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MAGNETITE DEPOSITS AT TUXEDNI BAY, ALASKA

by

Arthur Grantz

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ILLUSTRATIONS

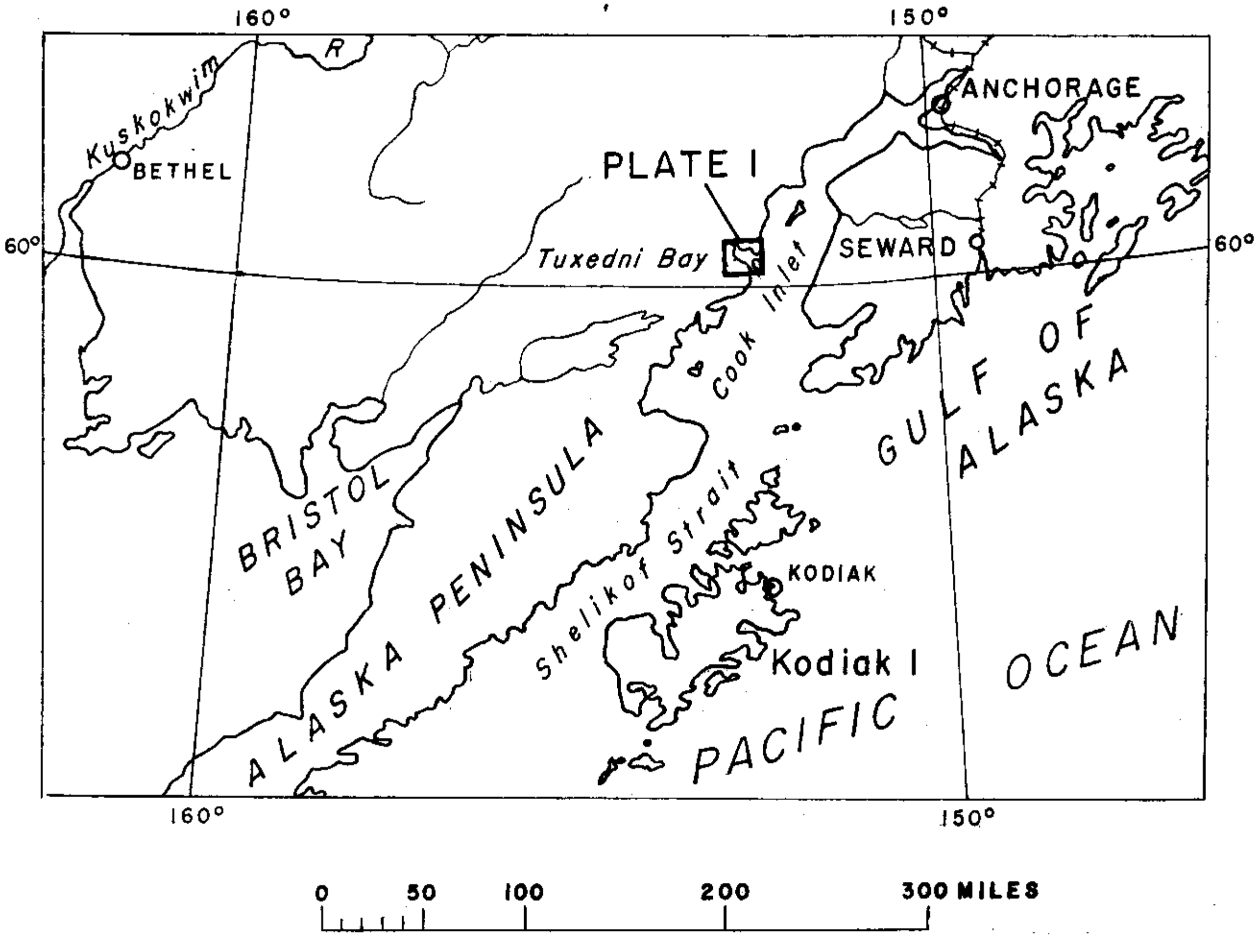

Figure I: Index map of southwestern Alaska, showing location of area studied.

