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The geology of Bomi Hill, Liberia, Africa

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THE GEOLOGY OF BOMI HILL
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This Thesis, presented by Roland I. Erickson in partial fulfillment of the requirements for the Degree of Master of Science, is hereby approved by the Committee on Instruction in charge of his work.

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[redacted]

CONTENTS

BOMI HILL ORE BODY

1. LOCATION: BOMI HILL IS SITUATED ABOUT FIFTY MILES INLAND FROM MONROVIA, THE CAPITAL OF LIBERIA, AFRICA. BOMI HILL IS ABOUT 6°55' N. LATITUDE AND 10°55' W. LONGITUDE. THE BOAT HAUL FROM MONROVIA TO BALTIMORE, MARYLAND IS ABOUT 4000 MILES.

11. TOPOGRAPHY AND CLIMATE: FROM MONROVIA THE TOPOGRAPHY RISES GRADUALLY TO AN ELEVATION OF 300 FEET ABOVE SEA LEVEL AT THE FOOT HILL OF BOMI HILL WHICH HAS A CREST HEIGHT OF 800 FEET ABOVE SEA LEVEL. THE RAINY SEASON IS FROM JUNE THROUGH NOVEMBER. DURING THIS SIX MONTH PERIOD THE AVERAGE RAINFALL IS 240 INCHES; UP TO 2 INCHES OF RAIN HAS FALLEN IN A ONE HOUR PERIOD. THE TEMPERATURE DURING THIS PERIOD VARIES FROM 60 TO 85 DEGREES F. THE DRY SEASON OF DECEMBER TO JUNE HAS HIGH TEMPERATURES.

111. HISTORY AND OWNERSHIP: IN THE LATE 1930'S THE HOLLAND SYNDICATE HELD A PROSPECTING CONCESSION; THEY SURVEYED, MAPPED THE OUTCROPS AND DID SOME DIAMOND DRILLING AT BOMI HILL.

DURING WORLD WAR 11 COLONEL L. K. CHRISTIE, WHO WAS WITH THE U. S. ARMY IN LIBERIA, BECAME INTERESTED IN BOMI HILL. HE LATER FORMED THE LIBERIAN MINING COMPANY OF WHICH HE IS PRESIDENT. TO PROVIDE THE REQUIRED CAPITAL, PARTICIPATION WAS MADE WITH THE REPUBLIC STEEL CORPORATION WHO NOW HAS A 60% INTEREST IN THE LIBERIAN MINING COMPANY.

1V. GEOLOGY OF LIBERIA:

GENERAL: THE GEOLOGY OF LIBERIA HAS NOT BEEN THOROUGHLY MAPPED. VARIOUS PRIVATE COMPANIES HAVE EXAMINED CERTAIN REGIONS FROM AN ECONOMIC ASPECT BUT OF COURSE THOSE REPORTS ARE OF A CONFIDENTIAL NATURE. IN 1944 DRS.

W. H. Newhouse, T. P. Thayer and Mr. A. P. Butler Jr., mapped and studied the geology in a joint survey between the Liberian Government and the U.S.G.S. The Report of the Geological Mission to Liberia (11), was put on open file in 1945 and contains much general geologic information. The published literature on the Geology of Liberia is reviewed in (11: p.24-27). Most of the data are from references to Liberia in papers on adjoining regions. Liberia is considered as occupying the central part of a shield of ancient crystalline rocks of Precambrian age. The formations have been mapped on Sierra Leone and from the descriptions they appear the same as those existing in Western Liberia.

Rock Formations in Liberia: The oldest rocks are: A. Ancient schists, gneisses and gneissic granites, they have been intruded by massive granites, B. Iron bearing formations related to the old schist series, C. Volcanic rocks near the coast and, D. Diabase at Monrovia and other places in Western Liberia of late Precambrian or Paleozoic age.

General Structural Features: The rocks are intensely metamorphased on a regional scale: Ridges trend from East-West to North East. Of particular interest is the mature-land scape with low relief and deep soil. The relief from the coast to Bomi Hill is about 8 feet per mile, farther into the interior the rocks have resisted erosion and peaks and mountains up to an elevation of 4500 feet above sea level exist.

Iron Ore Deposits: "Geologic investigations in Liberia from 1944 to 1952 have revealed two distinct types of bedrock iron deposits: (a) low grade iron formation and (b) replacement bodies of medium to high-grade ore", (13). The iron formation, occurs in large masses several hundred feet

THICK AND CAP THE HIGHEST MOUNTAINS IN LIBERIA. IT CONSISTS OF LAMINATED OR LAYERED HEMATITE, MAGNETITE, QUARTZ AND OTHER SILICATES AND CONTAINS 30 TO 40 PERCENT FE.

THE KNOWN HIGH GRADE IRON ORE BODIES ARE ALL ASSOCIATED WITH FOLDS ALTHOUGH VARIOUS STEEPLY DIPPING HOMOCLINAL MASSES SHOW LOCAL HYDROTHERMAL ENRICHMENT. THE DEPOSIT AT BOMI HILL IS THE ONLY ONE INVESTIGATED BY DIAMOND DRILLING AND THE ONLY IRON ORE DEPOSIT IN PRODUCTION.

OTHER MINERAL DEPOSITS: OTHER MINERAL DEPOSITS ARE KNOWN TO EXIST, DIAMONDS, GOLD, BAUXITE AND CORUNDUM. DIAMONDS AND GOLD ARE EXPLOITED TO A LIMITED EXTENT.

V. GEOLOGY AT BOMI HILL

SHAPE OF THE ORE BODY: BOMI HILL IS A SOUTH PLUNGING SYNCLINE WHICH CONTAINS THE HIGH GRADE IRON ORE BODY THAT IS OVERLAIN BY OVERBURDEN CONSISTING OF SCHISTS AND AN IRON FORMATION OF MILLING GRADE WHICH IN TURN IS CAPPED BY "CANGA", PARTLY CEMENTED IRON-RICH SURFACE DEBRIS. MUCH OF THE FOOT WALL IS GNEISSIC GRANITE, BUT ON THE EAST END THE FOOT WALL IS MAGNETIC IRON FORMATION. THE SOUTH BOUNDARY OF THE ORE IS 5000 FEET LONG; THE GREATEST WIDTH IS 3000 FEET. TO THE WEST ARE TWO OTHER DEPOSITS: YUPI HILL AND WEST HILL, NEITHER OF THESE TWO HAVE BEEN DIAMOND CORE DRILLED. REFERENCE TO THE TOPOGRAPHIC MAP DRAWING NO. 1 , ENVELOPE, AND PHOTOGRAPH PLATES NOS. 15-16, PAGES 66-67, WILL SHOW THE GENERAL STRUCTURE. ORIGINALLY THE ORE BODY WAS DESCRIBED AS FIVE OREBODIES, HOWEVER, THE DIAMOND CORE DRILLING HAS SHOWN QUITE CONCLUSIVELY IT MAY BE CONSIDERED AS ONE ORE BODY; THE NO. 2 BEING A LENSE OFF NO. 3 AND NO. 3 JOINING NO. 1; NO. 4 AND NO. 5 BEING THE NORTH ANTICLIMAL PORTION OF ORE BODY NO. 1.

<u>Folding and Fracturing</u>: Folding predominated over fracturing as may be seen by the flow banding in the drill cores of both the iron formation and the high grade ore. This is additional evidence that metamorphism occurred under a heavy load. Contact fracturing also occurred on the west and central portion at the base of the iron formation where replacement started and in the eastern portion within the iron formation.

<u>Faulting</u>: No fault has definitely been mapped, however one is inferred. The writer when in Liberia in 1952 suspected a fault in the vicinity of coordinate 21200 E. Gillies (3) in an oral statement 1953 said he believed a fault to be present in that area. Previous mapping (11:P.58-60) cites possibilities of a fault in the region of ore body No. 3.

