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GEOLOGIC REPORT NO. 16

Geology and Mineral Deposits of Central Knight Island, Prince William Sound, Alaska

By

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By

D.H. Richter

INTRODUCTION

Prince William Sound has been one of the major copper mining areas in Alaska, producing approximately 214,000,000 pounds of copper during the period between 1900 and 1930. Since 1930 no copper mines have produced and mineral industry activity has been largely limited to minor annual assessment work and occasional exploration projects. Knight Island, (figure 1), in southwestern Prince William Sound, has over 40 known copper prospects but only a limited quantity of ore was ever mined. At present, only one deposit on the Island, the Copper Bullion Mine at Rua Cover, is known to contain significant quantities of copper ore. Although a number of reconnaissance geological investigations have been conducted in the Prince William Sound area, there is a dearth of detailed geologic information in some areas of promising copper mineralization.

Historical Sketch

Vigorous prospecting began in the Prince William Sound area about 1895, and by 1907 when exploration activity had reached its peak most of the copper mines and prospects known today had been discovered. In 1897 both the Beatson-Bonanza mine, on Latouche Island southwest of Knight Island, and the Ellamar mine, near Valdez on the mainland, were discovered. These two mines, which contributed more than 96% of the copper mined from the area, began sustained production about 1900. The Beatson-Bonanza mine, largest of the two major producers, continued operation until 1930 when commercial grade ore was exhausted. The Ellamar mine had a shorter life, ending production in 1919.

On Knight Island, a great number of copper occurrences were found and prospected between 1895 and 1907. Some record is available for many of these, but for others the only evidence remaining is a few rotting timbers, which mark the site of a former cabin, or the obscure remains of a prospect pit. One of the principal areas of activity on Knight Island was in the central part around Drier Bay where possibly a few thousand tons of ore were shipped from the Jonesy and Pandora mines. Prospecting activity waned rapidly after 1907 but was again revived immediately preceding World War I. Shortly after 1916, however, prospecting and development work reached another low ebb and, with the exception of some exploration work at the Copper Bullion deposit, never recovered.

Geologic studies in the Prince William Sound area have been largely limited to reconnaissance surveys and mineral deposit investigations by the U.S. Geological Survey. In 1905, Grant (1906) made the first relatively detailed reconnaissance of the mineral resources of the area and described a number of prospects on Knight Island. Two years later Moffit (1908) reported briefly on the copper prospects in the Sound but did not visit the area. A comprehensive reconnaissance report by Grant and Higgins (1910) included some detailed mapping on Latouche Island and mine maps of some of the principal workings on Latouche and Knight Islands. In 1916 Johnson (1918) made another geological reconnaissance, principally of Latouche, Knight, Elrington, Hoodoo(Evans Island), and Bainbridge Islands.

Concurrent with the rapid decrease in mining and mineral exploration after 1916 geologic investigations in the area also waned. In 1943, due to shortages of strategic minerals, interest revived and in that year Moffit and Fellows (1950) undertook another reconnaissance of the Sound area and Stefanson and Moxham (1946) conducted a detailed study of the Copper Bullion deposit. Most recent of the U.S. Geological Survey's investigations in the area is a map of western Prince William Sound (including Knight Island) which shows the linear geologic features as determined from aerial photographs (Condon and Cass, 1958).

Present Investigation

The Division of Mines and Minerals began a program to investigate the areal geology, structure, and mode of-occurrence of the copper deposit of Knight Island in 1963. The Drier Bay-Bay of Isles area was selected because (1) it contains a larger concentration of copper occurrences than elsewhere on the Island and (2) has relatively sheltered waterways affording easy access to much of the area.

Approximately 50 square miles in a belt 4 to 6 miles wide across the Island was mapped during the 1963 and 1964 field seasons. In 1963, 40 days (May 20 - June 28) were spent in the Drier Bay-Johnson Bay area on the west side of Knight Island and in 1964, 22 days (May 27 - June 17) were spent chiefly in the Bay of Isles area on the east side of the island. Mapping was done at a scale of 1 inch = 1/2 mile on enlarged U.S. Geological Survey quadrangle maps. In 1963 both shoreline and overland traverses were conducted, but in 1964 mapping was largely limited to the shoreline due to late heavy snow cover in the highlands. Sediments in all active streams draining into Bay of Isles and Marsha Bay were sampled in 1964 and analyzed for trace heavy elements.

The writer was assisted in the field by Walter T. Phillips, Jr. in 1963 and David A. Schwab in 1964. Ronne C. Richter served as camp hand and boat handler during both field seasons. The cooperation of the Sport Fish Division, Alaska Department of Fish and Game, who furnished a boat and motor for the 1963 season, is gratefully acknowledged.

A study of the distribution of some selected trace heavy metals in the Knight Island rocks is presently underway by David A. Schwab as a graduate thesis project at the New Mexico Institute of Mining and Technology.

Geography

Knight Island is one of the larger islands in Prince William Sound, a major deep water bay indenting the southcentral coast line of Alaska (figure 1). The island is about 25 miles long and about 8 miles wide. The topography is extremely rugged with large fiords and numerous bays projecting deep into the island's interior. Maximum elevation in the map area is about 2900 feet. Overland traverses were generally restricted to terrain below 2000 feet due to the steepness of the higher slopes. Timberline varies between 500 and 900 feet.

Rock exposures are excellent along the shoreline and good above timberline. In the dense rain forest belt between the upper high tide level and timberline, exposures are extremely poor and walking often difficult.

The island is easily accessible by boat or float plane. The sheltered fiords and bays provide relatively safe boat anchorages and landing areas.

REGIONAL GEOLOGIC SETTING

Most of the exposed rocks in the Prince William Sound area are within the Chugach Mountains geosyncline and consist of a great thickness of graywacke and slate, with subordinate conglomerate, chert, limestone, and volcanic rocks. One prominent band of volcanic rocks, as much as 10 miles wide, extends from Elrington and Evans Island northeast across most of Knight Island and probably as far as Port Valdez in the northeast part of the Sound. The rocks are steeply dipping and relatively tightly folded parallel to the major structural trends in southcentral Alaska. Low grade regional metamorphism has imparted a crude foliation to most of the rocks with attendant development of a typical greenschist mineral assemblage.

These eugeosynclinal-like clastic sediments and minor volcanics were deposited in a rapidly subsiding trough along the unstable edge of the continent during late Mesozoic and possibly early Cenozoic time. (Payne, 1955). Source of most of the sediments was apparently to the north in the area of the ancestral Talkeetna Mountains whereas the volcanic rocks were locally derived from a chain of volcanoes within the geosyncline. Inversion and uplift of the geosyncline with concurrent folding, faulting, metamorphism,

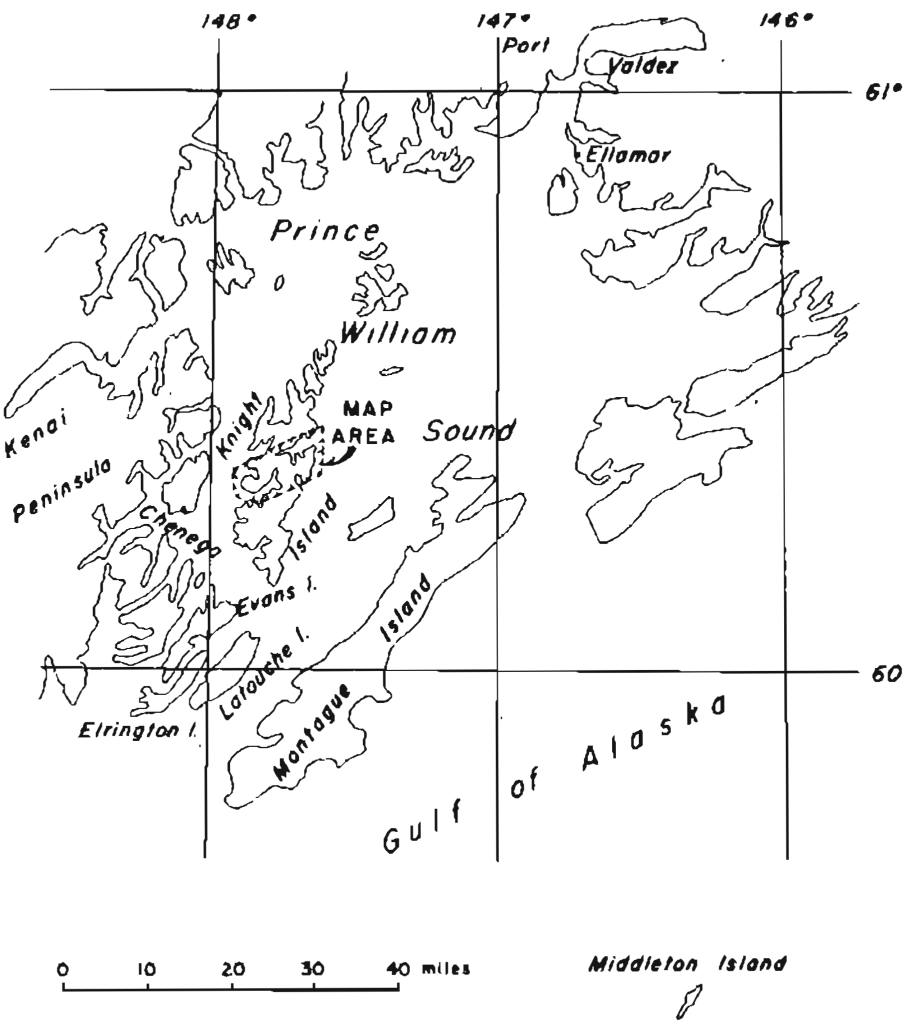


Figure 1. Index map of Prince William Sound area, southcentral Alaska, showing location of Knight Island.

and minor granitic intrusion probably began during the early Tertiary (Paleocene). Deformation reached its climax probably before the beginning of the Eocene, however, various stages and degrees of uplift have continued up to the present time.

GEOLOGY

The rocks of central Knight Island consist principally of basaltic and andesitic volcanics that are collectively referred to as greenstone. Minor slate, with some graywacke and chert, occurs interbedded with the volcanics but probably constitutes less than 5% of the total rock exposed. The bedded rocks have been intruded by hundreds of greenstone dikes and sills(?) and by a few larger bodies of coarse-grained rocks ranging in composition from diorite to gabbro. Bands of strongly schistose and mylonitic rocks, as much as 1000 feet wide, mark the major shear zones that transect the area.