MAGNETITE DEPOSITS AT TUXEDNI BAY, ALASKA

By Arthur Grantz

ABSTRACT

The magnetite deposits on an island in Tuxedni Bay occur in contact-metamorphosed volcanic and sedimentary rocks near their contact with a quartz diorite batholith which underlies large areas of the adjacent Aleutian Range. The deposits are pyrometasomatic in origin and are localized along northeast-trending fractures. The eastern deposit is a low-grade disseminated deposit occurring in hornfels. The western deposit occurs as a massive lens of magnetite and garnet with a marble hanging wall and a hornfels footwall. The tenor of mineral rock in the western deposit may average 75 percent of magnetite. The deposit is lenticular and can be followed along strike for 55 feet in outcrop and, where concealed beneath a cover of soil and vegetation, can be followed for an additional 55 feet with a dip needle. Where exposed in a sea cliff the deposit is 30 to 35 feet thick.

INTRODUCTION

Tuxedni Bay is on the west side of Cook Inlet about 120 miles southwest of Anchorage, Alaska. (See fig. 1.) The bay is very shallow except for Tuxedni Channel, which separates Chisik Island from the mainland. Tuxedni Channel is a secure anchorage. The area is rugged and slopes are generally steep. Mount Iliamna (10,016 feet in altitude) and Mount Redoubt (10,197 feet in altitude) are both within 15 miles of Tuxedni Bay. The area is covered with very heavy brush up to an altitude of about 2000 feet. Spruce timber may be found along the shores of Cook Inlet from Chinitna Bay to Johnson River and from Tuxedni Bay north, but occurs mainly below 750 feet.

The magnetite deposits, which are located near the head of Tuxedni Bay, may be reached by means of small boat and small seaplane. However, approach should ordinarily be attempted only at high tide and under favorable weather conditions. Most of Tuxedni Bay is dry at low tide and even at high tide most of the bay is shoal. Swift tidal currents and changeable winds necessitate caution in either landing at the head of Tuxedni Bay by seaplane or in visiting the area by small boat.

The field investigation upon which this report is based was made from September 8 through September 10, 1951. Its purpose was to determine the nature and possible extent of a reported magnetite deposit at Tuxedni Bay. (See Martin, 1920, p. 35;Brooks, 1921, p. 42; Moffit, 1927, pp. 55-56 and pl. 4). Mapping of the island upon which the previously reported western deposit is located revealed the presence of the eastern deposit. The first day was devoted to mapping the shoreline of the island upon which the magnetite deposits occur, the second day to mapping and sampling the western deposit, and the third day to examining the eastern deposit and tracing the extent of the western deposit with a dip needle. The interior portion of the island was not mapped, and except in the sea cliffs, no outcrops were noted in the vicinity of the western magnetite deposit.

The present investigation was made while the writer was engaged in a larger project of mapping the marine sedimentary rocks of Jurassic age in the vicinity of Iniskin, Chinitna, and Tuxedni Bays. The writer was very capably assisted in the field by R. Werner Juhle.

GEOLOGY

The geology of the area adjacent to the upper part of Tuxedni Bay has been described by Juhle (U. S. Geol. Survey open-file preliminary report in preparation) and is shown in part on plate 1. The following geologic description of the Tuxedni Bay area is in large part abstracted from his report.

The rocks underlying the Tuxedni Bay area are predominantly of Mesozoic age. Sedimentary rocks of Late Triassic age are the oldest that have been recognized in the area. They are overlain by volcanic rocks of Early Jurassic age and these in turn by marine sedimentary rocks of Middle and Late Jurassic age. Continental sedimentary rocks of early Tertiary age and volcanic rocks of later Tertiary and probably Quaternary age overlie the Mesozoic rocks both to the north and to the south of Tuxedni Bay. Tertiary rocks are not shown on plate 1 as their extent in the map area is small and as they do not crop out within 5 miles of the magnetite deposits.