<u>The Rock Formations</u>: The deposit except at the outcrops has, prior to clearing for stripping operations, covered by "high bush." The surface rock formation over much of the area is Canga, a rock formed by tropical chemical weathering. Underneath the Canga and exposed in a part of the area is a banded iron formation, consisting of alternate bands of hematite and quartz or magnetite and quartz. Underneath the iron formation on the east end is high grade magnetite iron ore, or magnetite ore with silicates, the western two-thirds of the area has chlorite schist below the iron formation and above the high grade ore. Lenses of gneiss containing garnet, hornblende and pyrrhotite are present in some places between the schist and high grade ore. The high grade which is fine-grained to massive rests on a gray granitic gneiss which grades into a pink gneissic granite. On the east end the foot wall is magnetite iron formation overlying gneissic granite. Refernce to the detailed geologic

cross-sections, Drawings Nos. 3-17, pages 22-36, show the locations of the formations.

Canga: Canga occurs as a caprock over much of the iron formation. It is a hard porous limonite containing about 50% Fe and 10% silica.

Iron Formation: The iron formation is a distinctly banded rock of alternating iron oxide and quartz layers. The upper 100-200 feet is now weathered and soft. The fresh unaltered iron formation as seen in the diamond drill cores is hard and fine-grained to granular. Above the high grade ore the hematite facies seems to predominate. The hematite grains range from .02 to .2 mm in diameter; the quartz grains are .05 to 1 mm in diameter. In the magnetite facies the magnetite is granular to euhedral and the grain size is 0.01 to 2 mm in diameter.

This formation is a milling ore, and the upper iron formation contains approximately 50% Fe and 25% silica (2). A composite sample in 125 feet of tunnel at an elevation of 700 driven from North to South to the schist contact gave 54.53% Fe and 19.23% silica (12). The most reliable assay on the hard presently existing unaltered iron formation is (11) 43.77% Fe and 36.58% SiO_2.

The iron formation may be described as a highly metamorphosed recrystallized sedimentary rock, composed mainly of alternating bands, 1 to 2 mm thick, of iron oxides, hematite and magnetite, quartz, some albite, and a few small scattered crystals of pyrite.

The iron formation has incorrectly been referred to as Itabirite after the iron formation in Brazil which is specular hematite and quartz.

The hematite or magnetite formed first, and the quartz last as can be observed by the quartz between the broken magnetite crystals. See plate No. 5, page 47, for polished sections, and plates Nos. 6-9, pages 49-55, for thin sections.

High Grade Iron Ore: The milling grade ore is described above under Iron Formation. Two types of high grade ore exist, in the upper horizon a fine-grained ore and nearer the base a massive ore. It has as a gangue mineral anthophylitte and minor amounts of chlorite. The magnetite crystals range from 0.02 mm to 5 mm in diameter. The spaces between the coarse crystals are filled with smaller crystals of magnetite. See plates Nos. 1-4, pages 39-45, for polished sections, and plate No. 6, page 49, for thin sections of the ore. Assays from thirteen samples for total iron and assays from tube tests indicate that 80% of the ore is magnetite and 20% is hematit The ore assays 62% to 70% Fe, and certain portions of the ore body have silicated zones with a lower iron content. Occasional minute pyrite crystal are present in the ore, pyrite is not important as the assays show less than 0.03 percent sulphur.

The massive ore shows distinct layering.

Ore With Silicates: More than ten percent of the direct shipping ore has large amounts of silicates. This ore occurs above, below, or in zones within the massive ore. At the outcrops, weathering has caused leaching of the silicates and cavities are present.

Iron Silicates: On the east end of the deposit particularily, and in other places in smaller quantities are iron silicates with approximately 35% Fe and 43% insoluble silicates. These at places grade into the ore from the top, exist below the ore, and/or are within the high grade ore zones.

Gneiss: Much of the western two-thirds of the ore body rests on a gray granitic gneiss footwall which grades downward into pink gneissic granite. The minerals in this gneiss are magnetite, orthoclase, albite, microcline, biotite, muscovite, epidote, chlorite and serpentine. See X-sections A'-A, B'-B, L'-L, and J'-J on pages 28, 27, 32, 30.

Grading from the high grade facies of the green schist series and present on the margins of the high grade ore in places is a hornblende, biotite, garnet, gneiss with pyrrhotite and/or pyrite. The sulphides apparently have replaced the magnetite. The more basic constituents may have been derived from original volcanic sediments.

Schists: The schists are fine to medium-grained, green schists. The low grade facies are nearly all chlorite (1). Most specimens have minor amounts of accessory magnetite. Any of the following minerals may be present: magnetite, pyrite after magnetite, quartz, biotite, hornblende, cummingtonite, chlorite, epidote, and serpentine.

The iron formation grades into the schists, and at places lenses of schist occur within the iron formation. The low grade facies grade into high grade facies and gneiss at the upper ore margin.

Granitic Rocks: The granitic rocks consist of a coarse-grained, gray, biotite-granite-gneiss below the ores. This grades into a pink gneissic granite.

Origin of the Iron Formation

In this region in Africa during Pre-Cambrian time, volcanism was prolific and volcanic tuffs would necessarily accumulate and be deposited with the colloidal siliceous iron precipitate that consolidated to form a tuffaceous shale with distinct micro-banding. Gruner (5) concludes that the addition of volcanic tuffs at Bomi Hill is more than probable.

The iron formation now remaining at Bomi Hill is a metamorphic rock of the siliceous facies. It seems reasonable to postulate it was originally of the shaly facies (tuffaceous), and by metamorphism changed to the present siliceous facies, in the iron ore deposits. No doubt much of the iron in the original sediments was reconstituted and concentrated during metamorphism, to form the banded iron formation.

ORIGIN OF THE HIGH GRADE ORE

Processes of Metamorphism: The banded iron bearing sedimentary rock was probably under several thousands of feet of sediments when metamorphism began.

Folding: Tectonic activity produced the existing asymmetrical syncline that contains the ore body.

Replacement: During and after folding, replacement occurred. Gruner (4) states that original sedimentary rocks are easily altered and replaced: "Sedimentary rocks which have all these properties are volcanic tuffs and co-deposited siliceous iron carbonate; that is colloidal precipitates." The replacement was effected by hydrothermal solutions. During igneous activity abundant hydrothermal solutions were available as well as heat and it is concluded that most of the replacement was contemporaneous with the folding.

Gruner (4) presents the following chemical equations for the Vermilion rang which could be applicable for replacement at this deposit:

"A likely chemical equation for a part of the replacement of carbonate is probably the following:

$$4\ FeCO_3 + SiO_2 + H_2O \longrightarrow FeSiO_3 + Fe_3O_4 + H_2 + 4\ CO_2$$

Another one which would lead to jasper and hematite from original iron silicates is:

$$2\ FeSiO_3 + H_2O \longrightarrow 2\ SiO_2 + Fe_2O_3 + H_2$$

In both H_2O at hydrothermal temperature would be the oxidizing agent of Fe."

"The removal of the sodium, magnesium and calcium is a very common hydrothermal process," Gruner (4).

Basic tuffs contain sufficient silica to satisfy the silica content of the present iron formation, therefore silica introduction was not a requirement. The iron formation that remains now, that is, the siliceous facies could thus be formed.

Hydrothermal activity continued and resulted in removal of silica from the zone now occupied by the green schists, iron silicates and high grade ore. This was accompanied by segregation of the iron oxides and their concentration at or near the granitic footwall on the west end of the deposit, and accumulation of silicates in the green schist series. Metasomatic replacement occurred in this zone, as indicated by the reconstitution of the constituents. On the east end of the deposit the iron concentration is due to enrichment, by removal of silica. The inferred fault mentioned on page 4 is based in part on contortion of the iron formation as compared to the ore. On the west end and central portion of the deposit replacement started at the contact between the tuffaceous shaly iron formation and the granite. At the east end the replacement was effected along bedding

FRACTURES, NAMELY WITHIN THE SO-CALLED OREBODY No. 3 AND LENSED WESTWARD TO FORM OREBODY No. 2. THE EAST REPLACEMENT ZONE ORE HAS LESS COMPLETE REMOVAL OF SILICA AND CONTAINS MORE SILICATES.