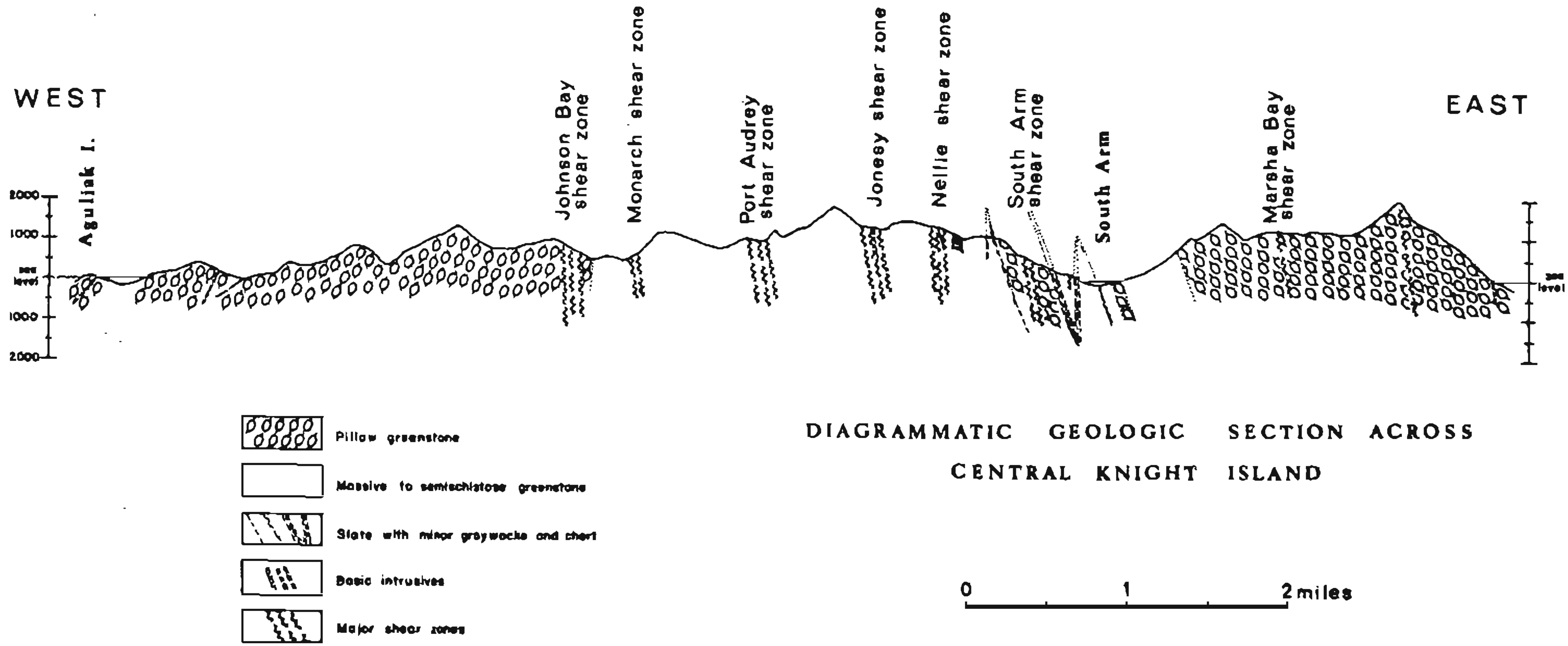
The age of the volcanic rocks and interbedded sediments is not well known. Moffit (1954) summarizes the various lines of fossil and field evidence of past and present investigations and supports a late Cretaceous age for most of the rocks in the Sound area. Recently, however, the U.S. Geological Survey, on the basis of new paleontological evidence, appears to favor an early Tertiary age for at least some of the sedimentary rocks (Chapman 1965).

Bedded rocks

Greenstones

The greenstone volcanics are separable into two relatively distinct map units: a pillow greenstone unit and a massive to semischistose greenstone unit. Pillow greenstones occur principally along the east and west sides of Knight Island, whereas massive to semischistose greenstone appears to be restricted to the core or central portion of the island (figure 2; see also geologic map).

The pillow greenstone unit consists almost entirely of a heterogeneous accumulation of pillow lavas and pillow lava breccias. A few massive greenstones that may represent either flows or nonsorted water-laid tuffs were observed, but are not common. An argillaceous matrix is occasionally present between the pillows but in general they are characterized by a lack of included sedimentary material. Size of the pillows ranges from less than a foot to more than four feet across their greatest dimension. Most of the pillows have retained their original shape although in and near zones of shearing, they have been noticeably fractured and deformed. Stratification is not evident in the pillow greenstones and only where interbedded sediments are present is there any indication of the general attitude of the unit.



DIAGRAMMATIC GEOLOGIC SECTION ACROSS CENTRAL KNIGHT ISLAND

Figure 2

Attempts to determine stratigraphic tops on the basis of the shape and form of individual pillows did not prove useful. The deposition of the pillow greenstone unit evidently was not orderly or uniform but very sporadic with great masses of pillows accumulating from time to time on a very irregular surface and accompanied by considerable post-solidification readjustment.

In hand specimen the pillow greenstones are typically fine-grained dark green to gray, nonporphyritic to porphyritic, and often amygdaloidal. Quartz epidote veinlets are common but not abundant. Under the microscope the groundmass of the pillow greenstones generally consists of a dark ill-defined mixture of albite, actinolite, chlorite, and opaque minerals. Vestiges of an original intersertal to intergranular texture are sometimes discernible in the more coarse-grained varieties, and in the porphyritic rocks relict plagioclase (An_{55}) and clinopyroxene phenocrysts are often present. Invariably, however, the plagioclase is strongly saussuritized and largely replaced by albite and the clinopyroxene replaced by actinolite (uralitized). Vesicles, where present, are filled with chlorite. Spherulitic aggregates of bladed albite with epidote cores are occasionally observed and may represent a different type of vesicle filling.

The massive and semischistose greenstone unit in the central part of the map area consists of a monotonous group of porphyritic and nonporphyritic, fine- to medium-grained rocks that generally lack any discernible primary structures. Crude ellipsoidal structures were recognized at a few localities and a banding that might be interpreted as flow banding is evident in a number of exposures. Xenolithic nodules of gabbro and peridotite were observed in some of the massive rocks, especially along the east and southeast shores of Drier Bay. The more massive rocks typically exhibit a blocky fracture pattern and all rocks are cut by abundant quartz-epidote veinlets. Disseminated pyrite is common throughout the unit and, where plentiful, results in a conspicuous limonite stain. Color of the rocks is quite variable ranging from light greenish gray to almost black.

A possible volcanic vent is present on the high southwest flank of the 2125-foot peak between Port Audrey and Johnson Bay (see geologic map). Here, massive jointed greenstones crop out over a vertical distance of about 1000 feet in a roughly circular area approximately 1000 feet in diameter. Pillow greenstones apparently completely surround the body of massive greenstone.

In thin section the massive and semischistose greenstones are not too unlike the pillow greenstones. They range from intergranular basalt and andesite with relict saussuritized plagioclase (zoned An_{55} to An_{40}) in a groundmass of plagioclase, actinolite, epidote, chlorite, and carbonate to actinolite-chlorite-albite semischists. Most of the medium-grained rocks probably represent thick flows but some may actually be intrusive.

One porphyritic variety contains saussuritized plagioclase phenocrysts as much as ½" long, zoned from An_{60} to An_{25} in a medium-grained (1-2 mm) groundmass of uralitized clinopyroxene, relatively fresh plagioclase (An_{50}), minor interstitial alkali feldspar, and serpentine.

The available evidence suggests that the massive and semischistose greenstones were laid down on a subaerial volcanic pile and that the pillow greenstones are their submarine equivalents. The irregular nature of the massive-pillow greenstone contact, plus the presence of minor interbedded sediments and possibly some pillow lavas in the massive greenstone unit further suggests that the subaerial volcanic eminences were extremely transitory. This simple picture of the volcanic activity on Knight Island, however, is complicated by post-depositional folding and shearing. As discussed in more detail later, the attitude of bedding and minor fold structures indicate that the core of the volcanic pile (and probably the entire volcanic chain) has been uplifted and preserved in a large, complex anticline.

Sedimentary rocks

Thin beds of slate, with subordinate graywacke and chert, are present in minor amounts throughout most of the map area. Although the sedimentary rocks occur chiefly in the pillow greenstone unit, they are also found interbedded in the massive and semischistose greenstone unit. The greatest concentration of sedimentary rocks in the area is exposed along the south side of the Bay of Isles from its mouth to the entrance of West Arm (see geologic map). Except for a few beds of slate on the north side of West Arm, none of these sedimentary bands project across to the north side of the Bay of Isles.

The sedimentary beds rarely exceed a few hundred feet in width and in general average less than 50 feet wide. They are very discontinuous due both to primary depositional features and post-depositional shearing and folding. The bedding strikes between N and N50°E and dips steeply to the east with the exception of the few sediments on the west side of the island which apparently dip steeply to the west. Prominent slaty cleavage and the axial planes of folds parallel the bedding except at the noses of folds or where the slate cleavage wraps around boudins of competent greenstone, chert, or occasionally graywacke.

In thin section the slate consists principally of quartz, muscovite, and carbonaceous material. The graywackes exhibit the same metamorphic mineral assemblage as the greenstones (albite-epidote-chlorite-actinolite) but generally also contain some muscovite.

The field and structural data suggest that the many sedimentary beds exposed between West Arm and Cape Poi in the Bay of Isles may belong to the same general stratigraphic horizon. Repetition of the beds has been effected largely by folding and to some extent by displacement along the shear zones. Elsewhere in the area the scattered sedimentary beds probably reflect local areas of deposition throughout a considerable range of time.

<u>Shear zone rocks</u>

The rocks in the major shear zones that transect the area are for the most part the sheared and schistose equivalents of the massive and pillow greenstones. Metasediments, however, are relatively common within the shear zones, suggesting that the shear zones follow, at least in part, local sedimentary bands or lenses in the volcanics.

Principal shear zone rocks are dark green chlorite schists and chlorite-quartz schists containing variable and subordinate amounts of epidote, actinolite, and albite. With a decrease in schistosity these rocks grade into the chlorite-quartz-actinolite-albite semischists of the massive greenstone unit. In one thin section of a chlorite schist from the Jonesy mine, ghosts of elongated fragments with chlorite/quartz and chlorite/actinolite ratios different than the matrix were observed. In another thin section of a schistose breccia (Nellie shear zone), with flattened fragments as much as 6 inches long, shard-shaped forms of chlorite-quartz were observed in a matrix of quartz, albite, and acintolite. These rocks probably represent deposits of subaerial pyroclastic origin.

Chert mylonites, although uncommon, occur as conspicuous light-colored lenses that are generally less than 100 feet long and 10 feet wide. In the field they form boudins of massive, thinly banded rock, and under the microscope show the effects of pronounced cataclastic deformation. The quartz grains are very fine-grained and occur in bands which flow around small lenses of unsheared quartz-epidote-albite(?).

Boudins of competent massive greenstone are a common feature of the shear zones. The boudins range in size from small microscope fragments to blocks as much as a few tens of feet wide and possibly as much as a few hundred feet long (see figure 5). Unlike the chert boudins the greenstone boudins do not exhibit any pronounced obvious mylonitization features although the rocks have been entirely recrystallized.

Quartz-epidote veinlets and disseminated pyrite are common in the shear zones. In many exposures the quartz-epidote veinlets appear to randomly crosscut the schistosity indicating a post-shearing age for at least some of the veinlets.

Intrusive rocks

Greenstone dikes and sills(?)

Greenstone dikes and possible sills which evidently represent feeders for the volcanic flows are common throughout the entire mapped area. The dikes range from a few inches to more than 100 feet wide and average about 4 to 5 feet wide. As a group the dikes strike northwesterly with steep dips (see figure 3) across the structural grain of the country. In the field three varieties of dikes have been recognized. In order of abundance these are: (1) fine-to medium-grained, dark gray-green dikes; (2) porphyritic dikes and (3) gray, aplitic-textured dikes. In general appearance the dike rocks show less mineralogical and structural changes than the greenstone country rock.

The first two varieties are basaltic in composition. Under the microscope textures are usually discernible and vary from intergranular to ophitic with intersertal to hyalophitic margins. The rocks typically consist of 40 to 50 percent clinopyroxene partially altered to actinolite and a like amount of plagioclase (An_{55}) partially replaced by albite. Interstitial glass where originally present has been metamorphosed to a fine-grained mixture of chlorite with minor epidote, actinolite, and albite(?). In the porphyritic varieties, phenocrysts of plagioclase as much as 1 inch long are present.

