grossularite-andradite compositions (unit cell=11.92A°). Bright secondary copper minerals stain many of the exposures but only an occasional small segregation of chalcopyrite and pyrite was observed in the tactite. However, large fragments of solid sulfides on the dumps of the old workings and zones of intense limonite alteration attest to the presence of massive sulfides at least locally through the tactite.

A relatively large complex tactite (or 3 small ones) is exposed in 3 small open cuts and one outcrop on the steep hillside immediately above the Pilot Knob granodiorite-volcanic rock contact about a mile south of Pilot Knob Lake (locality 1, geologic map). Two of the open cuts about 150 feet apart expose secondary copper minerals malachite and chrysocolla, filling fractures and coating crystal faces of bladed actinolite and euhedral quartz. Between the two open cuts massive magnetite, associated with actinolite, garnet, epidote, and quartz, crops out over a width of 15 feet. About 400 feet north of these three exposures, a small open cut exposes epidote-garnet tactite with minor magnetite, calcite, and a 2 inch vein of black tourmaline. Talus and brush between the exposures obscures the size and structural relation of the tactites.

A few shallow prospect pits over a distance of about 200 feet exposes a body, or a number of small lenses, of complex tactite between Crevice Creek and the unnamed fork of the Paint River (locality 9, geologic map). In one pit a 10 foot wide band of tactite in volcanic rock is distinctly zoned with a thick outer shell of garnet-epidote -actinolite, an irregular intermediate zone of thin sulfide lenses and stringers, and a core of marble. In another pit, small lenses of sulfides without tactite are localized along a marble-volcanic rock contact that trends N-S and dips 55°W. No copper mineralization was observed in any of the exposures.

Another complex tactite occurs in the valley of Sargent Creek at an elevation of about 1,800 feet slightly less than 1/2 mile northwest of the large Crevice Creek tactite (locality 7, geologic map). At the time of our investigation the entire outcrop area was covered by snow. Pieces of tactite rock piled nearby, presumably from exploration pits into the body, consist of epidote-garnet rock locally veined by garnet-magnetite, massive magnetite, and massive magnetite-calcite. Copper staining shows on many of the samples and an occasional small segreation of chalcopyrite was observed.

The tactite rocks are contact metasomatic deposits which apparently owe their origin to the Pilot Knob granodiorite. Those somewhat removed from the granodiorite contact may indicate a shallow depth of the intrusive or may be controlled by secondary chemical or structural features. The large tactite north of Crevice Creek, for example, lies along the unconformity between the chert unit of the sedimentary rock series and overlying volcanics. The source of the high calcium content (garnet, epidote, and calcite) of the tactites is probably limestone or calcareous rock at depth in the contact zone. The immediate presence of limestone, however, does not appear to be necessary as a chemical control for the localization of the tactites. Where concentrations of magnetite and sulfides are present, iron, copper, and sulfur must have been transferred from either the volcanic rocks or granodiorite or both.

## Mineral Deposits

Occurrences of both copper and iron minerals of possible economic significance are present in the Paint River area. As far as is known, all are contact metasomatic deposits restricted in occurrence to the bodies of tactite rock. The few quartz veins and relatively common limonite-stained zones scattered elsewhere throughout the area appear to contain only minor concentrations of pyrite.

Chalcopyrite and the secondary copper minerals, malachite, azurite, and chrysocolla have been observed in the tactites at localities 1,7, and 8 (geologic map). The chalcopyrite generally occurs as small irregular masses and segregations in association with pyrite, calcite and actinolite. With the possible exception of the large tactite north of Crevice Creek, however, the sulfides were not found in sufficient concentration to form ore deposits. In some of the workings at the large Crevice Creek tactite, Jasper (1956) observed lenses of sulfides up to 3 feet wide and possibly 10 feet long that contained upwards of 7% copper, but at the time of our visit, most of the exploration pits and adits were either caved or filled with limonite mud. The tactite at locality 7 is reported (E Sargent, oral communication, 1963) to contain abundant disseminated chalcopyrite but at the time of our visit deep snow covered much of the area and only a few pieces of chalcopyrite-bearing tactite rock were observed.