AS FOLDING STARTED THE CONTACT BETWEEN THE SHALY IRON FORMATION AND THE GRANITE FOOTWALL SERVED AS A ZONE OF FAULTING. THE SEDIMENTS ABOVE THE HORIZON OF THE INTRUSIVES YIELDED AROUND THE LATERAL MARGINS. (9P.141). THE HYDROTHERMAL SOLUTIONS WERE EMITTED ON THE SOUTH AND MOVED NORTHWARD AND LATERALLY ALONG THE CONTACT ON A DECELERATING GRADIENT. SOMEWHERE EAST OF CO-ORDINATE 21200 E A FAULT SERVED AS A CONDUIT TO FEED THE SOLUTIONS TO A BEDDING FRACTURE SOME 50 FEET ABOVE THE GRANITE CONTACT AND EFFECTED SILICA REMOVAL AND THE FORMATION OF OREBODY No. 3 AND No. 2. IN BOTH THE METASOMATIC REPLACEMENT ZONE AND THE ENRICHMENT ZONE THE ADVANCE WAS ACCOMPANIED BY GRADUAL DEPLETION OF THE ROOF (THE IRON FORMATION). THE EXTENT OF THE COMPLETE REPLACEMENT MAY BE SEEN ON THE GEOLOGIC CROSS-SECTIONS. PARTIAL REPLACEMENT SUCH AS REMOVAL OF THE CARBONATES, SODIUM, MAGNESIUM AND CALCIUM EXTENDED AT LEAST 400 FEET PERPENDICULARILY FROM THE GRANITE AS INDICATED BY THE SCHIST LENSES IN THE GRANITE, SEE CROSS-SECTION B'-B, PLATE No. 8 , PAGE No. 27 . ABOVE THIS IN PLACES TO DEPTHS UP TO 200 FEET, THE REMAINING IRON FORMATION HAS BEEN ALTERED BY SILICA REMOVAL BY METEORIC WATERS AND THE EVIDENCE DESTROYED; SIMILARILY EROSION HAS REMOVED EVIDENCE ABOVE THAT ELEVATION.

<u>RECRYSTALLIZATION</u>: IN THE IRON FORMATION, CRYSTALS OF BOTH QUARTZ AND MAGNETITE HAVE BEEN ENLARGED BY RECRYSTALLIZATION. THE QUARTZ IS OF TWO VARIETIES, THAT ARE STRAINED WHERE THEY OCCUR BETWEEN BROKEN MAGNETITE

ILLUSTRATIONS

crystals. Some of the original micro-banding was later recrystallized to megascopic layering of iron oxide and quartz. The magnetite ore in the metasomatic replacement zone, particularily in the lower margins, has developed large crystals and aggregates. Finer-grained crystals filling in the spaces between the large crystals.

In the east replacement zone the ore is fine to medium grained, and porous where recrystallization is less advanced. In the green schist series, recrystallization of the high grade facies has occurred at the top margin of the ore. The low grade facies has only crystallized to a fine-grained schist. The magnetic iron formation under the ore has magnetite that is crushed and several periods of quartz is evident. The gray underlying gneiss also has large distorted crystals.

The pink gneissic granite is crushed and some of it has a sugary texture.

<u>Source of the Iron</u>: The accumulation and deposition of the iron in the iron formation preceding metamorphism is discussed above. The source of the iron in the silicated and high grade ore zone is the iron previously contained in the replaced zone now occupied by the green schists, hanging wall gneiss, iron silicates, and high grade ore. The iron from the iron formation is quantitatively adequate to supply all the iron in the replaced zone. See Table No. 1, page 13 for the iron balance in the replaced zone. Crystal size, larger near the footwall gneissic granite can be attributed to slower cooling. On the east end (No. 3 ore body) the source of heat was more distant as compared to the central and western ore portions. The iron was not removed but rather the sodium, magnesium, calcium and lastly the silica; the volumes from which the percentage tonnages were calculated are from the mine-layout ore reserve

tonnages and through the proper source may be verified (8).

The assay as shown for the original iron formation is admittedly of the formation after some removal of sodium, magnesium and calcium, however, most probably before silica removal, and is therefore reasonably representative. Iron has been concentrated and recrystallization of the iron in the original iron formation accounts for the iron in the existing high grade ore.

<u>Silica Balance</u>: Table No. 11, page 14, was prepared to study the gain or loss of silica. Assays of cores of the iron formation which appear to have had no silica removed show about 36% silica provided the replaced zone was formerly occupied by such iron formation then Table No. 11 which shows 20.8% silica now, indicates a loss of 40% of the original silica. These data in Table No. 11 is presented for information rather than as a basis for conclusions; the loss could represent the source of silica during metasomatism.

<u>Granitization</u>: Granitization is inferred by the crushing present in the old minerals and the presence of a younger generation of quartz (1). The ore grades into a gray, biotite, granitic-gneiss which grades into the pink gneissic granite.

TABLE No. 1

IRON BALANCE

TABLE OF COMPARISON OF IRON PRESENTLY IN REPLACED ZONE AND IRON IN SAME ZONE BEFORE REPLACEMENT

Present Rock Type		% Cu. Yds.	Cu. Ft/Ton	Crude Tonnage in %	% Fe	Fe Tonnage in %
1. Schist		50.24	12	39.95	13.32	532
2. Iron Ore	10% Silicates	43.03	8	47.91	66.90	3205
3. Iron Ore	10% Silicates		8	6.82	57.20	390
4. Iron Silicates		6.73	12.00	5.32	35.99	191
5. Totals and Averages		100.00	9.55	100.00	43.18	4318
6. Iron Formation Originally in Replaced Zone		100.00	9.55	100.00	43.77	4377

TABLE NO. 11

[illegible]CA BALANCE

SILICA NOW IN REPLACED ZO[illegible] AND IN THE SAME ZONE BEFORE REPLACEMENT

PRESENT ROCK TYPE	CRUDE TONNAGE IN %	% SiO_2	SILICA TONNAGE IN %
1. SCHIST	39.95	43.04	17.19
2. IRON ORE	47.91	2.97	1.42
3. IRON ORE	6.82	12.44	.84
4. IRON SILICATE	5.32	25.63	1.36
5. TOTALS AND AVERAGES	100.00	20.81	20.81
6. ORIGINAL IRON FORMATION	100.00	36.58	36.58

ASSAYS OF THE ROCK

TYPES IN THE REPLACEMENT ZONE
(NUMBERS REFER TO LINES ON TABLE NO. 1)

1. SCHIST

SAMPLES OF THE SCHISTS WERE NOT SENT TO LERCH BROTHERS LABORATORIES FOR IRON AND SILICA DETERMINATIONS. HOWEVER, FROM THE SCHIST CORE SAMPLES IN THE SUITE UNDER STUDY A COMPOSITE OF ELEVEN SAMPLES WAS MADE AND ASSAYED IN OUR NORTH DAKOTA SCHOOL OF MINES LABORATORY.

	TOTAL FE %	SiO_2 %
COMPOSITE	13.52	43.04

2. IRON ORE < 10% SILICATES (LERCH BROTHERS)

' THESE ASSAYS WERE DETERMINED FOR THE U.S.G.S. IN 1945 ON THE CORE SAMPLES FROM THE HOLLAND SYNDICATE DRILLING PROGRAM IN THE 1930'S AND ARE TOTAL FE.

'' THE ASSAYS ON THE LIBERIA MINING COMPANY DIAMOND DRILL PROGRAM OF 1951-52 ARE SOLUBLE IRON (EXCEPT ON CERTAIN SPECIFIED SAMPLES). THE HIGH GRADE ORE OF LIBERIA HAS NEGLIGIBLE AMOUNTS OF INSOLUBLE IRON (7); THE FOLLOWING ASSAYS ARE INCREASED TO COMPENSATE FOR INSOLUBLE IRON.