Although no thin sections were cut of the lighter-colored gray dikes, they appear to be more andesitic in composition than the darker dikes. In hand specimen, the rock consists of grains of cloudy feldspar and occasional quartz, with probably less than 30 percent altered mafic minerals. In a few places where both the dark and light dikes were observed together, the light-colored dikes were younger.

Coarse-grained gabbro and diorite

A number of relatively large elongate bodies of gabbro and two lens-like bodies of diorite have been mapped in the area. The larger gabbro bodies seem to be restricted to the massive-semischistose greenstone unit and are concentrated chiefly in the vicinity of the Nellie and South Arm shear zones. The bodies apparently parallel the regional structure, however, there is some evidence that some are crosscut at very slight angles by the shear zones. Smaller gabbroic bodies are found throughout the area. The two diorite bodies crop out at an elevation of about 1000 feet on the northeast flank of the 2125 foot mountain west of Port Audrey. Bodies of quartz diorite have also been mapped underground in the vicinity of the Copper Bullion mine (Stefansson and Moxham, 1946) but are not shown on the accompanying geologic map.

Modal analyses of the two rock types, including a magnetite-rich variety of the gabbro, are given in Table 1. The gabbros are dark rocks

TABLE 1

Modes of Coarse-grained Intrusive Rocks
from Central Knight Island

	K-63 Diorite	K-120 Gabbro	K-64-20 Magnetite-bearing gabbro
Primary minerals			
plagioclase feldspar	45 (An_{40}) 1/	40 (An_{55-65})	35 (An_{65})
alkali feldspar	5	tr	
myrmekite	8		
clinopyroxene	2	5	30
hornblende	5 2/		
magnetite	3	4	15
Metamorphic minerals			
actinolite		50 4/	20 4/
chlorite	12 3/	tr	tr
epidote	30	tr	
carbonate		tr	

1/ largely saussuritized
2/ replaced by epidote
3/ probably after biotite
4/ after clinopyroxene

Localities:

K-63 West of Monarch prospect (locality 1)
K-120 3/4 mile northeast of Jonesy mine (locality 3)
K-64-20 North shore of Bay of Isles near entrance to West Arm.

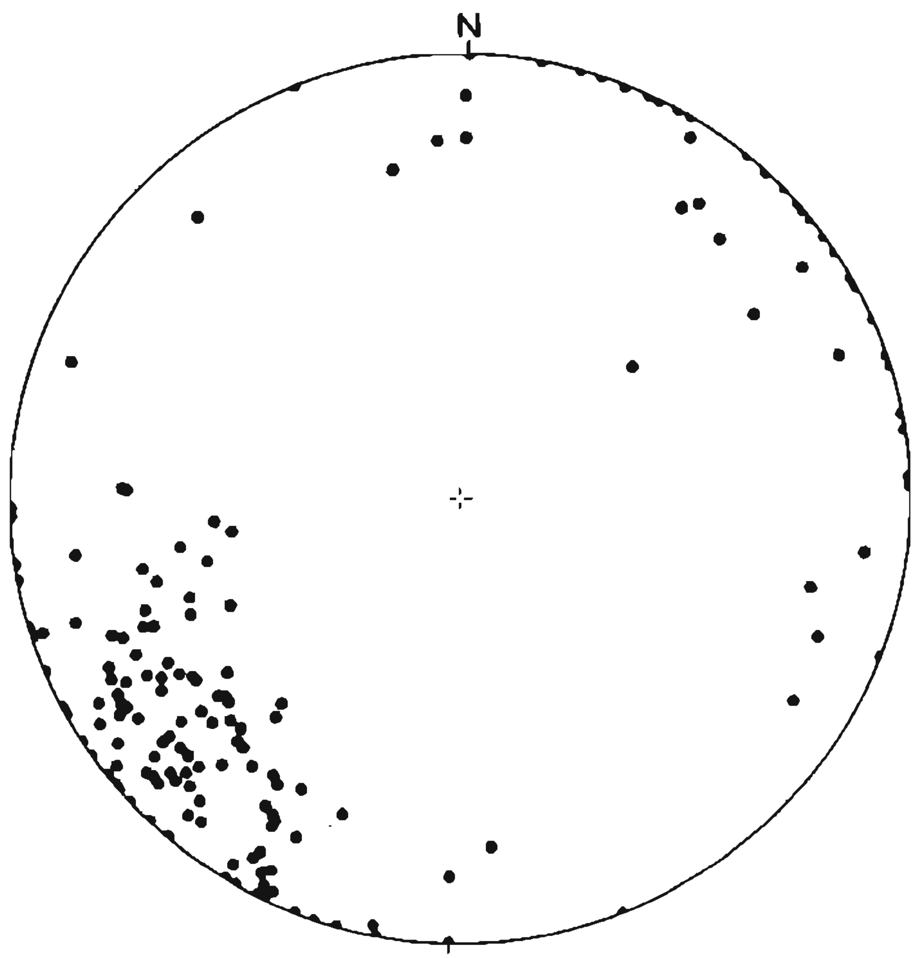


Figure 3. Lower hemisphere projection of poles of dikes in central Knight Island area.

consisting of a coarse-grained ophitic intergrowth of clinopyroxene, variably altered to actinolite, and locally saussuritized basic plagioclase. Magnetite is a common accessory mineral and is present in amounts as much as 15 volume percent in some of the gabbro bodies along the north shore of the Bay of Isles. The diorite is light greenish gray in color and contains a more varied mineral assemblage. Interstitial alkali feldspar is present in minor amounts and is generally separated from the saussuritized plagioclase by myrmekite. Biotite was apparently the principal primary mafic mineral but is now altered entirely to chlorite. Minor primary(?) clinopyroxene and hornblende are also present.

Veins, pods, and irregular masses of granophyre are common within some of the gabbro bodies and are also intrusive into the massive greenstone unit, especially along the north side of the Bay of Isles. The granophyre is a conspicuous light gray to white color and consists predominantly of a coarse-grained mixture of potash feldspar, and graphic albite-quartz intergrowths. The graphic intergrowths are generally cored with a euhedral crystal of albite. Minor epidote is present in small veinlets and irregular patches scattered through the rock.

Unconsolidated deposits

Many of the stream courses in the mapped area contain scattered deposits of glacial material of Recent or Pleistocene age. Most of these deposits are thin and discontinuous, but in three valleys relatively extensive moraines as much as 100 feet thick are present and are shown on the geologic map.

Metamorphism

All the consolidated rocks in the area show the effects of low grade regional metamorphism. The absence of biotite in the bedded rocks and the apparent alteration of biotite to chlorite in the diorite intrusives suggests that the grade of metamorphism was not higher than the quartz-albite-muscovite-chlorite subfacies of the greenschist facies. The observed mineral assemblages in the various rocks types are as follows:

Black slate:	quartz-muscovite-albite
Graywacke:	quartz-chlorite-epidote-actinolite-albite-muscovite
Chert:	quartz-muscovite-epidote-albite
Basic volcanics:	albite-chlorite-actinolite-epidote
Diorite:	epidote-chlorite-albite(?)-hydrous iron oxides
Gabbro:	actinolite-albite-chlorite-serpentine(?)

No contact metamorphic effects were observed. In the shear zones the same mineral assemblages are present but with a pronounced foliation.

Structure

The folding, shearing, and metamorphism of the Knight Island rocks evidently occurred contemporaneously. Axial planes of folds, and the attitude of shear zones, foliation, slaty cleavage, and most of the bedding are parallel, or nearly so, and form the regional structural grain of the area. The strike of these features ranges from a few degrees west of north to northeast with probably more than 80% falling between N5°E and N20°E. Dips are steep and generally to the east.

Folding is not obvious in the greenstone units but is well-displayed in the thin interbedded sedimentary beds (figure 2). The folds are overturned and asymmetric to isoclinal. Along the south shore of the Bay of Isles a number of fold noses were observed with limb-to-limb dimensions in the tens of feet. Minor drag folds in this area are relatively common. Most plunge steeply south and together with the larger folds suggest a major anticlinal structure to the west. On Squirrel and Aguliak Islands and along the west side of Knight Island the slaty cleavage dips vertically to westerly, and the few drag folds observed indicate an anticlinal structure to the east. Hence it appears that the axis of a large complex anticlinal structure, plunging to the south, follows the approximate center line of Knight Island.

At least seven major shear zones transect the map area (figure 2 and geologic map). Six of these occur in the massive-semischistose greenstone unit and only one in the pillow greenstone unit. The shear zones are upwards to 1000 feet wide and at least two (Jonesy and South Arm shear zones) extend both north and south out of the mapped area. Along the south shore of the Bay of Isles in the relatively sediment-rich section, the major shear zones are difficult to trace as evidently a large portion of the regional stress may have been relieved by slippage in the slate. There is no good evidence to indicate the sense or magnitude of motion along the shear zones. The Johnson Bay shear zone, which appears to follow a curvilinear path,north of Johnson Bay through the West Arm of Bay of Isles, may bring the pillow greenstone unit in fault contact with the massive greenstone unit. However, on the other hand, the shear zone ma_ locally follow a normal depositional contact between these two units. Left-hand strike slip movement as great as 1/2 mile is weakly suggested by the supposed dislocation of the coarse-grained gabbro body along the Nellie shear zone.

Minor shear zones, from a few inches to a few tens of feet wide, are common throughout the area. Most strike parallel to the major shear zones, although a number trend northwest and dip steeply to the southwest.

The greenstone dikes also show a preferred northwest orientation. A stereo-plot of over 100 dike attitudes is shown in figure 3. These data indicate a mean strike of N50W and a dip of 75°SW.

Not all the lineaments mapped from aerial photographs by Condon and Cass (1956) could be identified in the field. Some of their major lineaments coincided with parts of some of the major shear zones, but in general the broad shear zones are not characterized by a distinct topographic expression. The slate beds and minor shear zones probably form better linears because of a combination of their narrow width and relative ease of erosion.

MINERAL DEPOSITS

Mineralogy and origin

With the exception of one relatively minor mineral occurrence all known massive sulfide deposits in the area occur within the major shear zones. The exception is a prospect (locality 12) on the north shore of the Bay of Wales that occurs in a coarse-grained gabbro intrusive.

The sulfide deposits consist principally of massive pyrrhotite intimately associated with lesser amounts of chalcopyrite and cubanite*. Pyrite and occasionally sphalerite are present in some deposits; however, for the most part these two sulfides together with quartz, and epidote appear to occur largely in veins that have formed later under different conditions of deposition. The massive sulfides occur as pods, lenses, irregular vein-like segregations and disseminations ranging in size from a few tenths of an inch to masses as much as 500 feet long by 50 feet wide. Gangue material is predominantly chlorite-rich schistose to semi-schistose country rock. Oxidation of the sulfide has been negligible; minor amounts of secondary copper minerals have only been observed in a few localities.

Deposition of the massive sulfides probably occurred more or less contemporaneously with the main period of metamorphism, folding, and shearing of the greenstones. The possibility also exists that two ages of massive sulfide are present, the later one being remobilized from the earlier. Schistosity can be observed flowing around massive sulfides in some exposures while in others the sulfides appear to crosscut the schistosity. The veins of pyrite, quartz, and epidote with minor sphalerite appear to have formed at lower temperatures following the deposition of the bulk of the massive sulfides and after the main period of metamorphism. A simple paragenetic diagram for the ore and gangue minerals is shown in figure 4.