Quartz diorite and granophyric quartz monzonite, probably of Middle Jurassic age, intruded the Lower Jurassic and older rocks. Hornfels, marble, and locally tactite were formed near the borders of the intrusives. Possibly excepting the very earliest beds, the Middle Jurassic and younger bedded rocks have not been intruded by granitic rocks. Where the sedimentary rocks of Middle Jurassic or younger age have been intruded by mafic dikes, they are baked only immediately adjacent to the dike borders.

Bedded rocks.--Argillite, limestone, and interbedded andesitic lava flows, probably of Late Triassic age, crop out at the head of Tuxedni Bay. The base of the Upper Triassic section has not been recognized and its position may now be occupied by the quartz diorite of the adjacent Aleutian Range.

The Upper Triassic rocks grade conformably upward into volcanic rocks of probable Early Jurassic age. The contact between the two series of rocks has been arbitrarily placed at the base of the first thick tuff bed above the argillite beds. The lower part of the Lower Jurassic volcanic sequence consists chiefly of andesitic breccias and flows but contains some interbedded argillite. The upper part of the Lower Jurassic volcanic sequence is composed primarily of water-laid rocks of pyroclastic origin and tuffaceous marine sedimentary rocks. Overlying the Lower Jurassic volcanic rocks with apparent conformity are fossiliferous marine sedimentary rocks of Middle and Late Jurassic age. Siltstone predominates, but many thick units of graywacke sandstone and arkosic sandstone and some thick beds of conglomerate occur.

Continental sedimentary rocks of early Tertiary age overlie the Upper Jurassic marine sedimentary rocks with low angular unconformity. These rocks are exposed along the northwest shore of Cook Inlet both north and south of Tuxedni Bay.

Between Chinitna and Tuxedni Bays and north of Tuxedni Bay, mafic flows and associated pyroclastic rocks in many places overlie the truncated surfaces of the folded and faulted Triassic and Jurassic rocks. Both basaltic andesite of middle or late Tertiary age and extensive andesitic flows and breccias of late Tertiary or Quaternary age were reported by Juhle. The basaltic andesite crops out in limited areas immediately west of Squarehead Cove on the north shore of Tuxedni Bay and 2¼ miles west of Fossil Point on the south shore of Tuxedni Bay. Both Mount Iliamna, which lies between Chinitna and Tuxedni Bays, and Mount Redoubt, which lies north of Tuxedni Bay, are volcanoes which have been active in historic times (Coats, 1952, p. 38 and table 2).

Intrusive rocks.--The bedded rocks have been intruded by the biotite hornblende quartz diorite batholith of the Aleutian Range. This intrusive was emplaced during Middle or early Late Jurassic time, and possibly as early as early Middle Jurassic time. Dikes and stocks of pink granophyric quartz monzonite have injected both the quartz diorite and the bedded rocks near the borders of the quartz diorite. The monzonite was injected after most of the quartz diorite had solidified and may have been a late differentiate of the quartz diorite magma.

Mafic dikes, sills, and pipes intrude the Upper Jurassic and older rocks at many places in the Tuxedni Bay area. Except dikes that can be related to the diorite and monzonite intrusives, and the lamprophyre dikes that occur within these intrusives, only the dikes and pipes related to the flows of Mount Iliamna and vicinity can be dated even approximately at this time. It is probable that many of the mafic dikes and sills are related to the basaltic andesite flows of middle or late Tertiary age or to the andesitic flows and breccias of late Tertiary or Quarternary age. Dikes related to the volcanic activity of Late Triassic and Early Jurassic times may be present, but have not been identified. Where mafic dikes or sills have intruded marine sedimentary rocks, contact metamorphism has been limited to baking of the immediately adjacent country rock.

Structure.--Most fold axes and major fractures in the bedded rocks strike within 10° of N. 35° E. in conformity with the regional strike of the eastern border of the quartz diorite batholith. This structural trend is also present in the vicinity of the magnetite deposits, both of which strike from N. 35° E. to N. 45° E. and are parallel to the predominant strike of the bedding, fractures, dikes, and replacement zones in the marble and volcanic host rocks.