Magnetite is the ore mineral of iron in the area and occurs in magnetite-quartz tactite or as masses within epidote-garnet tactite. The best exposures and largest of the deposits observed are the magnetite-quartz tactites in the upper drainage basin of Sargent Creek (figure 5). Here 10 known magnetite-quartz tactite bodies are confined to an area covering about 6 acres (500 feet square). The largest body, which contains only minor

quartz, is approximately 75 feet long and 10 feet wide, resulting in an indicated tonnage of approximately 100 tons per vertical foot. The other magnetite bodies in the area are all much smaller with some containing as much as 50% quartz. Magnetic anomalies over the deposits are local and do not indicate an increase in size of the deposits with depth. No anomalies were detected in the area that could not be explained by surface exposures of magnetite.

Two small bands or lenses of magnetite in epidote-garnet-actinolite rock are poorly exposed on the steep hillside along the Pilot Knob granodiorite contact at locality 1 (figure 7). The magnetite bands are approximately 10 feet apart and 5 and 25 feet wide. As shown in figure 8 (profile 1) a sharp, but local negative and positive magnetic anomaly withaa total vertical relief of about 20,000 gammas is associated with the deposit. A parallel magnetic profile 100 feet to the north continues to show the anomaly but its intensity is greatly reduced. Minor amounts of magnetite are also poorly exposed in the same or another body of complex epidote-garnet tactite 400 feet north of locality 1 along the granodiorite contact. Although no magnetic anomaly appears to be associated with this deposit it may possibly represent a continuation of the magnetite at locality 1.

## MAGNETIC ANOMALIES OF UNKNOWN ORIGIN

In addition to the magnetic anomalies associated with known magnetite deposits in the area, a number of anomalies of unknown origin have been found, mostly in the vicinity of the Pilot Knob granodiorite. These anomalies, especially if they are caused by buried magnetite bodies, are interesting and tend to indicate a greater concentration of magnetite in the area than is obvious from surface exposures. The anomalies were found by cursory reconnaissance magnetometer surveys using a small hand-held Arvela magnetometer. No attempt was made to systematically survey the entire area, and only a few short traverses were run over the anomalies.

The spot magnetometer readings and location of magnetic anomalies and profiles are shown in figure 7. All values reported are vertical magnetic intensities in relative gamma units. In general, the average magnetic background for the area is between -2,500 and -1,000 gammas.

At the southwest end of the Pilot Knob granodiorite, two sharp anomalies were found relatively close together (localities 2 and 3, figure 7). Single profiles across these anomalies are