Secondary structures, which formed local areas of reduced pressure within the major shear zones during metamorphism, apparently played a dominant role in controlling the deposition of the massive sulfides. Where relationships are interpretable, massive sulfides have been observed;

*$CuFe_2S_3$. In the old literature this mineral is generally referred to as chalmersite. No cubanite was observed in the present study, however, only a few polished ore sections were prepared and examined. Moffit & Fellows (1950) report the presence of cubanite as an important ore mineral in most of the deposits. In hand specimens it is difficult to distinguish from chalcopyrite with which it is usually intergrown.

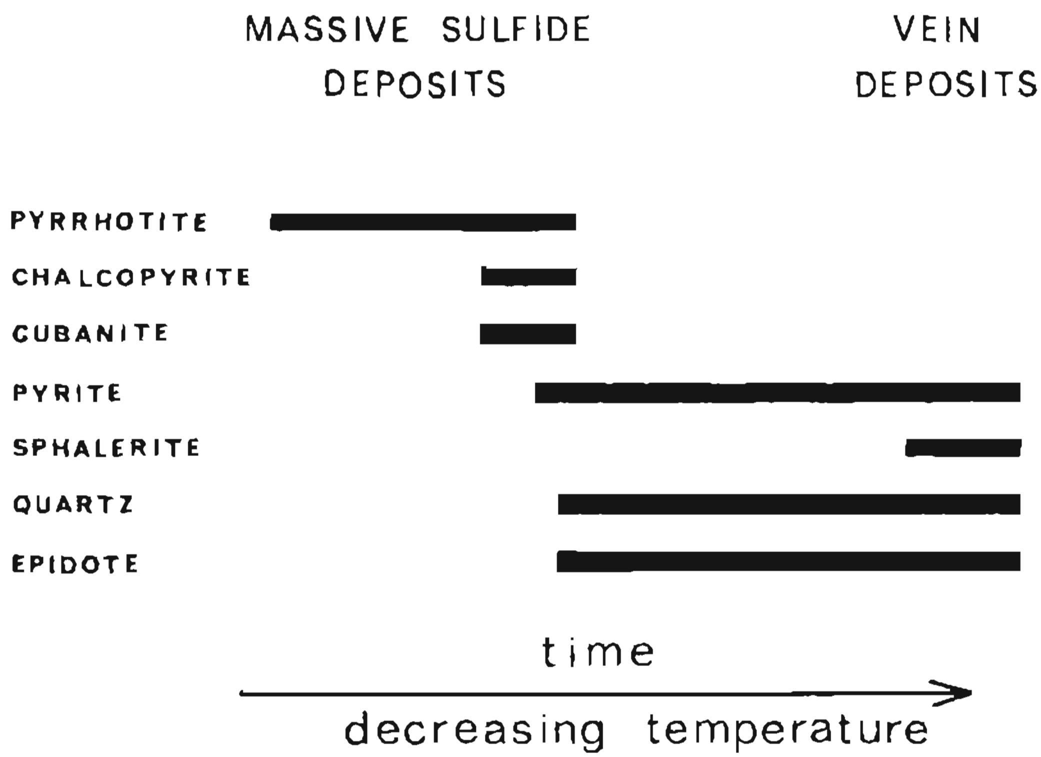


Figure 4. Paragenesis of ore and gangue minerals.

(1) in areas of subtle changes in direction of schistosity; (2) in warped schist at the contact of large bodies of competent rocks; and (3) in strongly warped schist at the apices of small lenses or boudins of competent rock. The latter two are similar and gradational, however, in (2) the competent rock mass has remained relatively static, whereas in (3) the competent rock mass has been rotated (figure 8, locality 13). Although (2) and (3) appear to be the most common ore controls (Jonesy mine, figure 5; Pandora mine, figure 6; and locality 13, figure 8) they are also the most obvious and may not be responsible for controlling the deposition of the larger massive sulfide bodies, such as the Copper Bullion mine.

Cross-shearing or cross-jointing, such as observed at localities 9 and 15 (figure 8), apparently has exercised some control in localizing sulfide mineralization. In both of these localities, however, pyrite is present and the deposits may represent a stage of mineralization intermediate between the massive sulfide deposits and the pyrite-bearing vein deposits.

The original source of the metal elements and sulfur in the massive sulfide deposits is believed to be the volcanic country rock. Evidently during metamorphism these elements were scavenged from the greenstone, transported and concentrated by hot metamorphic aqueous solutions, and finally deposited in areas of reduced pressure within the shear zones. There appears to be no need, nor is there any substantial evidence, to call upon a buried igneous intrusive body as a source for the sulfide ores.

Description of mines and prospects

Locality 1, Monarch prospect

The Monarch prospect (Knight Island Consolidated Copper Co., Hubbard-Elliott Co.) is at an elevation of approximately 700 feet on the steep, densely wooded mountain slope 3/4 of a mile northwest of the tidal inlet at the head of Port Audrey in Drier Bay. The underground workings are reported to have a length of about 320 feet (Moffit and Fellows, 1950) but at the time of our visit in 1963 the adit was caved at the portal.

The prospect is in the Monarch shear zone and the country rock consists of both schistose and massive greenstone. At the portal a band of strongly schistose greenstone is exposed that strikes N7° - 15°W and dips vertically to 75°W. Fragments of chlorite schist containing veins and irregular masses of quartz and epidote with abundant pyrite and minor chalcopyrite are scattered throughout the dump.

Locality 2

On the same shear zone, approximately 1/2 mile north of the Monarch prospect and at an elevation of about 1250 feet, a 10-foot-deep prospect

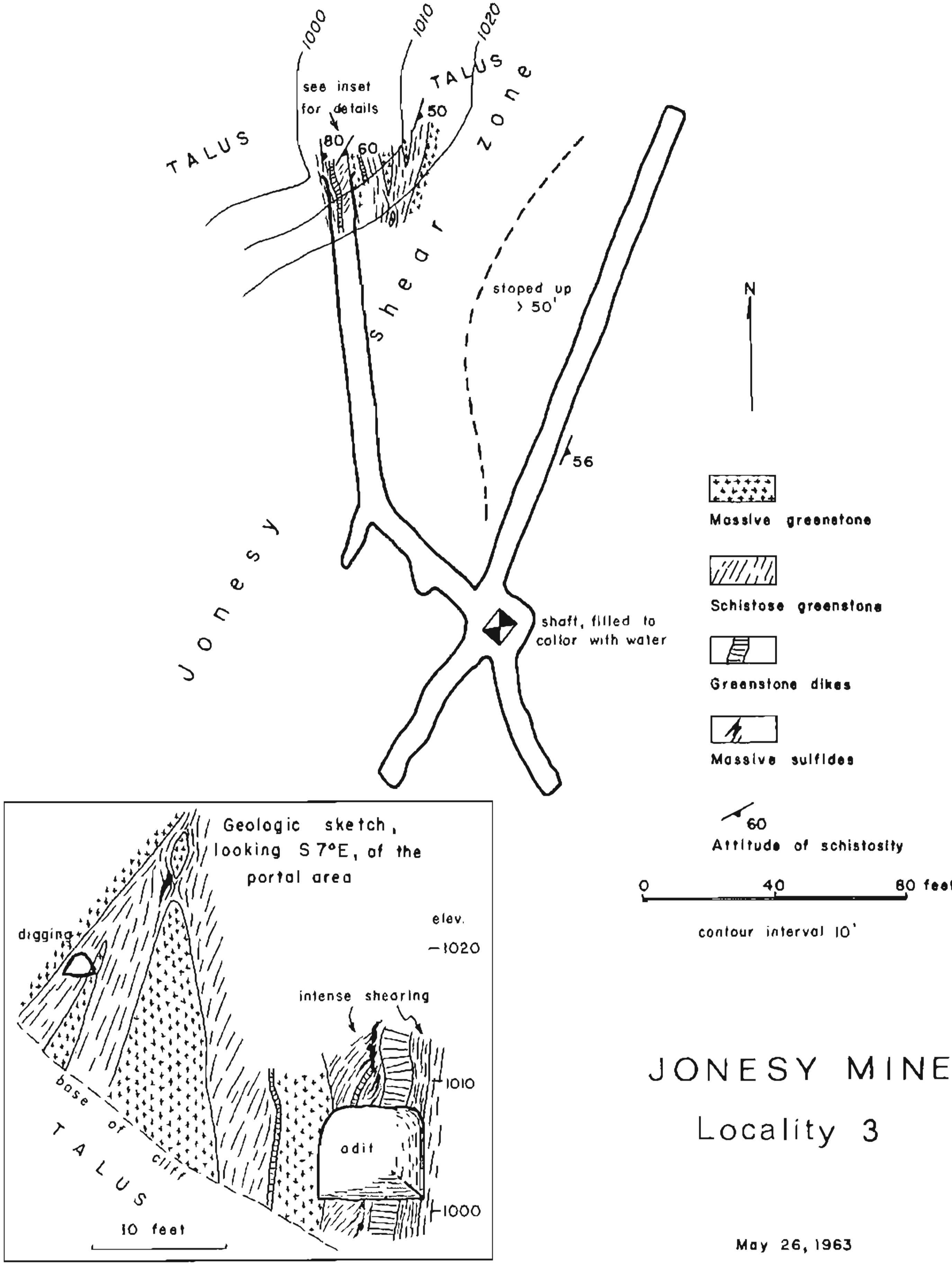


Figure 5. Geologic map of the Jonesy mine.

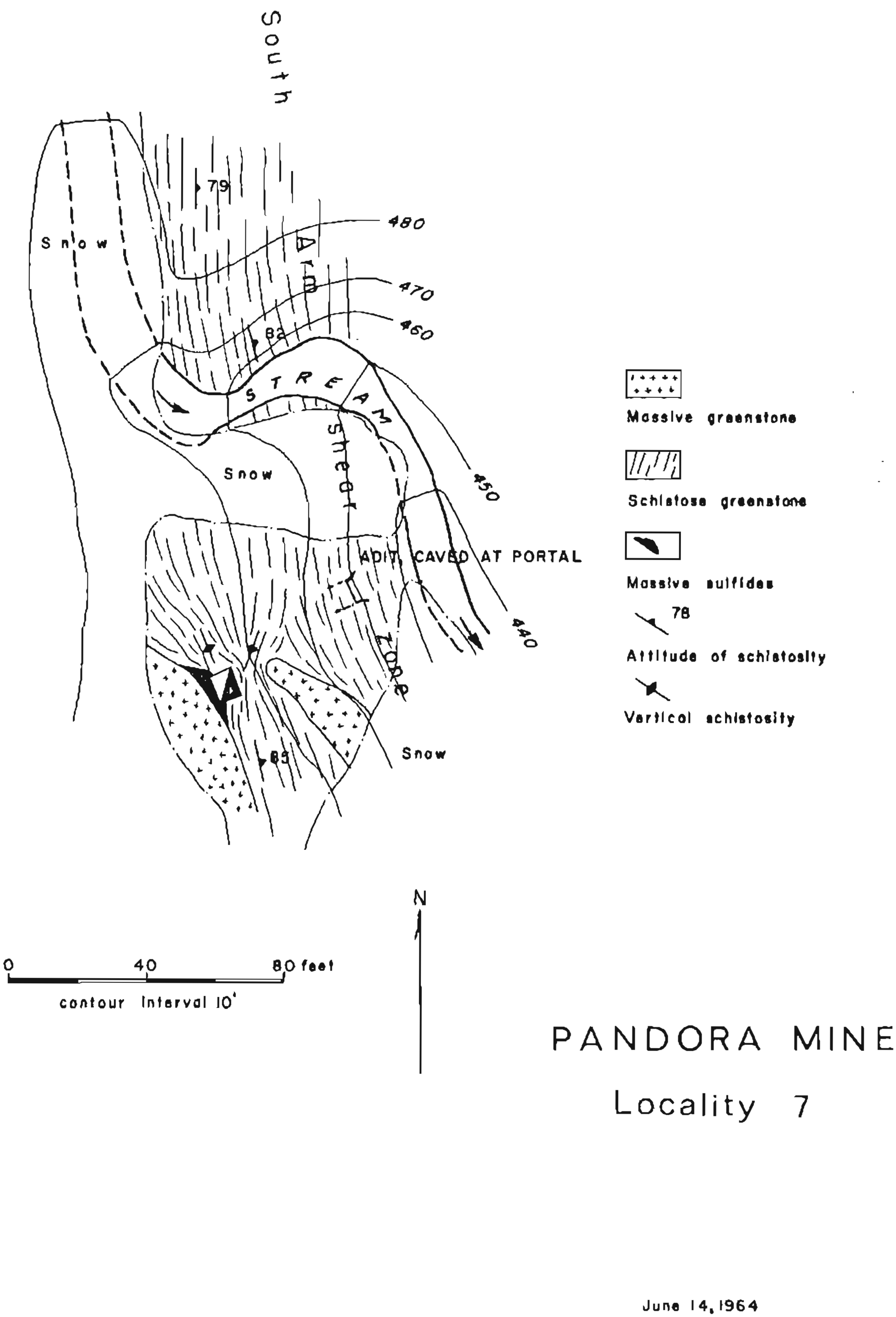


Figure 6. Geologic map of the Pandora mine.