MAGNETITE DEPOSITS

Two deposits of magnetite are exposed on a small island of metamorphosed volcanic rock in the tidal marsh at the north shore of Tuxedni Bay. The island is about 9¼ miles N. 60° to 65° W. of the northern tip of Chisik Island. (See pls. 1 and 2A). The eastern deposit, magnetite disseminated in hornfels, is exposed almost down to marsh level in the hillside on the northern shore of the island. The western deposit, a massive lens of magnetite and garnet with a marble hanging wall and a hornfels footwall, is exposed in a sea cliff at the extreme western end of the island.

The western deposit was staked, and samples taken, at least as early as the summer of 1916. However, the only development of this deposit still apparent in 1951 was a crude tunnel about 5 feet wide and 3 to 5 feet high which had been driven about 13 feet beyond the end of a sea cave. No development of the eastern deposit was noted.

The deposit referred to in previous reports on the magnetite at Tuxedni Bay (Martin, 1920, p. 35; Brooks, 1921, p. 42; Moffit, 1927, pp. 55-56 and pl. 4) is the western deposit of this report. Although the location of the magnetite deposit as shown by Moffit (1927, plate 4) is not identical with the location given in this report, the two descriptions are believed to refer to the same deposit. The deposit was not visited by Moffit but was described to him by Mr. Roy A. Trachsel of Anchorage, Alaska, the owner of the deposit at that time.

Geology near the magnetite deposits.--Contact metamorphism has altered the rocks in the vicinity of the magnetite deposits to hornfels (pl. 2A). Tactite, however, seems to have formed only locally, and sizeable bodies of skarn were found at only two places. The metamorphism is evidently related to the nearby quartz diorite batholith. The outcrop pattern of the quartz diorite indicates that the top of the batholith is near the surface in the vicinity of the magnetite deposits.

Although the original nature of the rocks has been obscured by metamorphism, most of the strata on the island are believed to be of volcanic origin. However, in a northeast-trending zone which lies roughly between the two deposits, some argillite may be interbedded with the volcanic rocks. Juhle (op. cit., pl. 1) shows an inferred contact between Upper Triassic sedimentary rocks to the west and Lower Jurassic volcanic rocks to the east that strikes approximately N. 30° W. across the island from a point near the disseminated magnetite deposit.

Adjacent to the massive magnetite deposit is a small area of white medium-grained marble which has been completely recrystallized by contact metamorphism. The recrystallized grains range from 2 to 6 millimeters in diameter, but streaks of very coarse marble contain grains as much as 2.5 centimeters in diameter. Magmatic additions to the marble consist chiefly of a few massive dikes of garnet rock and a few small veinlets of magnetite. However, streaks of well-disseminated small garnet crystals and of fine-grained magnetite occur in the marble in a few places. Juhle (op. cit., p. 45) reports idocrase to be present in the marble.

Western deposit.--The western deposit is in a skarn zone consisting of a massive lens of high-grade magnetite and much massive garnet rock. Exposures are limited to a high sea cliff, to two sea caves cut into the sea cliff, and to a short tunnel driven beyond the end of the southern sea cave. There are no surface exposures back from the sea cliff in the vicinity of the deposit.

The garnet-magnetite body is irregular in shape. It strikes approximately N. 40° E., and the dip averages about 40° SE. It is about 30 to 35 feet thick and is exposed in the sea cliff for about 55 feet in the dip direction. The deposit may be followed for 55 feet along the strike in the sea caves and the short tunnel driven beyond the end of the southernmost sea cave. A reconnaissance dip needle traverse indicated that magnetic anomalies caused by the presence of the magnetite end about 110 feet back from the cliff face. The contact of the deposit with the marble hanging wall is sharply defined. Very little disseminated magnetite or garnet occurs in the marble. The contact of the deposit with the hornfels footwall is less well defined and in places the hornfels has been garnetized. Contacts between the garnet rock and the magnetite, although gradational in places, are locally well defined. A dike of garnet cuts the massive magnetite with sharp contacts.