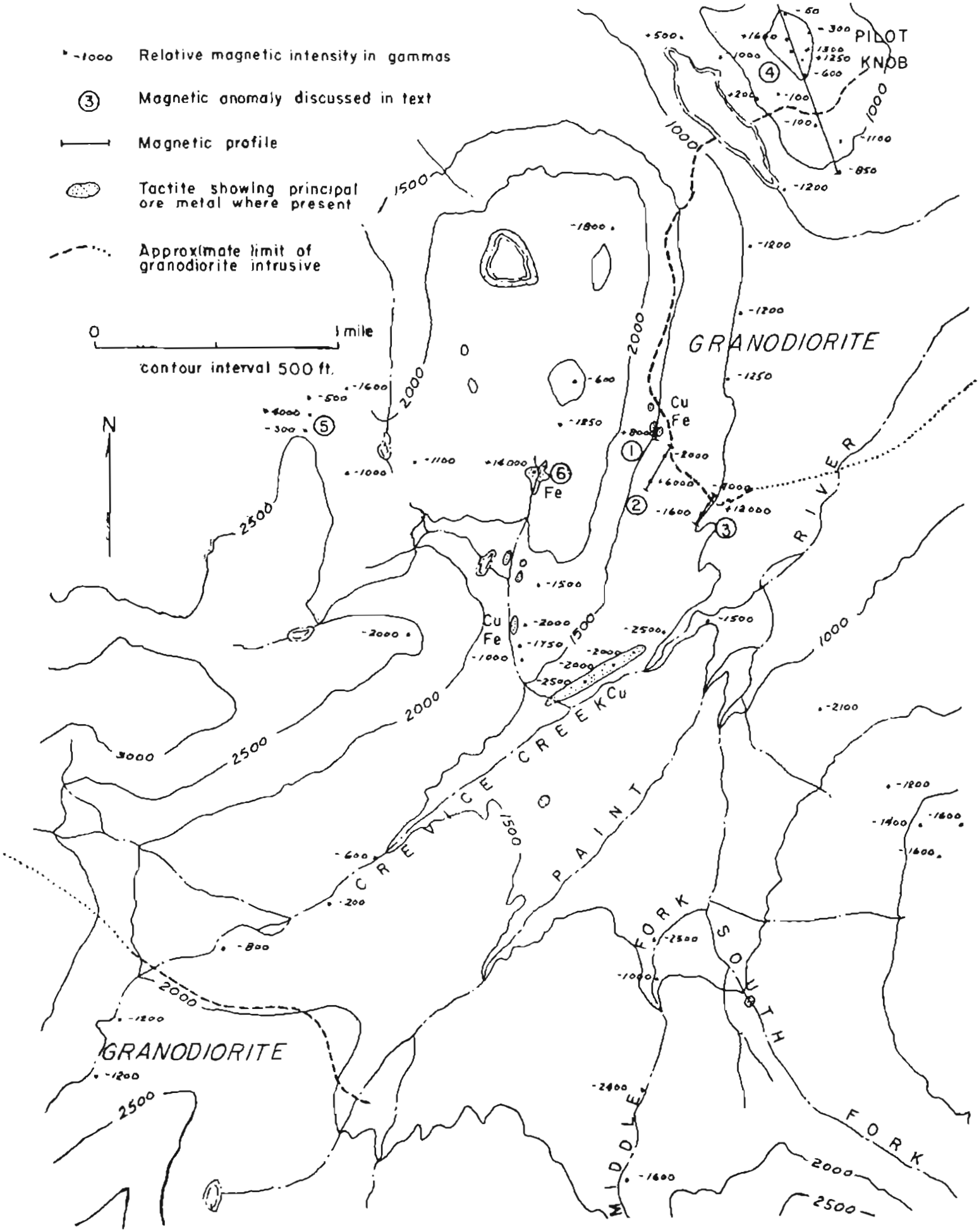


Figure 7. Map of part of the Paint River area showing spot magnetometer readings and locations of magnetic profiles.