shaft has been sunk in an area of intense shearing and strong limonite staining. The rock is a chlorite schist containing irregular masses of quartz and pyrite and disseminated pyrite; no copper sulfides were observed.

Locality 3, Jonesy mine

The Jonesy mine (Bald Eagle claim, Knight Island Consolidated Copper Co., Hubbard-Elliott Co.) is at an elevation of about 1000 feet in a north-facing cliff, slightly more than 1/2 mile east of the tidal inlet at the head of Port Audrey. The mine workings are still open but all surface facilities, including an aerial tram, power plant, and several buildings, have either been removed or destroyed by decay. In 1908 the mine was mapped by Grant and Higgins (1910) and at that time the underground workings totaled approximately 350 feet. Since then, but probably before 1916, an additional 50 feet of drifting was completed and considerable stoping undertaken on the main ore zone.

A plan of the mine workings and sketch of the surface geology in the vicinity of the mine portal is shown in figure 5. Because of the thick accumulation of dirt and secondary minerals on the walls of the workings no attempt was made to map the mine geology. The mine is in a band of moderately to strongly sheared greenstone, containing boudins of massive greenstone and nonfoliated greenstone dikes, within the Jonesy shear zone. The sheared rocks are principally dark green chlorite schists with subordinate and variable amounts of quartz and actinolite. The massive, nonfoliated rocks consist of mixtures of saussuritized plagioclase and uralitized clinopyroxene with variable amounts of chlorite, albite, and opaque minerals. In general, the schistosity trends between N10E and N25E and dips between 50° and 75°E. Locally, however, the schistosity may be extremely variable, especially where it wraps around boudins of massive competent greenstone. Irregular pods and lenses of massive sulfides, consisting principally of pyrrhotite and chalcopyrite, appear to be localized where maximum flexure of the schistosity has occurred. In the exposures on the cliff face massive sulfides are present: (1) along a zone of flexure in a 3- to 4-foot wide band of strongly schistose rock between a boudin of massive greenstone and a 3-foot-thick nonfoliated dike and (2) at the apex of an elliptical-shaped pod of massive greenstone encased in schistose greenstone.

The mine adit was driven approximately S5°E on the sulfide-rich zone in the band of strongly schistose rock, but as indicated by the plan of the underground workings this zone was followed for only a little over 100 feet. The adit was then directed more to the east where at about 150 feet from the portal it apparently intersected a relatively large concentration of sulfide minerals trending N20°E and dipping 56°SE. From the length of the drift and extent of the stoping it appears that as much as 1000 tons of ore may have been mined.

Locality 4, Nellie prospect

The Nellie prospect is in a steep-walled ravine 3/4 of a mile east of Port Audrey in Drier Bay. According to Moffit and Fellows (1950) it was explored by open-cuts, a 6-foot shaft, and a 36-foot adit. However, by the time of the writers' visit in 1963 landslides and avalanching in the ravine had covered or destroyed all of the workings.

Although no evidence of prospecting activity remains at the Nellie prospect, the mineralized area is relatively well-defined. At an elevation of approximately 700 feet a 25-foot band of intensely sheared and limonite-stained rock in the Nellie shear zone is exposed in the bottom of the ravine. The rocks are dark green chlorite schists with minor black phyllite layers and an occasional boudin-like lenses or pods of massive greenstone. Quartz veins paralleling the schistosity are common in the phyllites. The schistosity is irregular and averages N14°E, 75°SE or virtually conformable with the trend of the Nellie shear zone. Massive sulfides were not observed in place, but are present in talus fragments thoughout the prospect area. Typical specimens consist of massive pyrrhotite and minor chalcopyrite with included fragments of chlorite schist and rounded aggregates of white quartz.

Locality 5, 20th Century prospect

The 20th Century prospect (Twentieth Century Knight Island Copper Mining Co.) is in a small ravine, at an elevation of approximately 650 feet, south of the entrance to the Northeast Cove. Moffit and Fellows (1950) mention that the prospect was explored by "several old tunnels ... the longest... probably several hundred feet long" but the only evidence of workings observed in 1963 was a curving 90-foot adit, heading south at the portal and S22° W at the face.

The adit was driven on a 10-foot wide strongly sheared and highly limonite-stained lens of chlorite schist in the Nellie shear zone. At the portal the schistosity trends N5°E and dips 82°E. No sulfide mineralization was observed in the adit but fragments of massive pyrrhotite and chalcopyrite are common in the mine dump.

Locality 6, Barnes Cove prospect

At the head of Barnes Cove, many ruined buildings and large piles of rusting pipe, mine rails, and other mining equipment of the Knights Island Copper Mining Company suggest an exploration venture of rather large proportion. However, neither the workings described by Moffit and Fellows (1950) nor what was observed in 1963 appear commensurate with the amount of equipment and facilities in the area. Moffit and Fellows describe two adits -- one 15 feet long and the other buried in snow but "evidently much longer"-- 1/4 mile southeast of the Cove at an elevation of 300 feet. In 1963 only one 25-foot adit was found at approximately the same elevation but 1/4 mile due east of the head of the Cove and in an area free of snow.

The 25-foot adit was driven S39°E in semischistose fine-grained to porphyritic greenstone. The only evidence of mineralization is minor limonite staining at the portal. Moffit and Fellows (1950) mention that samples of ore contain iron and copper sulfides but further state that their source in the tunnels was not identified. Although the available evidence points to a promotional venture the prospect area lies within the Nellie shear zone and the possible presence of mineral deposits should not be discounted.

Locality 7, Pandora mine

The Pandora mine is at an elevation of between 450 and 475 feet, about 1/2 mile southwest of the head of South Arm in the Bay of Isles. The underground workings, which are now inaccessible, lie on the west bank of the main stream flowing into South Arm and consist of an adit about 10 feet above stream level and a vertical shaft about 25 feet higher on the stream bank (figure 6). In 1916, which presumably was the last year the mine operated, the property was examined by Johnson (1918). At that time the shaft was 95 feet deep, with some crosscutting at the 65 foot level and 110 feet of drifting at the 86-foot level. On the adit level there was about 155 feet of drifting and crosscutting.

The mine is in the South Arm shear zone and the rocks are principally chlorite and quartz-chlorite-muscovite schists enclosing at least two large lenses of massive, nonfoliated greenstone. The general trend of the schistosity is between N15W and N-S with dips ranging from vertical to 79°E. Extreme variations of the foliation attitude occur where the schistose rocks contact the more competent greenstone. From the limited evidence seen on the surface these areas of maximum foliation flexure also appear to have served as a structural control in the localization of the sulfide deposits. The shaft was sunk on a large pod of massive sulfides, as much as 5 feet thick, at the contact between massive and schistose greenstone. Johnson (1918) also noted that a number of smaller sulfide lenses, up to 15 inches thick, and sulfide fissure-fillings were encountered in the mine. The ore minerals were pyrrhotite, chalcopyrite, and cubanite; gangue consisted chiefly of quartz and schistose rock fragments.

Locality 8, Knights Island Alaska Copper Co. Mine

The Knights Island Alaska Copper Co. explored a sulfide-bearing band in the South Arm shear zone 1/2 mile northeast of the head of Northeast Cove. At an elevation of approximately 1200 feet, three prospect pits were dug on surface exposures of the sulfide zone, and from an elevation of about 900 feet a tunnel was driven to intersect this zone at depth (figure 7). The tunnel is 760 feet long on a heading averaging S70°E. Three small drifts, aggregating 165 feet in length, and a short raise and winze were driven from the eastern end of the tunnel.

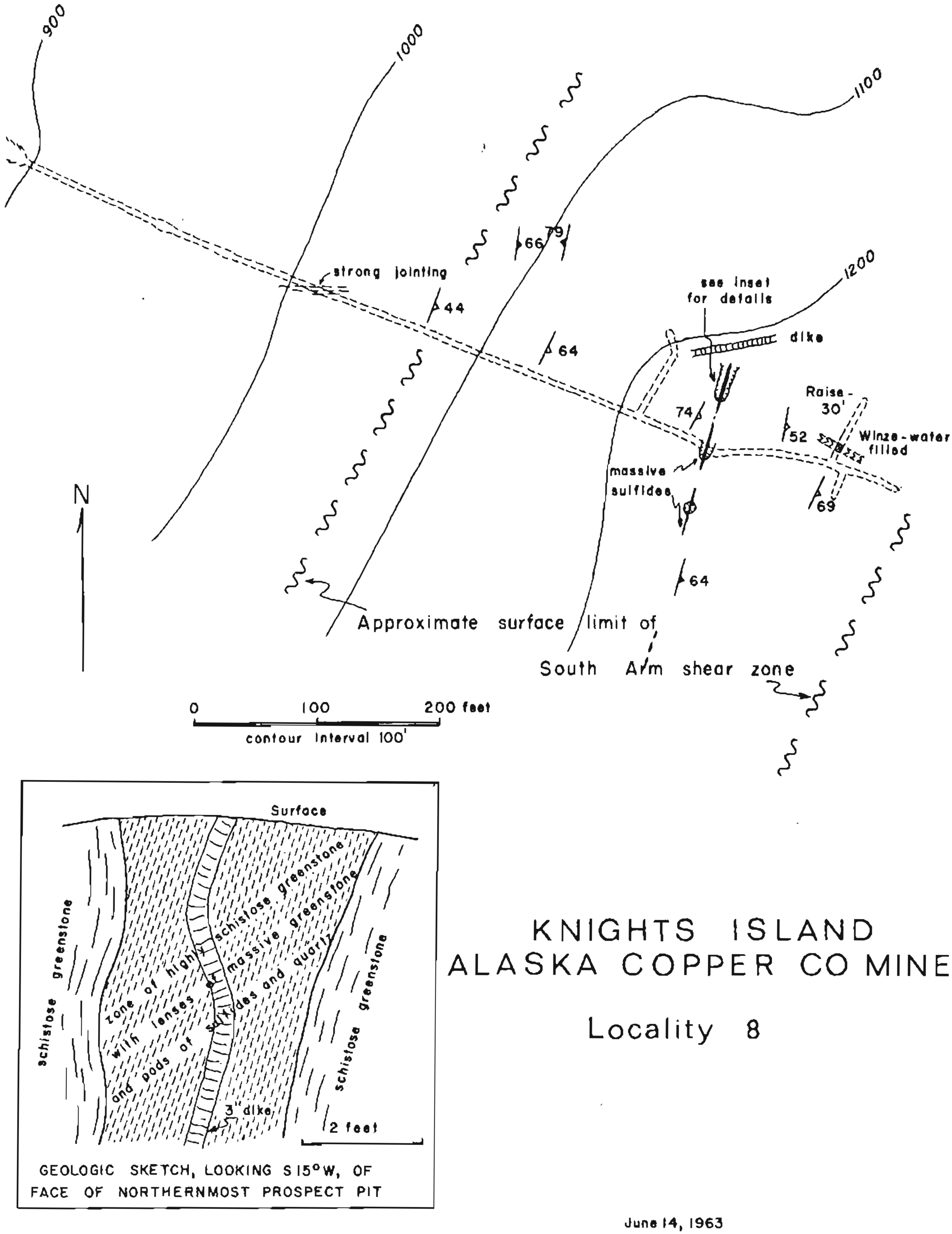


Figure 7. Geologic map of
the Knights Island Alaska Copper Co. mine.