The attitude of the deposit is similar to the attitude of most of the fractures and bedding in the area, and to the attitude of the eastern deposit. The juxtaposition of marble in the hanging wall with hornfels of probable volcanic origin in the footwall on opposite sides of a lenticular skarn zone having an attitude similar to the attitude of most of the fractures and bedding in the area is suggestive of a pre-mineral fault contact. However, no direct evidence for pre-mineral faulting was noted, and the possible fault zone, where exposed, has been entirely replaced by skarn. Evidence for post-mineral movement in the marble is afforded by a very thin vein of magnetite which occurs in the marble about 50 feet south of the western deposit. This vein has been broken and the pieces rotated, the marble having flowed around the rotated pieces.

The western deposit may thus have formed along a fault between the marble and the hornfels. The presence of the marble may have caused deposition of massive magnetite in the western deposit whereas only disseminated magnetite formed in the eastern deposit, which is entirely in hornfels.

Magnetite is the only ore mineral, although traces of pyrite and probably chalcopyrite are present locally. No other sulfides were noted, and chemical analyses of samples taken from the deposit show the sulfur content to be low. Copper and gold are either absent or present only in traces.

The chief gangue mineral is garnet. Other silicate minerals, typically associated with contact-metamorphic deposits, are present but were not specifically identified. The garnet occurs as a minor constituent in the massive magnetite lens and as a massive dike cutting the lens. Large masses of garnet rock lie adjacent to the areas of massive magnetite (pl. 2B), and locally these contain as much as 50 percent of disseminated magnetite. In other places, however, the garnet rock adjacent to the massive magnetite contains only traces of other silicates or magnetite. An irregular mass of garnet rock lies in the marble hanging wall immediately adjacent to the massive magnetite lens. Where associated with the magnetite, the garnet is grayish to moderate yellowish green and contains between 70 and 90 percent of the andradite molecule (the calcium-iron garnet). Where associated with limestone, the garnet tends to be grayish or yellowish brown and contains between 60 and 70 percent of the andradite molecule. The balance of both varieties of garnet is composed of the grossularite molecule (the calcium-aluminum garnet) and probably several percent of the almandite molecule (the iron-aluminum garnet). A rough check by qualitative chemical tests indicated that some of the manganese in the magnetite deposits (table on p. 16) occurs in the associated garnet.

No channel samples were taken, but spot samples representative of high-, medium-, and low-grade portions of the massive magnetite lens of the western deposit were collected during the present investigation for assay and chemical analysis. (See tables on p.16 and p.18). Samples of this deposit had also been privately submitted for assay and chemical analysis in 1916 and during the winter of 1920-1921. Results of the latter analyses and a description of the deposit were furnished the Geological Survey by Mr. Roy A. Trachsel of Anchorage, owner of the deposit, and were published by Moffit in 1927. These analyses are also included in the table on page 16. All the analyzed samples from the western magnetite deposit contain 50 percent or more of iron as metal. However, for iron ore, all samples contain an undesirable amount of sulfur, and four contain an undesirable amount of phosphorous. The highest phosphorous content and the highest sulfur content are in the same sample.

<u>Eastern deposit</u>.--This deposit consists of a skarn zone formed in hornfels that was probably derived from volcanic rocks. The mineralization occurred in two parallel zones. The upper zone is about 30 feet thick and is separated from a lower zone by 20 feet of country rock. The lower zone is at least 10 feet thick, but its base is not exposed. The strike length of the deposit is not known. Exposures occur only in a limited area near the shore of the island. To the northeast the deposit is covered by tidal marsh and to the southwest by soil and heavy vegetation. The mineralized zones strike approximately N. 35° to 45° E. and dip approximately 45° SE. Bedding and fractures in the vicinity of the deposit have similar trends, and may have controlled the locus of mineralization.