DRILL HOLES	NO. SAMPLES	SOL FE	EST. INSOL FE	TOTAL FE
' HOLLAND SYNDICATE	59			68.50
'' 1951-52				
17	8	65.70		
16	20	67.74		
24	6	67.40		
26	15	59.68		
28	10	66.64		
23	8	66.92		
36	3	67.25		
22	3	65.20		
25	3	64.57		
1951-52 AVERAGE	76	65.43	0.25	65.68
TOTAL AVERAGE	135			66.90

3. Iron Ore > 10% Silicates (Lerch Brothers)

Samples from the 1951-52 drilling program. The soluble iron is increased as shown below to obtain total iron.

Drill Hole	No. of Samples	% Sol Fe	% Insol. Silicates	Est. % Fe Insol	Total Fe
17	1	42.97	14.63		
17	1	54.66	18.08		
17	1	61.15	11.06		
24	1	66.61			
23	1	54.89	21.0(E)		
23	1	53.28	22.0(E)		
23	1	54.57	20.0(E)		
24	1	57.46	18.0(E)		
Average	8	55.70	14.98	1.50	57.20

4. Iron Silicates (Lerch Brothers)

These samples are from the 1951-52 diamond drilling program; the tonnage is small and no increase for insoluble Fe is made.

Drill Hole	No. Samples	% Fe	% Insol. Silicates
18	8	35.99	46.74

5. See Geometric Summation Table No. 1

6. Iron Formation (Lerch Brothers)

In the data from the 1951-52 drilling program, the iron formation ranges from 37.0 to 49% Fe. The assays on the Holland Syndicate drill cores similarily are within the range. 17 such samples have an average of 42.11% Fe.

For use in Table No. 1 in the iron balance it appears preferable to use composite sample #L25 "selected fresh core essentially free from silicates; ("typical hematitic iron formation")."

Sample No.	Fe	SiO_2	P	S	Mn	Al_2O_3	TiO_2	CaO	MgO
(1945-) L25	43.77	36.58	.071	.052	.06	.39	.22	.14	.16

ASSAYS OF THE ROCK (SILICA)

SOURCE OF ASSAYS FOR - TABLE NO. 11

1. SCHIST (U.N.D. LABORATORY)

	SiO_2%
COMPOSITE (11 SAMPLES)	43.04

2. IRON ORE 10% SILICATES (LERCH BROTHERS)

	DRILL HOLES	NO. SAMPLES	SiO_2%
	17	8	5.52
	16	20	2.44
	24	6	0.89
	26	15	3.58
	28	10	2.58
	23	8	2.16
	36	3	2.63
	22	3	2.89
	25	3	4.91
AV.	1951-52	76	2.97

3. IRON ORE 10% SILICATES (LERCH BROTHERS)

DRILL HOLES	NO. SAMPLES	SiO_2%
17	1	14.63
17	1	18.08
17	1	11.06
24	1	11.32
23	1	11.04
23	1	15.06
23	1	10.90
24	1	7.46
		12.44

4. IRON SILICATES (LERCH BROTHERS)

DRILL HOLES	NO. SAMPLES	SiO_2%
18	8	25.63

5. GEOMETRIC AVERAGE OF 1-4 BY TONNAGE DISTRIBUTION - SEE TABLE NO. 11

6. IRON FORMATION (LERCH BROTHERS)

SAMPLE NO.	NO. SAMPLES	SiO_2%
(1945) 125	COMPOSITE	36.58

TABLE NO. III. **PARAGENESIS**

WHEN PRESENT THE FOLLOSING APPEARS TO BE THE SEQUENCE OF MINERAL OCCURRENCE:

TYPE OF ROCK

IRON FORMATION		PLATE NO.	PAGE NO.
ORIGIN:	COLLOIDAL IRON OXIDES	5	47
	AND SILICA HYDROSOLS	6	49
	PLUS VOLCANIC MATERIAL.	7	51
BANDED	HEMATITE - MAGNETITE	8	53
SEDIMENTARY:	FELDSPAR - TUFFS - ASH	9	55
	AND QUARTZ AND/OR		
	HEMATITE - MAGNETITE		
	QUARTZ		
METAMORPHISM:	MAGNETITE		
	ORTHOCLASE		
	ALBITE		
	QUARTZ		
	CORDIERITE		
	BIOTITE		
	MUSCOVITE		

ALTERING TO:

SCHIST	ORE
CHLORITE	MAGNETITE
SERPENTINE	ANTHOPHYLLITE
QUARTZ	CHLORITE
	HEMATITE WHERE WEATHERED

CHLORITE SCHIST:

	PLATE NO.	PAGE NO.
MAGNETITE	12	61
BIOTITE		
EPIDOTE		
CUMMINGTONITE	13	63
CHLORITE		
QUARTZ		
SERPENTINE		

GNEISS (ABOVE ORE)

	PLATE NO.	PAGE NO.
MAGNETITE		
MICROLINE	10	57
ALBITE		
QUARTZ	10	57

Table No. III

Gneiss (above ore) continued		
Garnet		
Biotite		
Pyrrhotite (after magnetite)		
Cummingtonite		
Chlorite		
Iron Silicate Facies	4	45
Hematite		
Magnetite		
Quartz		
Cummingtonite		
Anthophyllite		
Chlorite		
Granitic Gneiss (under ore)		
Magnetite	10	57
Orthoclase		
Albite	11	
Quartz		
Garnet *		
Biotite		
Cummingtonite		
Chlorite		
Serpentine		
Quartz		
Gneissic Granite (Pink)	14	65
Orthoclase		
Microcline		
Albite		
Quartz		
Muscovite		
Chlorite		
Serpentine		
Quartz		
Sericite		

* In one sample #15

<u>Mineral Identification:</u> The mineral identifications were made optically from 14 thin sections, 12 polished sections and fragments from the hand specimens of these samples and various others totaling 77.

Powder x-ray analysises were made on 12 samples. Cordierite was identified as present in several specimens by optical analysis, however it did not show in the powder x-ray analysis.

<u>Summary and Conclusion</u>

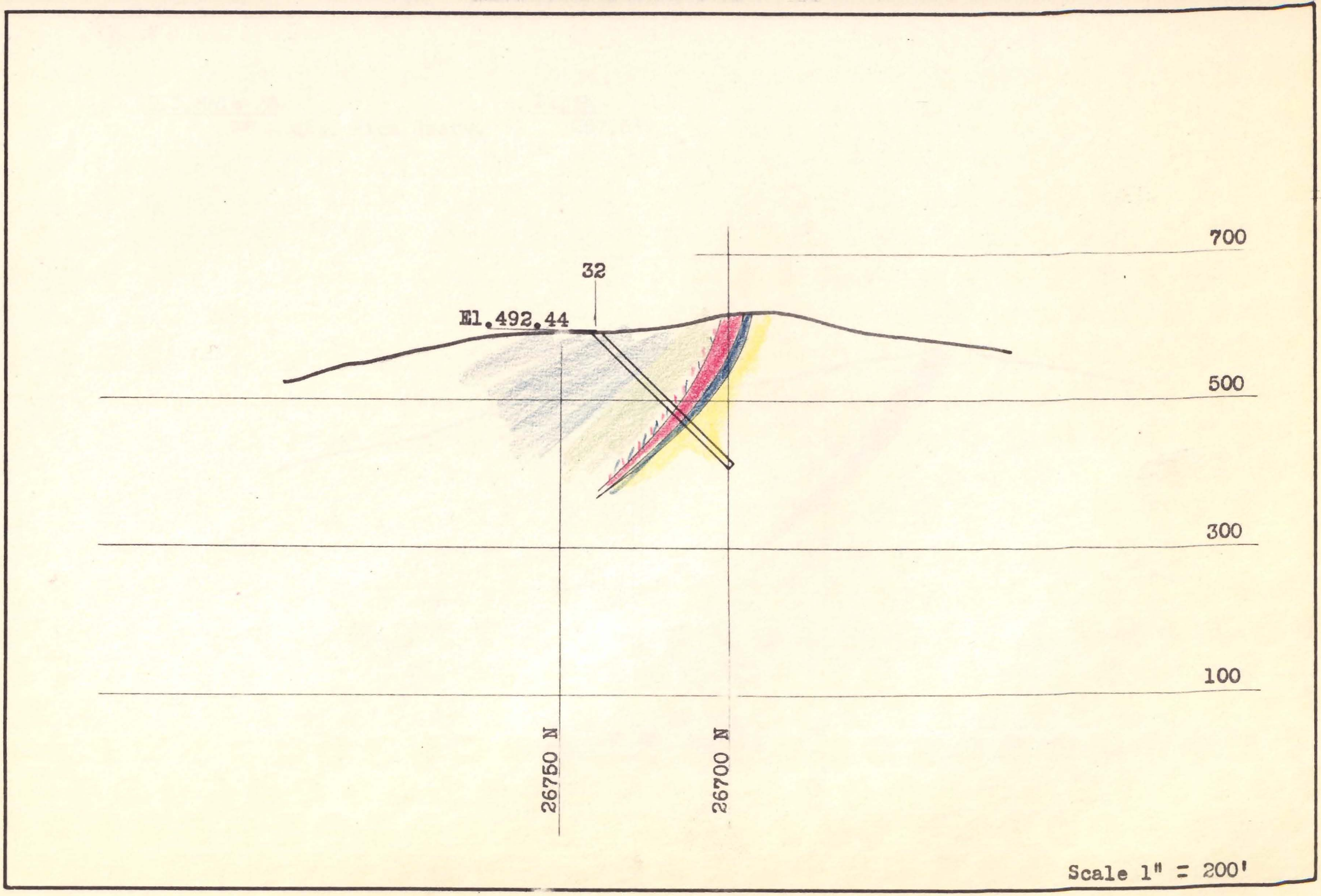
1. The banded iron formation was formed by co-deposition of volcanic tuffs and siliceous iron bearing colloidal precipitates.
2. The high grade iron ore originated from the iron bearing sediments by metamorphism which involved folding accompanied by metasomatic replacement of a part of this iron bearing material.