The rocks in the vicinity of the surface workings are principally quartz-chlorite and chlorite schists with an average trend of N15°E and a steep easterly dip. The degree of schistosity exhibited by the rocks is quite variable and imparts a banded appearance to the outcrops. Sulfide minerals appear to be restricted to a single band of extremely schistose and brecciated(?) rock that is intermittently exposed along a strike length of about 300 feet. This band attains a maximum width of about 6 feet and consists of dark green chlorite schist, lenses and blocks of massive nonfoliated greenstone, veins of quartz with minor epidote, and scattered lenses and irregular patches of massive pyrrhotite, chalcopyrite, and minor quartz. In the northernmost pit a 3 inch wide, fractured but non-foliated, greenstone dike cuts through the middle of the sheared and mineralized band. In the tunnel strong schistosity was observed at distances of 350, 440, 580-610, and 650-720 feet from the portal but no sulfide minerals were observed.

Locality 9

A small but conspicuous iron-stained outcrop, in which a shallow pit has been dug, is exposed a few feet above sea level on the east side of Marsha Bay. The area is within the Marsha Bay shear zone and the rocks consist of alternating zones of schistose and massive pillow greenstone. At the prospect a lens of light gray dense chert about 4 feet thick is bordered by schistose greenstone (figure 8). The foliation of the schist strikes N20°E and dips between vertical and 80°E. The chert is massive, but fractured, with the prominent fractures striking N50°E and dipping 5°-20°NW. Locally the fractures are filled with smaller irregular masses of pyrrhotite, quartz, and minor chalcopyrite and pyrite. Boulders containing quartz and massive sulfides are present in the large stream bed 100 feet east of the prospect, and indicate additional mineralized areas in the Marsha Bay shear zone to the north.

Locality 10

South of locality 9 in the Marsha Bay shear zone on the west side of Marsha Bay another conspicuous iron-stained outcrop is present. The outcrop extends from sea level up to an elevation of about 50 feet and shows the scars of very old superficial pits and trenches. The principal rock in the mineralized area is a light-colored breccia containing fragments of schistose rock and gray chert in a quartzose matrix. To the west in the shear zone the rocks are dominantly quartz-chlorite schists interlayered with quartz-muscovite schists. The schistosity strikes N10°E and dips 80°-85°E. Unlike the typical mineral occurrences elsewhere in the map area the sulfide minerals here are pyrite with very minor chalcopyrite and sphalerite scattered in small irregular masses through the breccia. Well-developed cubes of pyrite as large as 1 inch square are common.

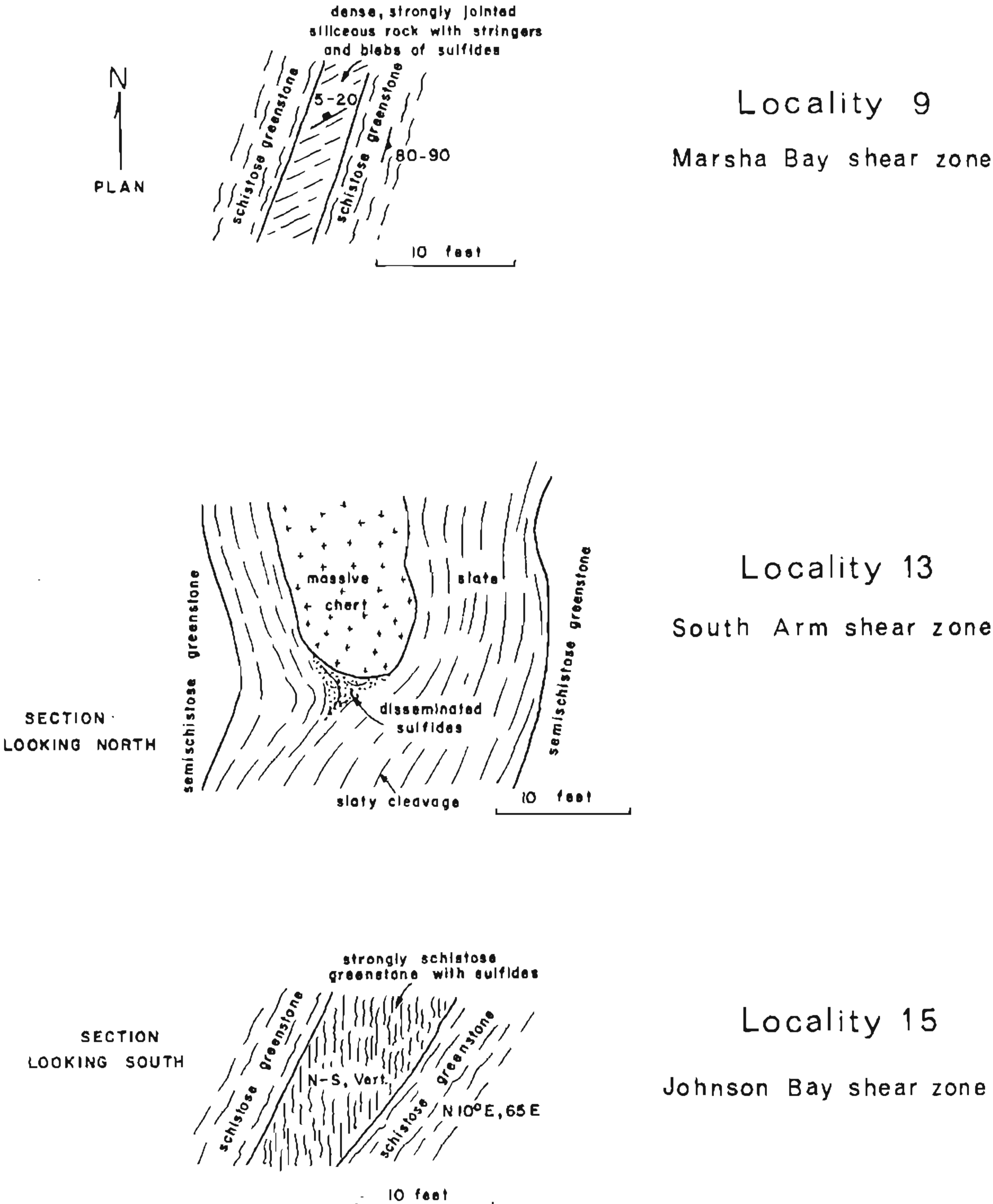


Figure 8. Geologic sketch maps of 3 sulfide-bearing localities in central Knight Island.

Locality 11, Copper Bullion mine

The Copper Bullion mine (Rua Cove mine) is the largest and best known copper deposit on Knight Island, and is the only property within the map area on which annual assessment work has been kept current. The deposit is in a relatively small shear zone on the steep mountainside on the east side of Knight Island between the Bay of Isles and Marsha Bay (figure 9). The deposit has been explored by about 2850 feet of underground workings, 3200 feet of diamond drilling, and a number of surface cuts and trenches.

Due to inclement weather and hazardous access by small boat, only a few hours were spent in the area during the present investigation. However, the deposit has been examined and mapped by several U.S. Geological Survey parties (including Johnson, 1918 and Stefansson and Moxham, 1946) and explored by the U.S. Bureau of Mines in 1948-1949 (Rutledge, 1953) and 1964. In this report a brief sketch of the geology and ore deposits and a resume of the U.S. Bureau of Mines 1964 exploration is presented. 1/ For more detailed geologic information the reader is referred to the comprehensive and relatively recent report by Stefansson and Moxham.

The deposit consists of large bodies of massive sulfides in a shear zone trending northeast and dipping between 80°E and 60°W. Three principal rock types have been recognized and mapped in the area: sheared fine-grained greenstone, blocky porphyritic pillow greenstone, and altered quartz diorite. At the time of the U.S. Geological Survey's and the U.S. Bureau of Mines' studies in the 1940's, at least two massive sulfide bodies were known to occur within the shear zone. The largest of these bodies on the west side of the shear zone is 500 feet long and 25 to 50 feet wide as exposed in the 370 foot elevation adit (figure 9). On the surface this body crops out as a lens 200 feet long by about 50 feet wide. The second body occurs along the east side of the shear zone; it is less explored than the other and does not appear to continue through to the surface. Both sulfide bodies terminate at an east-west fault on the 370 foot level. In general, the contact between massive sulfide and unmineralized greenstone is gradational, resulting in a thick envelope of disseminated sulfides around the ore bodies. Pyrrhotite is the principal sulfide mineral present; chalcopyrite and minor sphalerite occur as veinlets and small irregular patches in the pyrrhotite. Stefansson and Moxham (1946) believe that the sulfide minerals replaced sheared greenstone chiefly in areas adjacent to faults and fracture planes within the shear zone. Johnson (1918), on the other hand, suggested that the "ore body ..... is a linked system of

1/ Bureau of Mines data is published in accordance with an agreement with the Alaska Division of Mines and Minerals providing for cooperation and collaboration in certain investigations of mineral resources within the State of Alaska.