The magnetite in the eastern deposit is disseminated and is associated with a greater variety of contact-metamorphic minerals than are present in the massive magnetite deposit. Garnet is most abundant, and epidote, diopside, chlorite, plagioclase, and other silicates are present. No sulfides were noted. The upper zone of magnetite mineralization is of higher grade than the exposed upper 10 feet of the lower zone. An analysis of the richest sample obtained from the upper zone of the deposit contained 25.8 percent of iron and 0.01 percent of sulfur. However, the magnetite content of the deposit as a whole was estimated in the field to be of the order of 10 percent to 20 percent.

Origin of the deposits.--The association of magnetite with andradite-rich garnet, epidote, diopside, chlorite, plagioclase, and idocrase, and with a trace of iron and copper sulfides occurring in irregular replacement zones and lenses is characteristic of magnetite deposits of pyrometasomatic origin. A large quartz diorite batholith crops out within 1,000 feet of the deposits and probably underlies the deposits at no great depth. The quartz diorite has an iron content of about 6 percent_/ and the deposits are probably genetically related to it.

_/ _/ Juhle, op. cit. p. 57

The granophyric quartz monozonite, which also outcrops in the area, has an iron content of only about 0.73 percent._/

Tenor and reserves.—The field-estimated grade of the exposed parts of the eastern deposit is of the order of 10 to 20 percent of magnetite, although a selected, relatively high-grade sample from this deposit contained 25.8 percent of iron. Each reported analysis of the western deposit, however, shows over 50 percent of iron, with one analysis showing 67.8 percent of iron. Sulfur and phosphorous, which were shown by the analyses to be present in all the samples from the western deposit, occur in most of the samples in amounts which are undesirable in iron ore.

However, the total sulfur content in most samples was low. Samples from both deposits were assayed for copper, silver, and gold by the Geological Survey, but these metals were present only in traces or were absent. No sample of the deposit or of the adjacent country rock registered as much as twice background count on a portable field type Geiger counter. Massive garnet, as is found in the western deposit and elsewhere on the island, is not of the quality generally preferred for abrasive garnet.

The small outcrop area of marble, the presence of which may have controlled deposition of massive magnetite of minable grade, the probable presence of quartz diorite at no great depth, and the tendency for pyrometasomatic deposits to be irregular in shape and lenticular, would all have a bearing on an estimate of possible total reserves available in the western deposit. The depth of mud fill beneath the tidal marsh, which covers the western deposit beyond the sea cliff, and the slope of bedrock beneath the mud fill might determine how far the deposit extends to the southwest. Assuming an estimated grade of 75 percent magnetite for the mineral rock, the reserves of ore that may be inferred to be present in the western deposit above the level of the tidal marsh, and only within the limits of outcrop data, are only several thousand tons.

A reconnaissance examination of the shore of the peninsula that lies immediately east of the island failed to find evidence of mineralization other than sparsely disseminated pyrite. The area of argillite and limestone of Late Triassic age which occurs west of the island, across Tuxedni Bay, was briefly visited in 1951, but no evidence of mineralization was found. Juhle (op. cit.), who mapped the latter area, did not report any mineralized rocks.

Analyses of samples from the magnetite deposits at Tuxedni Bay, Alaska

	A	B	C	D	E	F
Loss on ignition..........	....	....	....	.11	....	....
SiO_2..........	11.4	7.3	1.4	4.34	2.80	37.4
Al_2O_3..........	1.9	1.8	.72	1.20	....	5.7
FeO..........	17.0	21.4	25.1	....	....	9.1
Fe_2O_3..........	53.2	58.8	67.8	....	....	26.7
Fe_3O_4..........	....	....	....	88.89	....	....
MgO..........	1.6	2.2	1.4	1.12	....	1.4
CaO..........	11.0	6.2	1.4	1.55	....	19.4
Na_2O..........	.14	.14	.15	....	....	.15
K_2O..........	.08	.08	.11	....	....	.08
TiO_2..........	.31	.42	.44	....	....	.38
P_2O_5..........	.64	.11	.02	....	....	.08
P..........	(.28) a/	(.05) a/	(.009) a/	.05	.064	(.035) a/
MnO..........	1.2	1.7	1.6	....	....	.40
Mn..........	(.9) b/	(1.3) b/	(1.2) b/	2.06	....	(.31) b/
Cr_2O_3..........	<.02	<.02	<.02	....	....	<.02
S..........	.98	.03	.20	.59	.11	.01
Fe..........	(50.4) c/	(57.7) c/	(66.[illegible]) c/	(64.27)	97.82	(25.8) c/
	99.47	100.2	100.35	99.91		100.82