EXPLANATION

1. Weathered Iron Formation
2. Iron Formation
3. Iron Silicates
4. Schist
5. Iron Ore $>$ 10% Silicates
6. Iron Ore $<$ 10% Silicates
7. Gneiss
8. Presence of Garnet
9. Granite

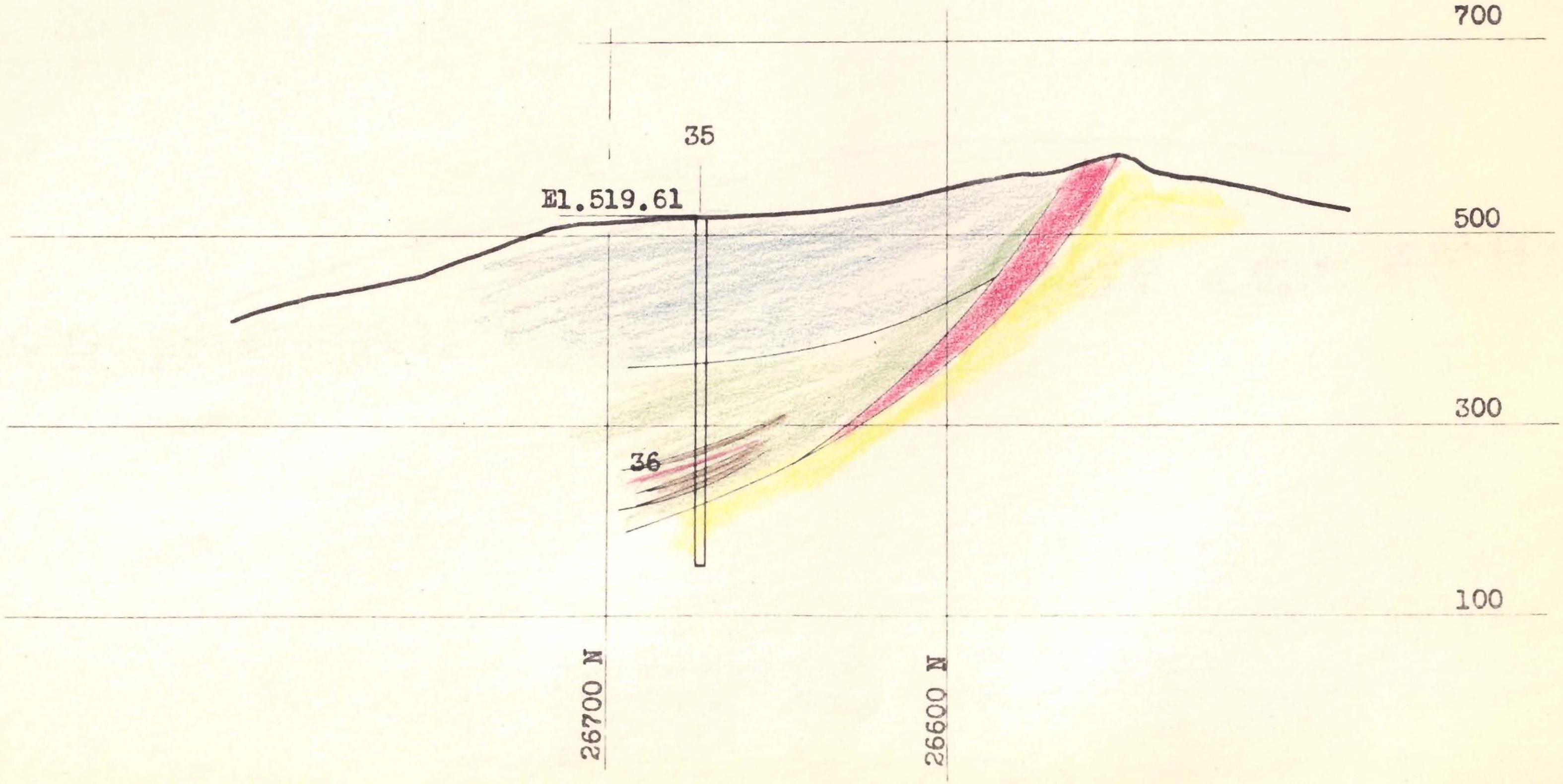
No. 2