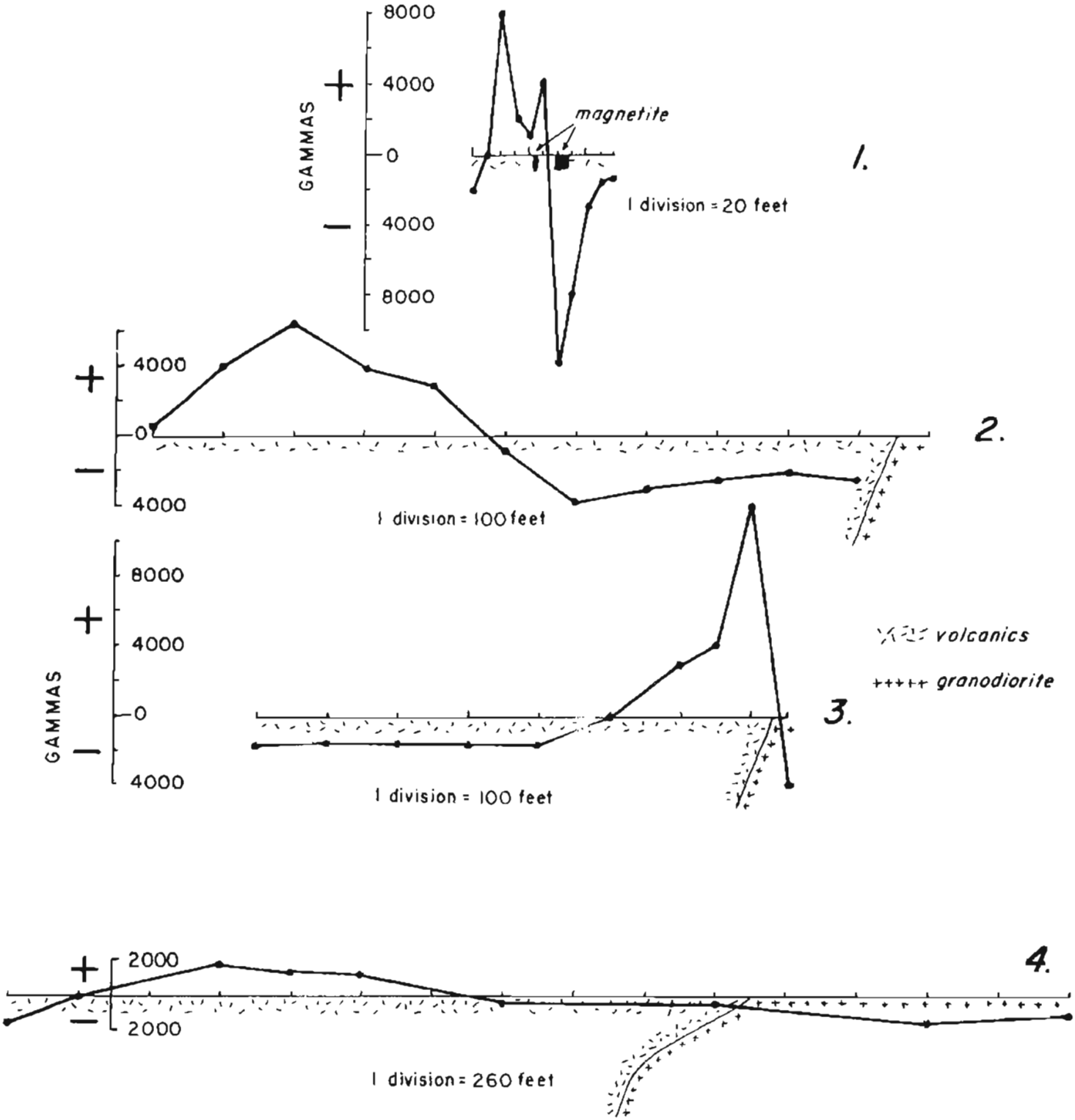


Figure 8. Magnetic profiles in the Paint River area.

shown in figure B. At locality 2, at an elevation of about 1,250 feet, the anomaly begins in the volcanics about 400 feet southwest of the granodiorite contact, builds up to a maximum of +6,500 gammas 800 feet from the contact and is still relatively high (+200 gammas) at the end of the profile,1,000 feet from the contact. Locality 3 is at an elevation of about 1,000 feet on the foot trail from Pilot Knob Lake to the workings in the big tactite body north of Crevice Creek. Here the anomaly begins at the granodiorite contact, builds up to +12,000 gammas within 100 feet, and essentially disappears 200 feet from the contact.

A low broad anomaly occurs over Pilot Knob northeast of Pilot Knob Lake (locality 4, figure 7 and profile 4, figure 8). Strongest vertical magnetic intensity measured was +1,600 gammas on top of the Knob. The anomaly is underlain entirely by excellent exposures of hornfelsic volcanic rocks; no evidence of any tactite rock or magnetite was observed on the surface.

Only one anomaly was found which appears to bear no relation to the Pilot Knob granodiorite. This local anomaly of +6,000 gammas occurs in volcanic rocks approximately 1 1/2 miles west of the granodiorite contact (locality 5, figure 7).

## GEOCHEMICAL ANOMALIES

Approximately 103 stream sediment samples were collected and tested in the field for heavy metals during the course of the investigation. These samples represent almost every water course, from major stream to sluggish trickle, in the upper Paint River drainage. All streams with anomalous heavy metal content are shown on the accompanying geological map. Streams with the strongest anomalies are: (1) those draining the large copper-bearing tactite north of Crevice Creek, (2) those originating from limonite-rich springs at the base of the long promonotory (el. 2334) south of Crevice Creek, and (3) a left limit tributary to the Middle Fork about 1/2 mile south of the South Fork junction. With the exception of the anomaly at the springs, most can be explained by drainage over known bodies of sulfide-bearing tactite or local pyrite-rich zones in the volcanics or sedimentary rocks. The limonite-rich springs with their high heavy metal content may possibly originate from subsurface sulfide-bearing zones along the Crevice Creek granodiorite contact.