a Calculated from P_2O_5. b Calculated from MnO. c Calculated from FeO and Fe_2O_3.

(Analyses of samples from the magnetite deposits at Tuxedni Bay, Alaska, continued.)

A. Representative sample of low-grade portions of the massive magnetite lens of the western magnetite deposit. Collected by Arthur Grantz. S. M. Berthold and E. A. Nygaard, analysts, U. S. Geological Survey.

B. Representative sample of medium-grade portions of the massive magnetite lens of the western magnetite deposit. Collected by Arthur Grantz. S. M. Berthold and E. A. Nygaard, analysts.

C. Representative sample of high-grade portions of the massive magnetite lens of the western magnetite deposit. Collected by Arthur Grantz. S. M. Berthold and E. A. Nygaard, analysts.

D. Sample probably from the massive magnetite lens of the western magnetite deposit. Described by F. H. Moffit, U. S. Geol. Survey Bull. 789, pp. 55-56, 1927. Analysis by Kansas City Testing Laboratory, Kansas City, Mo., October 14, 1920.

E. Sample probably from the massive magnetite lens of the western magnetite deposit. Described by F. H. Moffit, U. S. Geol. Survey Bull. 789, pp. 55-56, 1927. Analysis by Abbot A. Hanks, San Francisco, Calif., February 25, 1921.

F. Sample from the eastern magnetite deposit. Collected by Arthur Grantz. S. M. Berthold and E. A. Nygaard, analysts.

Assays of samples from the magnetite deposits at Tuxedni Bay, Alaska.

	A	B	C	D	E	F
Gold, ounces per ton	.....	.....	.....	none	.01	....
Silver, (p.p.m.)....	0	0	0	.....	trace	0
Copper, (p.p.m.)....	65	30	70	......	......	5
Copper, percent.....	.....	.....	.....	......	.40	....

A. Representative sample of low-grade portions of the massive magnetite lens of the western magnetite deposit. Collected by Arthur Grantz. Hy Almond, assayer, U. S. Geological Survey.

B. Representative sample of medium-grade portions of the massive magnetite lens of the western magnetite deposit. Collected by Arthur Grantz. Hy Almond, assayer.

C. Representative sample of high-grade portions of the massive magnetite lens of the western magnetite deposit. Collected by Arthur Grantz. Hy Almond, assayer.

D. Composite of eight samples from the massive magnetite lens of the western magnetite deposit. Collected by Arthur Grantz. Dwight L. Skinner, assayer, U. S. Geological Survey.

E. Sample probably from the massive magnetite lens of the western magnetite deposit. U. S. Geol. Survey Bull. 787, pp. 55-56, 1927. Assay by Bogardus Testing Laboratories, Seattle, Wash., July 25, 1916.