X-SECTION G'-G

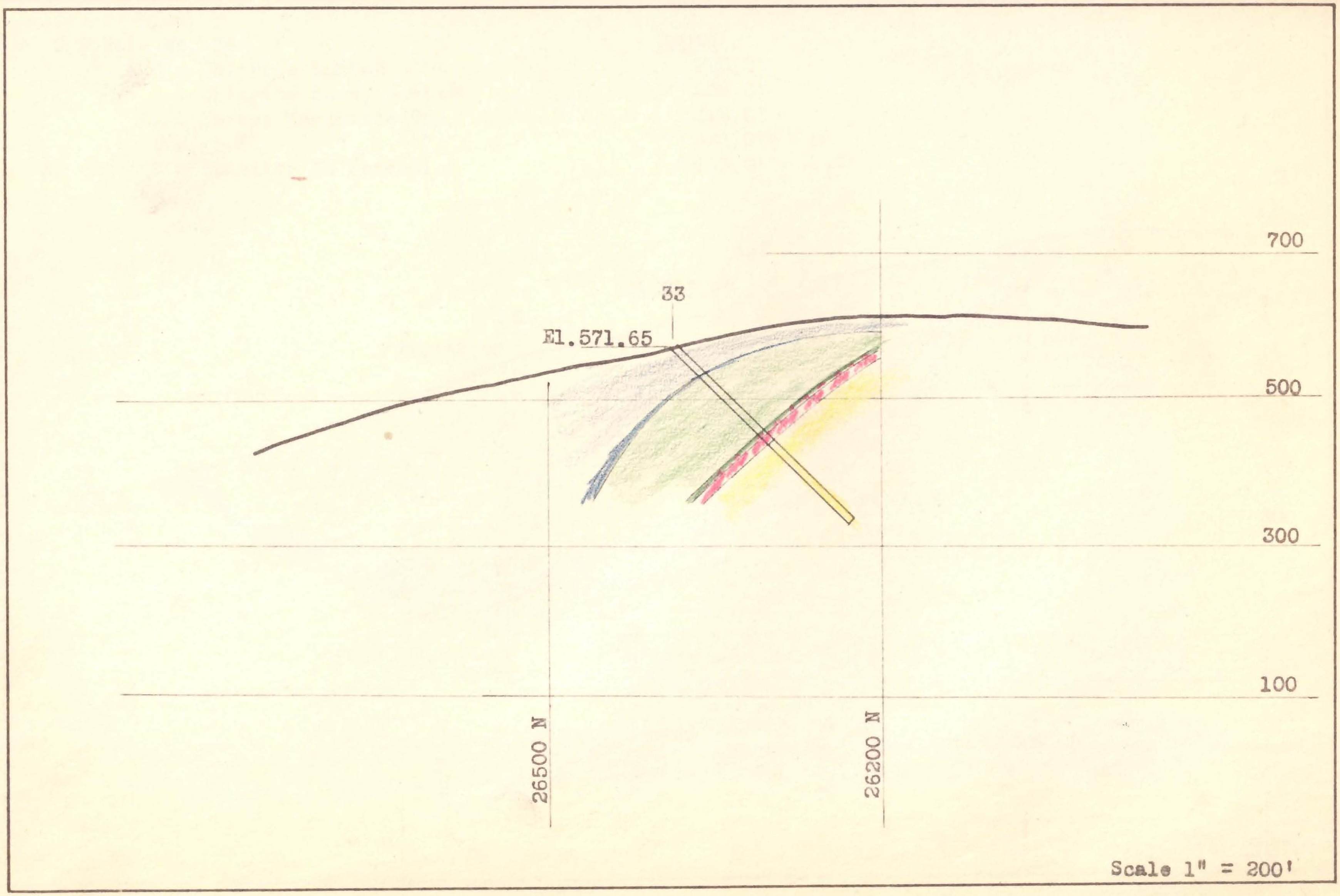


X-SECTION F'-F

D.D. Hole 35	Depth
36 - Qtz. Mica Gneiss	257.5'

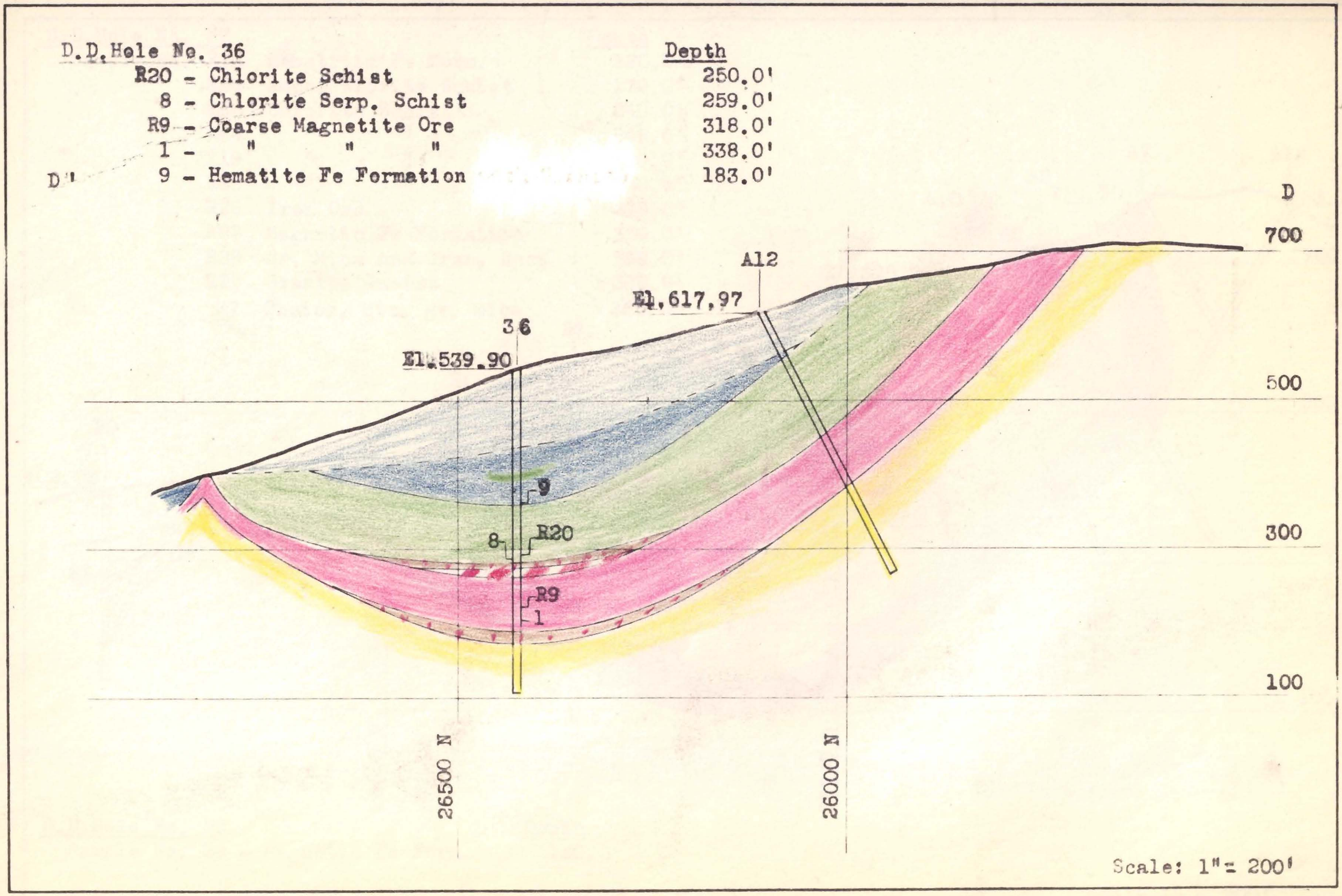


Scale 1" = 200'


700
33
El.571.65
500
300
100
26500 N
26200 N
Scale 1" = 200'