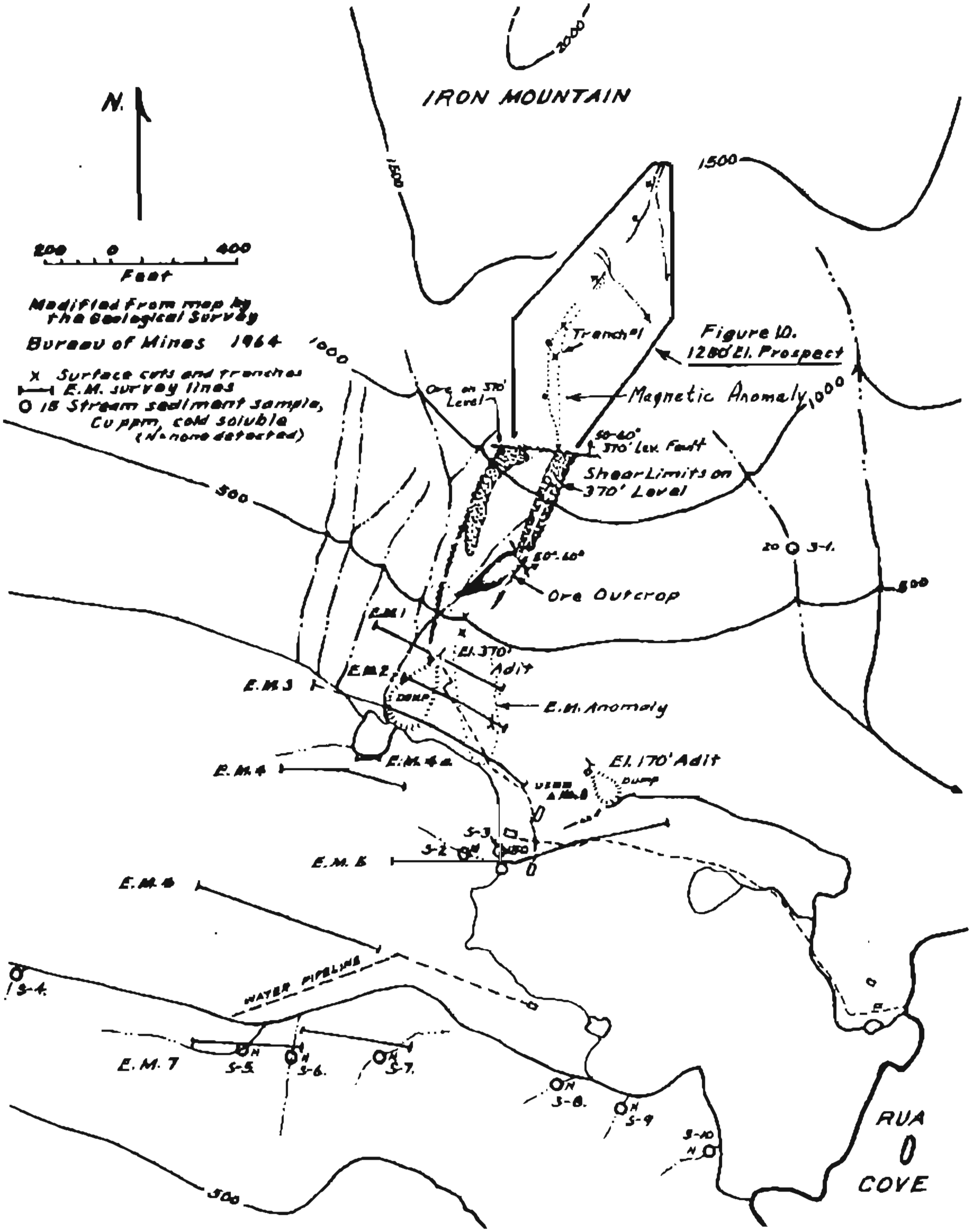


Figure 9. Copper Bullion mine, Rua Cove, showing electro-magnetic and magnetic anomalies detected by U.S. Bureau of Mines in 1964.

mineralized shear zones inclosing large horses of unsheared, unmineralized country rock".

Ore reserves, calculated by Stefansson and Moxham (1946), are 1,125,000 tons of indicated ore and 260,000 tons of inferred ore with a minimum grade of 1.25% copper. These figures are conservative and do not include any ore below the level of the drill holes. Also, several million tons of material with a grade between 0.6% and 1.25% copper are present in the known ore bodies.

In August 1964, a Bureau of Mines field party 2/ visited the Copper Bullion property to study the application of magnetic and electromagnetic surveys as guides to further development of the massive sulfide deposits. Test surveys over known ore bodies gave positive results by both methods and prompted a brief investigation of the possibility of using such surveys to trace extensions or to detect other deposits in the shear zone both north and south of the mine area (figure 9). The magnetic traverses were run with a hand-held flux-gate magnetometer having a sensitivity of 10 gammas per scale division, and the electromagnetic (E.M.) studies were made with induction equipment of the slingram type.

A massive sulfide body, at least 300 feet long and as much as 40 feet wide, is indicated by the magnetic traverses at an elevation of between 1150 and 1300 feet north of the known ore bodies (figure 10). Wallace McGregor of Salt Lake City, Utah, who presently controls the property, cleaned out the old trenches and prepared the topographic and geologic base map for figure 10. Sampling of two trenches cut across the strike of the shear zone shows 40 feet of 1.37% copper in trench No. 1 and 22 feet of 1.35% copper in trench No. 2.

An electromagnetic anomaly was outlined beginning 25 to 170 feet east of the 370 foot elevation adit portal and extending southerly 300 feet to line E.M. 3 (figure 9). The area of highest readings lies about 300 feet from the portal on a bearing of S35°E. The east edge of this anomaly lies approximately along the upward projection of the east edge of a body of greenstone containing disseminated sulfides that is exposed in the 170 foot elevation adit. The dump of a small, caved adit in this area, which is not shown on any available maps, is composed of greenstone, breccia, and gossan. The anomaly area is overgrown with brush and trees and covered by talus. Magnetic intensities along the E.M. lines are generally low. A magnetic high of up to 200 gammas lies from 65 to 90 feet west of the portal on line E.M.-1. A small 300 gamma high near the portal of the caved adit on line E.M.-2 may be due to buried metallic objects. No electromagnetic conductors were found along lines E.M. 4, 5, 6, or 7.

2/ Under the leadership of Tom L. Pittman, Supervising Physical Scientist, Bureau of Mines, Area VIII Mineral Resource Office, Juneau, Alaska.

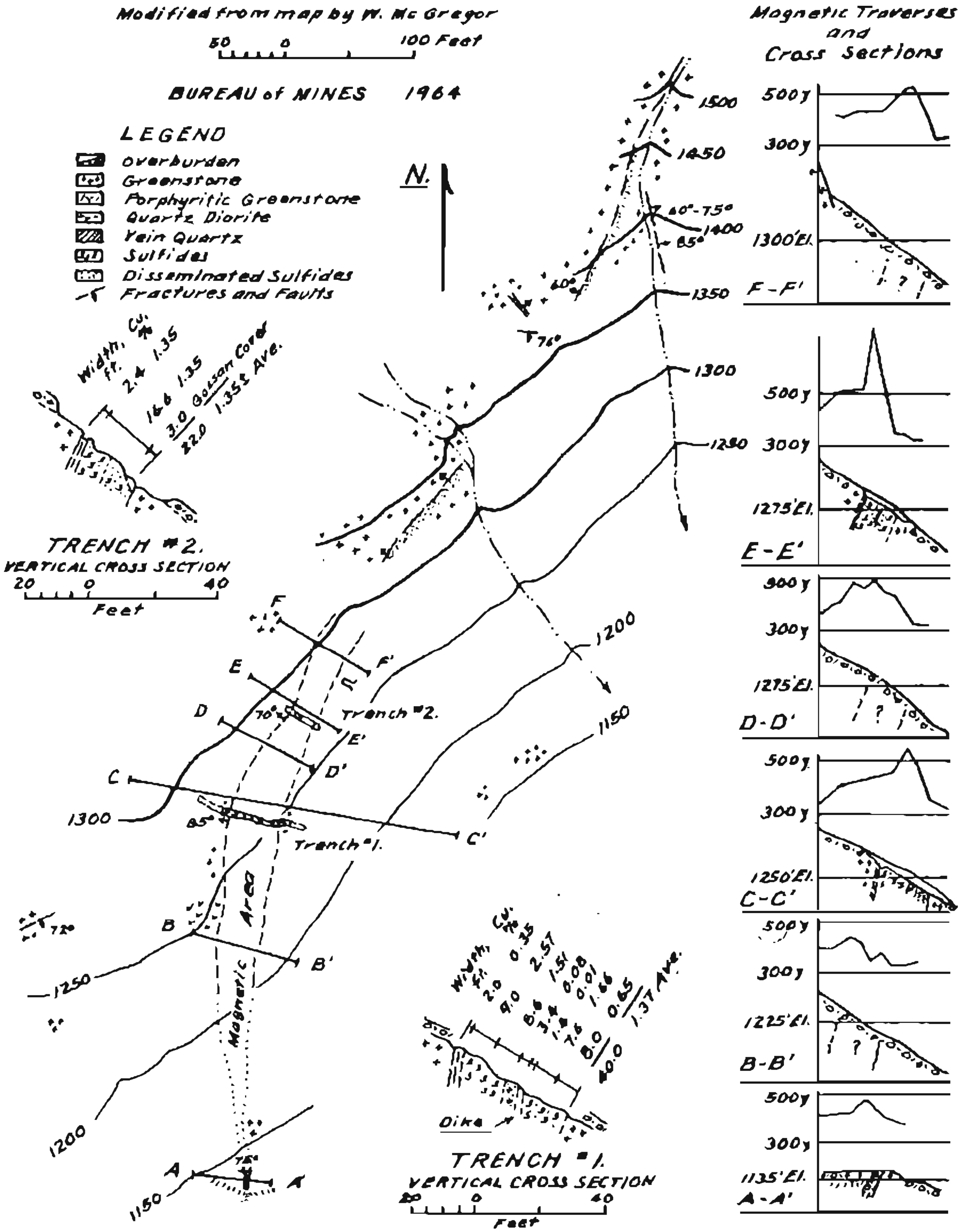


Figure 10. Detailed map of magnetic anomaly (1250' el. prospect) in Copper Bullion mine area, showing magnetic profiles and results of trench samples.

Locality 12

This deposit, in a small inlet on the north side of the Bay of Isles, is the only occurrence observed in the map area that does not appear to be associated with a prominent shear zone. The deposit has been explored by a 30-foot adit heading N20°W from a portal a few feet above sea level.

The deposit consists of pyrrhotite with minor chalcopyrite disseminated through a magnetite-bearing coarse-grained gabbro intrusive. The gabbro mass is about 30 feet thick and trends roughly N20°E. Country rock is fine- to medium-grained massive greenstone. The patches of sulfide minerals appear to be generally less than 1/2 inch in diameter, although some larger masses were observed in gabbro fragments on the mine dump.

Locality 13

Disseminated pyrrhotite and minor chalcopyrite are present in a band of black slate on the west side of South Arm, Bay of Isles. The sulfide minerals are concentrated in the slate where it wraps around the nose of a boudin-like inclusion of massive gray chert (figure 8). The deposit does not appear to have any economic significance; however, it is an excellent example of the structural control of these synkinematic deposits.

Locality 14

Lenses of massive pyrite with minor pyrrhotite as much as 2 inches thick and veinlets of pyrite, quartz, and epidote occur in a small iron-stained area at an elevation of about 1750 feet in the Jonesy shear zone. The principal host rock is a semischistose greenstone, apparently enclosed in a band of chlorite and quartz-chlorite schist. The sulfide lenses, 1 inch wide, are conformable with the schistosity (N-S, 74°E), whereas the veinlets are very irregular and crosscut the schistosity.

Locality 15

Another small pyrite-bearing area crops out at an elevation of 1600 feet one mile northwest of Port Audrey on the extreme east side of the Johnson Bay shear zone. The pyrite occurs with quartz, epidote, and very minor chalcopyrite in lenses and veinlets apparently restricted to a narrow-band of strongly schistose greenstone enclosed in less schistose greenstone (figure 8). The foliation attitude in the two rock types is not conformable. In the schistose country rock the foliation is N10°E, 65E, whereas in the sulfide-bearing band the foliation has the appearance of cross shears with a N-S strike and a vertical dip.