F. Sample from the eastern magnetite deposit. Collected by Arthur Grantz. Hy Almond, assayer.

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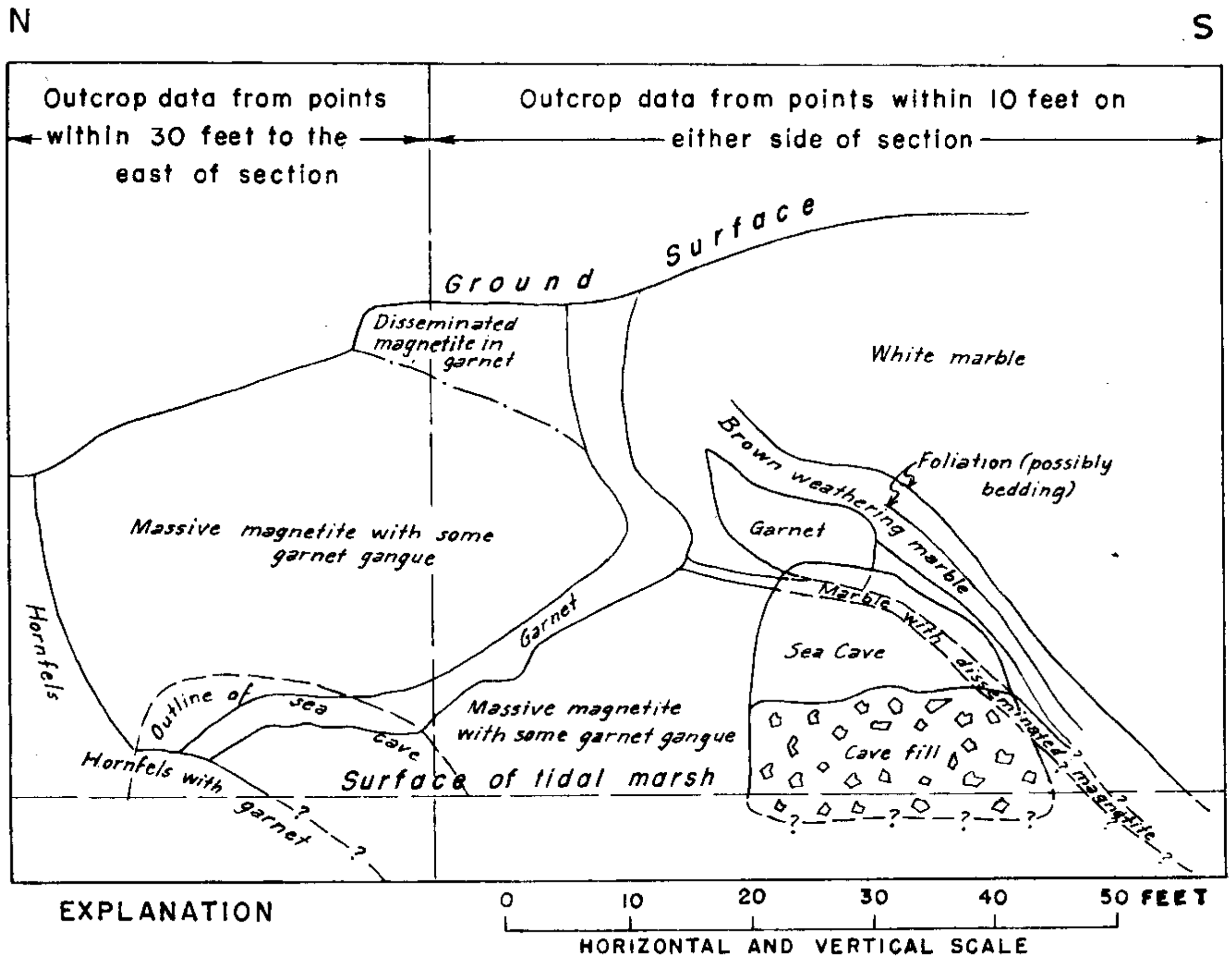
PLATE 2B



EXPLANATION

Gradational contact

Contact projected across sea cave

— — ? — — ? —

Contact projected beneath alluvium

Note: Section not normal to strike. Strike of section approximately N15W. Strike of deposit approximately N40E. Outcrop data projected at right angles to plane of section.

Geology by Arthur Grantz

GENERALIZED CROSS SECTION OF THE WESTERN MAGNETITE DEPOSIT. AS EXPOSED IN A NORTH - SOUTH TRENDING SEACLIFF

Location of the deposit is shown on Plate 2A.