## SUMMARY AND CONCLUSIONS

In the Paint River area a thick assemblage of greenstone volcanic rocks tentatively correlated with the Lower Jurassic

Talkeetna Formation overlie with marked angular unconformity a series of thin-bedded cherts, limestone, and argillite of the Upper Triassic Kamishak Formation. Three bodies of granodiorite, all apparently part of the Middle Jurassic Alaska Peninsula batholith, passively intrude the bedded rocks. Contact metasomatic epidote-garnet and magnetite-quartz tactites occur as small lenses and masses spatially and apparently genetically related to the Pilot Knob granodiroite body. The tactites are mostly found in the volcanic rocks or along the unconformable volcanic-sedimentary rock contact within one mile of the granodiorite. Where sedimentary rocks are associated with tactite along the unconformity they are generally chert or porcellanite. Limestone, although conspicuously absent, is the probable source of calcium and carbon dioxide in the tactites, and may be present in the intrusive contact zone at depth. The known iron and copper deposits within the area are restricted in occurrence to the tactites.

Although the early and recent prospecting in the Paint River area and surrounding region has been almost entirely devoted to the search for copper and gold, the area's greatest potential may be in its magnetite deposits. Exposed copper mineralization is weak and erratic. The small, rich lenses of massive pyrite and chalcopyrite, which are occasionally encountered, appear to be distributed at random throughout the tactites without any obvious control. Magnetite, on the other hand, generally occurs in well-defined massive pods or lenses that can be delineated by relatively inexpensive geophysical exploration. In spite of this fact, the areas in which these deposits occur have been subject to only cursory exploration and the known reserves are accordingly small. As our limited magnetometer surveys have revealed a number of magnetic anomalies that may be caused by buried magnetite-bearing tactite, it seems likely that more extensive magnetic exploration may disclose additional magnetite deposits in the area.

As equally favorable intrusive and host rocks continue beyond the arbitrary border of the Paint River area, there is good reason to believe that potentially economic tactite bodies are present elsewhere in the Alaska Peninsula. Furthermore, the areas where the batholithic rocks are either bounded by or are in close proximity to the Bruin Bay fault may be especially favorable for the deposition of ore minerals. The Tuxedni Bay magnetite-tactite deposits, approximately 100 miles northeast of the Paint River area, occur at the border of the batholith (Grantz, 1956), probably near the Bruin Bay fault; and within the past year a major oil company has staked a large number of claims for magnetite between Tuxedni Bay and Kamishak Bay.

## Suggestions for exploration and prospecting

Aerial magnetometer surveys, either of regional extent or perhaps restricted to the contact zones of intrusive bodies, if the surface geology is well enough understood, are recommended as a preliminary step in any attempt at regional exploration. The scale of the surveys should be dependent on the minimal size of a magnetite body that could be profitably mined, which, based on mining operations elsewhere in North America, may be as small as 5 to 7 million tons. Such a deposit, assuming a depth of 200 feet, could have a minimum surface area of 175,000 square feet or, if 100 feet wide, a length of 1750 feet.

Within the Paint River area the following exploration is suggested:

(1) Detailed ground magnetometer surveys should be made over the Pilot Knob granodiorite-volcanic rock contact from north of Pilot Knob to the Paint River. These survey lines should be run perpendicular to the contact, and extend at least 1,000 feet into the volcanics. Lines should be not more than 500 feet apart with stations every 100 feet.

(2) Any indication of anomalous magnetic intensity should be checked and delineated with intermediate or additional lines and stations.

(3) A relatively detailed and systematic magnetometer survey should be conducted in the drainage basin of Sargent Creek, south as far as Crevice Creek, and east to the magnetite deposits along the Pilot Knob granodiorite contact.

(4) Reconnaissance magnetometer or aeromagnetometer surveys should check the contact zones of the other two granodiorite bodies.

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