Copper Coin prospect

This prospect on the southeast side of Drier Bay between Barnes Cove and Mallard Bay was not found during the present study. It has been

TABLE 2

Mines and Prospects
Central Knight Island

Name of mine or prospect	Locality	Shear Zone	Feet of underground workings
Monarch prospect	1	Monarch	320 1/
unknown	2	Monarch	surface work only
Jonesy mine	3	Jonesy	410
Nellie prospect	4	Nellie	35 1/
20th Century prospect	5	Nellie	90
Barnes Cove prospect	6	Nellie	25
Pandora mine	7	South Arm	360 2/
Knights Island Alaska Copper Co. mine	8	South Arm	955
unknown	9	Marsha Bay	surface work only
unknown	10	Marsha Bay	surface work only
Copper Bullion mine	11		2850 3/
unknown	12	None	30

Other unprospected areas of sulfide mineralization

	13	South Arm	
	14	Jonesy	
	15	Johnson Bay(?)	
Copper Coin prospect	not found during present study	Port Audrey(?)	60 1/

1/ Moffit, F.H., and Fellows, R.E., 1950, Copper deposits of the Prince William Sound district, Alaska: U.S. Geological Survey Bulletin 963-B.

2/ Johnson, B.L., 1918, Copper deposits of the Latouche and Knight Island districts, Prince William Sound, in Mineral Resources of Alaska, 1916: U.S. Geological Survey Bulletin 662, p. 193-220.

3/ Stefansson, K., and Moxham, R.M., 1946, Copper Bullion Claims, Rua Cove, Knight Island, Alaska: U.S. Geological Survey Bulletin 947-E.

described by Grant and Higgins (1910), Johnson (1918) and Moffit and Fellows (1950) who remark that in 1943 all buildings and surface facilities had disappeared. The property was explored by 60 feet of adit and crosscuts at an elevation of 550 feet and several other openings at lower elevations.

From the descriptions by the earlier investigators it is possible that the prospect is in the Port Audrey zone. Host rock is a sheared greenstone striking N10°W and dipping 70°E. Lenses of massive pyrrhotite, chalcopyrite, and cubanite, as much as 12 inches thick, were encountered in the workings.

GEOCHEMICAL STUDIES

Stream sediment sampling for trace heavy metal analysis was undertaken during the 1964 field season in the Bay of Isles-Marsha Bay area. A total of 33 samples, representing all streams in the area, were collected. The samples were tested in the field for cold extractable metals using the University of Alaska method (Mukherjee and Mark Anthony, 1957) and in the laboratory for total copper, zinc, and lead by the pyrosulfate fusion technique.

The quantitative laboratory data are listed in Table 3 and are also shown on the geochemical map in figure 11. No field test data are given as all results were negative. Threshold values (upper background limit) for the three elements are considered to be: copper, 90 ppm; zinc, 80 ppm; and lead, 30 ppm.

Most of the detected anomalies are on streams draining or flowing across terrain underlain by major shear zones. However, not all streams in shear zone areas were anomalous. The strongest anomaly (sample 102) with 500 ppm copper is on the large stream draining into South Arm. This stream flows across the South Arm shear zone in the immediate vicinity of the Pandora mine about 3/4 of a mile above the sample site. Copper-zinc anomalies occur in three streams on the north shore of the Bay of Isles (samples 121, 122, 123) which apparently drain the Jonesy shear zone beyond the map area. In Marsha Bay both streams (samples 127 and 131) which follow the course of the Marsha Bay shear zone are slightly enriched in zinc.

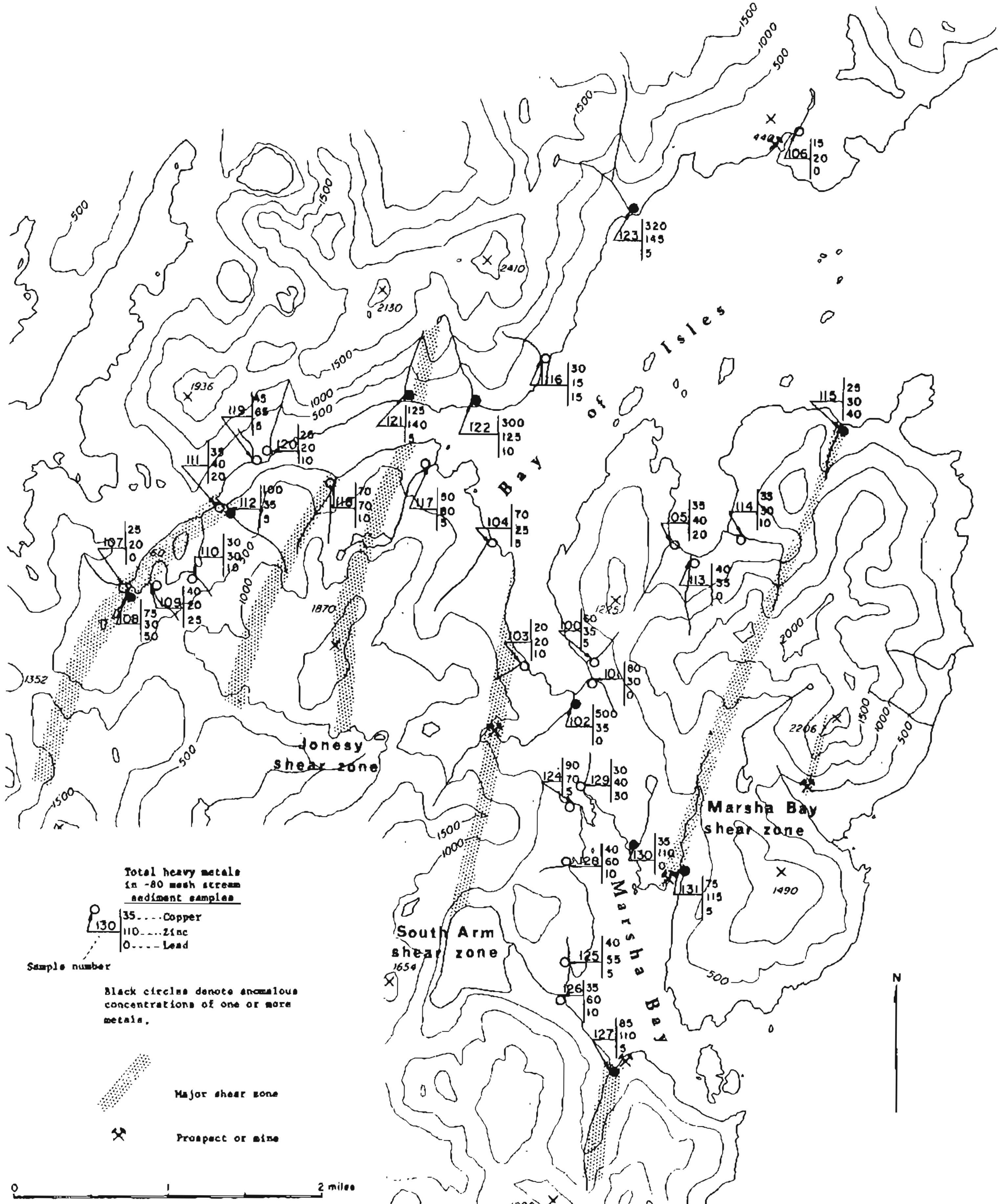
Based entirely on a comparison between the one strong anomaly whose source is known (sample 102) and the lesser anomalies whose source is unknown, it does not appear that any of the anomalies are significant. However, it does seem advisable to investigate further the northern extension of the Jonesy shear zone, the apparent source of anomalous samples 121, 122, and 123.

TABLE 3

Concentration of copper, zinc, and lead in stream sediment samples from Bay of Isles-Marsha Bay area

Sample No.	ppm Copper	Zinc	Lead
100	60	35	5
101	80	30	0
102	500	35	0
103	20	20	10
104	70	25	5
105	35	40	20
106	15	20	0
107	25	20	0
108	75	30	50
109	40	20	25
110	30	30	10
111	35	40	20
112	100	35	5
113	40	35	0
114	35	30	10
115	25	30	40
116	30	15	15
117	50	80	5
118	70	70	10
119	45	65	5
120	25	20	10
121	125	120	5
122	300	125	10
123	320	145	5
124	90	70	5
125	40	55	5
126	35	60	10
127	85	110	5
128	40	60	10
129	30	40	30
130	35	110	0
131	75	115	5
132	85	120	10

Analyst: A. Gooch, State Division of Mines and Minerals, Ketchikan, Alaska.



GEOCHEMICAL MAP OF THE BAY OF ISLES-MARSHA BAY AREA

Figure 11

SUMMARY AND CONCLUSIONS

Knight Island, in Prince William Sound, is underlain by a thick assemblage of basaltic to andesitic volcanic flows and tuffs with minor interbedded clastic sediments of probable Late Cretaceous age. Massive to semischistose volcanics, the predominant rock type throughout the central part of the island, were probably deposited on the exposed summits and flanks of active volcanoes in the Chugach Mountains geosyncline. Pillow volcanics, the submarine equivalents of the massive volcanics crop out on both sides of the island. Thin bands of slate with subordinate graywacke and chert occur interbedded with both volcanic types but are not commonly associated with the submarine rocks. Thin dikes of basalt and andesite occur throughout the island. Less abundant are larger, coarse-grained sill-like intrusive bodies ranging in composition from diorite to gabbro. Low grade regional metamorphism of the greenschist facies has affected all the rocks in the area.

The rocks are steeply to isoclinally folded parallel to the regional NNE structure. Moreover, the bedding, schistosity, slaty cleavage, and axial fold planes are all virtually parallel except at the noses of folds. Drag folds and other minor structures suggest that the crest of a large and complex anticline coincides with the linear belt of massive subaerial volcanics exposed in the core of the island.

A number of shear zones or zones of strong schistosity are present in the massive and pillow greenstones. These zones, which also trend parallel the fold axis, are upwards of 1000 feet wide and tens of miles long. Where slate bands are common, the shear zones are difficult to recognize as evidently all deformational stress has been relieved by movement within the slate. The rocks within the shear zones are predominantly chlorite and chlorite-quartz schists.

Deposits of massive sulfides (pyrrhotite, chalcopyrite, and cubanite) in the form of discontinuous pods, lenses, and irregular dissemination, with only one known exception, are localized in the shear zones. These sulfides were apparently deposited in the shear zones by metamorphic solutions where local conditions produced areas of reduced pressure. The source of the metal elements and sulfur is believed to be the volcanic country rock. Mineralization evidently occurred concurrently with the folding, shearing and metamorphism. Late uneconomic veins and veinlets of pyrite, quartz, and epidote with minor sphalerite and occasional chalcopyrite are present, both within and outside the shear zones.

Although the map area and probably most of Knight Island has been heavily prospected, the possibility of discovering massive sulfide deposits at least as large as the Copper Bullion deposit appear good. A case in point is the recent exploration by the U.S. Bureau of Mines, which disclosed the possibility of two additional massive sulfide bodies in the vicinity of the Copper Bullion mine.

Specific recommendations for exploration on Knight Island are:

1. Trace and prospect the Port Audrey, Jonesy, Nellie, and South Arm shear zones into the rugged alpine country south of the map area.

2. Trace and prospect the Jonesy shear zone, and other shear zones, if found, north of the map area into the area drained by the geochemically anomalous streams 121, 122, and 123.

3. Magnetic and electro-magnetic geophysical exploration should be conducted over the known major shear zones. At a minimum, it appears that geophysical exploration of this type would be highly desirable along the shear zones in areas of known sulfide mineralization.

4. A stream drainage geochemical survey, utilizing hot extraction techniques (laboratory analyses), may be helpful in delineating zones of anomalous metal concentration and guiding exploration.

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