X-SECTION D'-D

No. 6

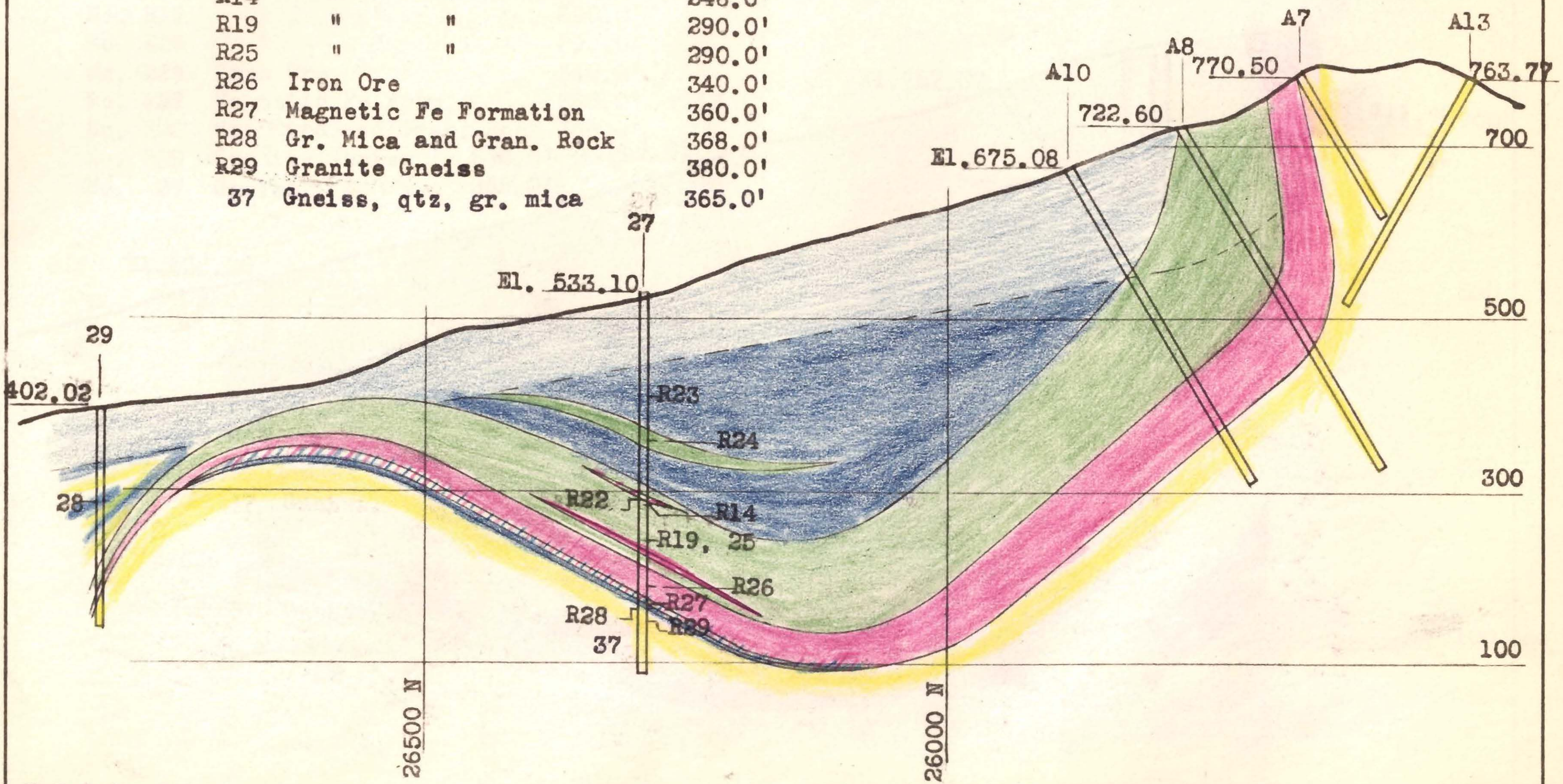


X-SECTION C'-C

No. 7

D.D.Hole No. 27

Sample No.		Depth
R23	Hematitic Fe Form.	120.0'
R24	Amph. Biotite Schist	170.0'
R22	Chlorite Schist	240.0'
R14	" "	248.0'
R19	" "	290.0'
R25	" "	290.0'
R26	Iron Ore	340.0'
R27	Magnetic Fe Formation	360.0'
R28	Gr. Mica and Gran. Rock	368.0'
R29	Granite Gneiss	380.0'
37	Gneiss, qtz, gr. mica	365.0'



D.D.Hole No. 29

Sample No.		Depth
28	Magnetic Fe Form.	120.0'

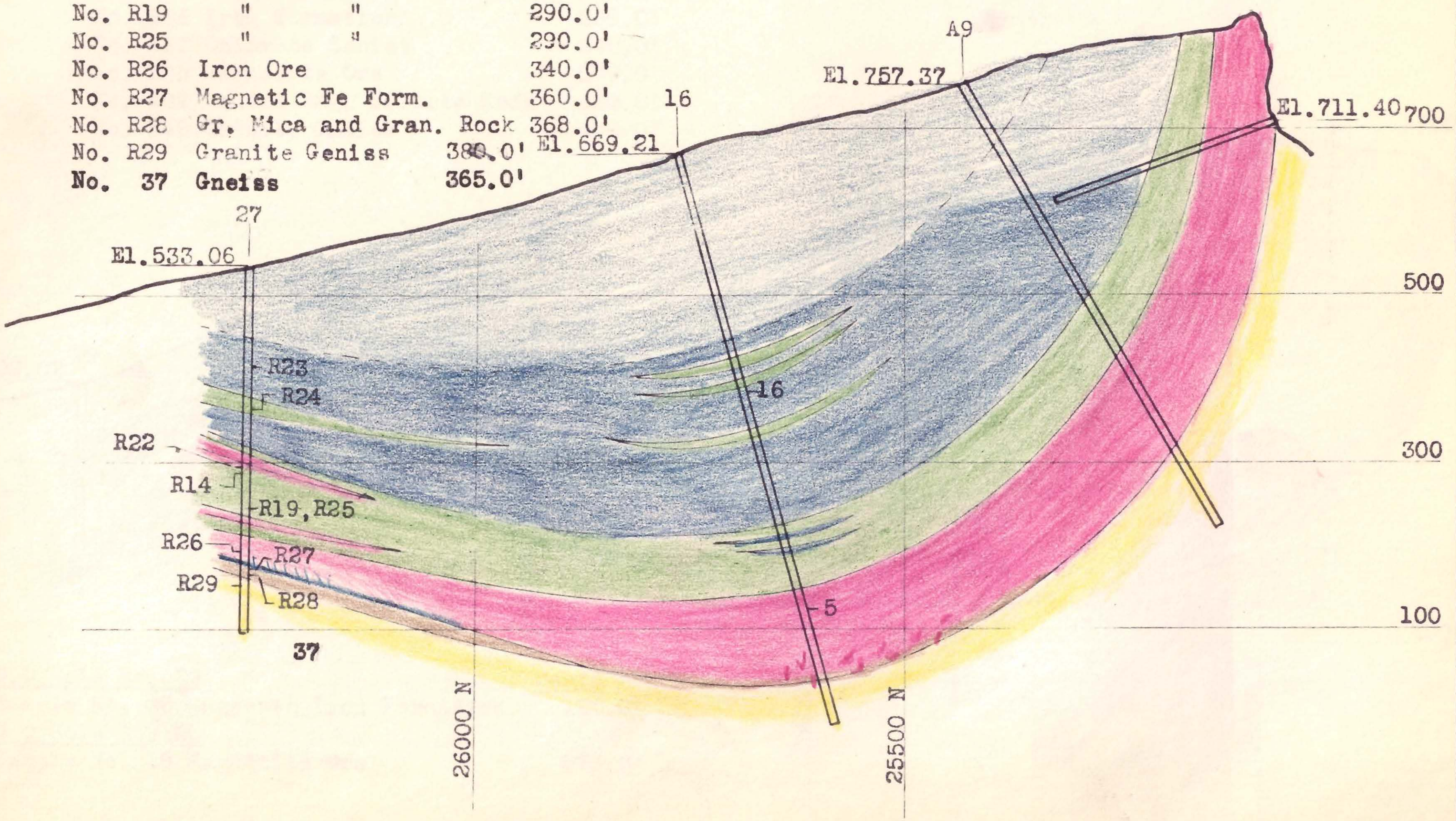
Scale 1" = 200'

D.D. Hole No. 27

			Depth
Sample No.	R23	Hematitic Fe Form.	120.0'
No.	R24	Amph. Biotite Schist	170.0'
No.	R22	Chlorite Schist	240.0'
No.	R14	" "	248.0'
No.	R19	" "	290.0'
No.	R25	" "	290.0'
No.	R26	Iron Ore	340.0'
No.	R27	Magnetic Fe Form.	360.0'
No.	R28	Gr. Mica and Gran. Rock	368.0'
No.	R29	Granite Geniss	380.0'
No.	**37**	**Gneiss**	**365.0'**

D.D. Hole No. 16

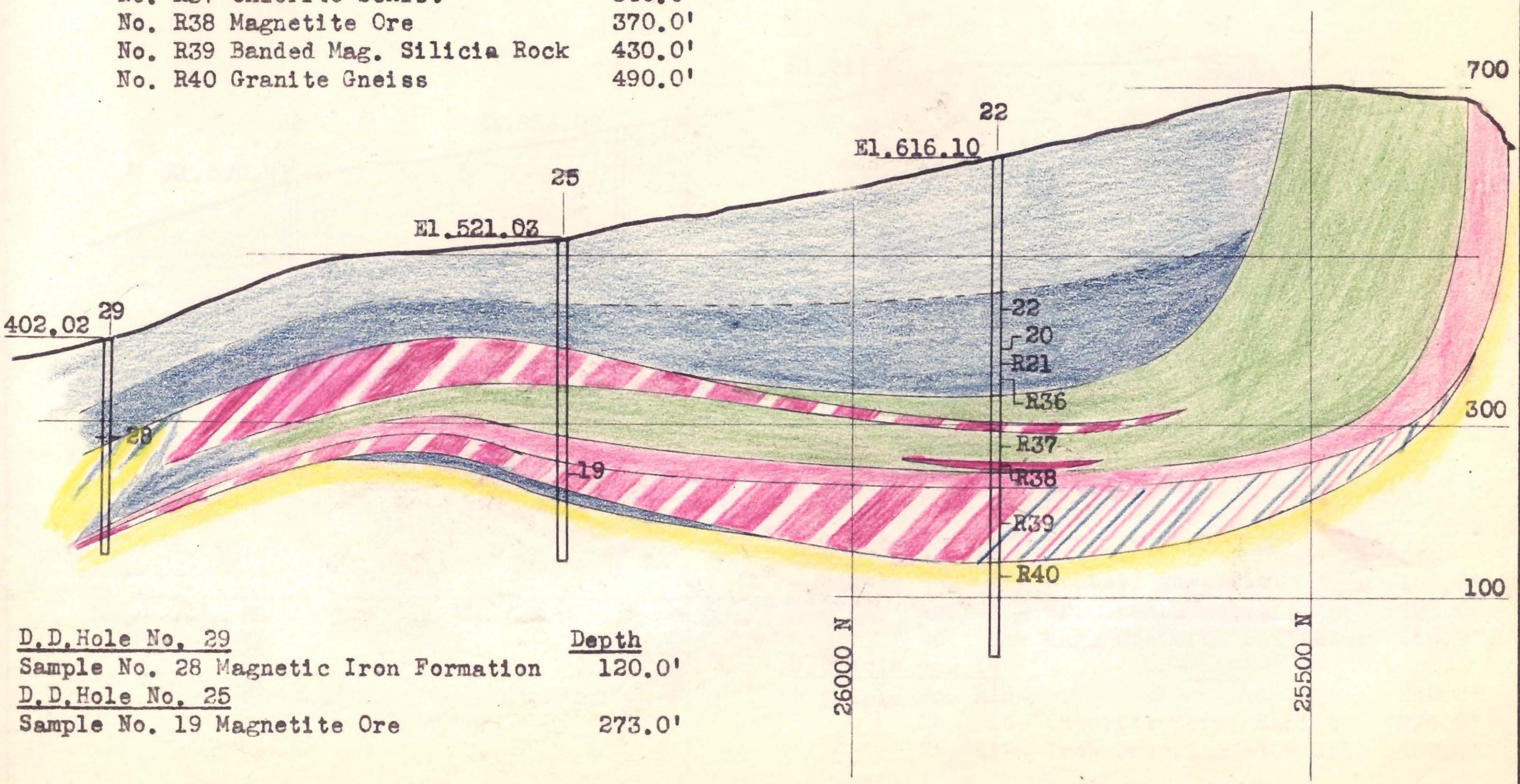
			Depth
Sample No.	16	Hematitc Fe Form.	291.0'
No.	5	Magnetite Ore	566.0'



Scale 1" = 200'

X-SECTION A'-A

D.D.Hole No. 22		Depth
Sample No. 22	Hematite Iron Formation	175.0'
No. 20	Chlorite Epidote Schist	222.0'
No. R21	Schistose Iron Formation	240.0'
No. R36	Iron Formation	260.0'
No. R37	Chlorite Schist	340.0'
No. R38	Magnetite Ore	370.0'
No. R39	Banded Mag. Silicia Rock	430.0'
No. R40	Granite Gneiss	490.0'

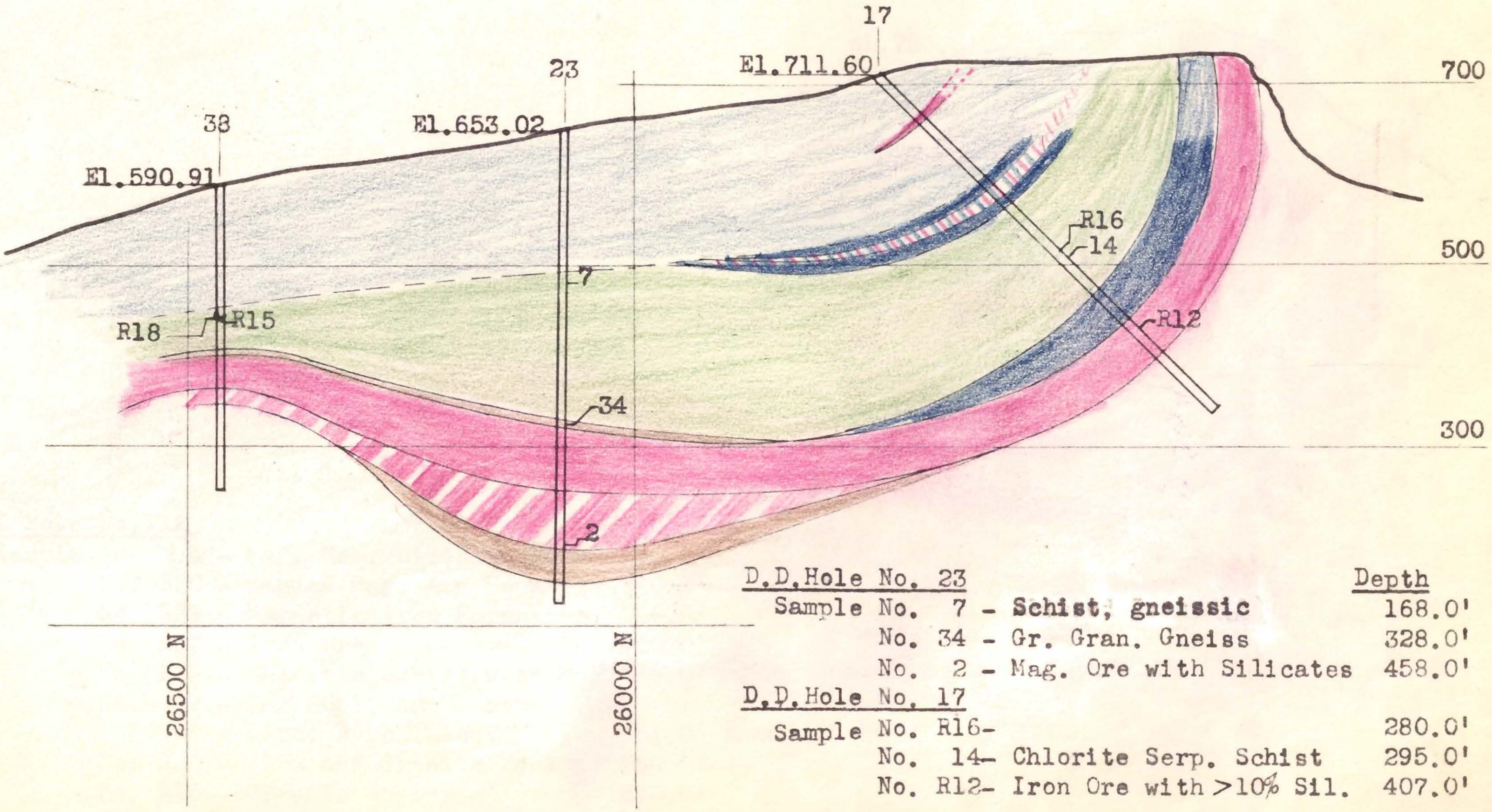


D.D.Hole No. 29		Depth
Sample No. 28	Magnetic Iron Formation	120.0'
D.D.Hole No. 25		
Sample No. 19	Magnetite Ore	273.0'

Scale 1" = 200'

D.D.Hole No. 38 — Depth

Sample No. R18 - Fe Formation 150.0'
No. R15 - Fe " 152.0'



D.D.Hole No. 23 — Depth

Sample No. 7 - **Schist, gneissic** 168.0'
No. 34 - Gr. Gran. Gneiss 328.0'
No. 2 - Mag. Ore with Silicates 458.0'

D.D.Hole No. 17

Sample No. R16- 280.0'
No. 14- Chlorite Serp. Schist 295.0'
No. R12- Iron Ore with >10% Sil. 407.0'

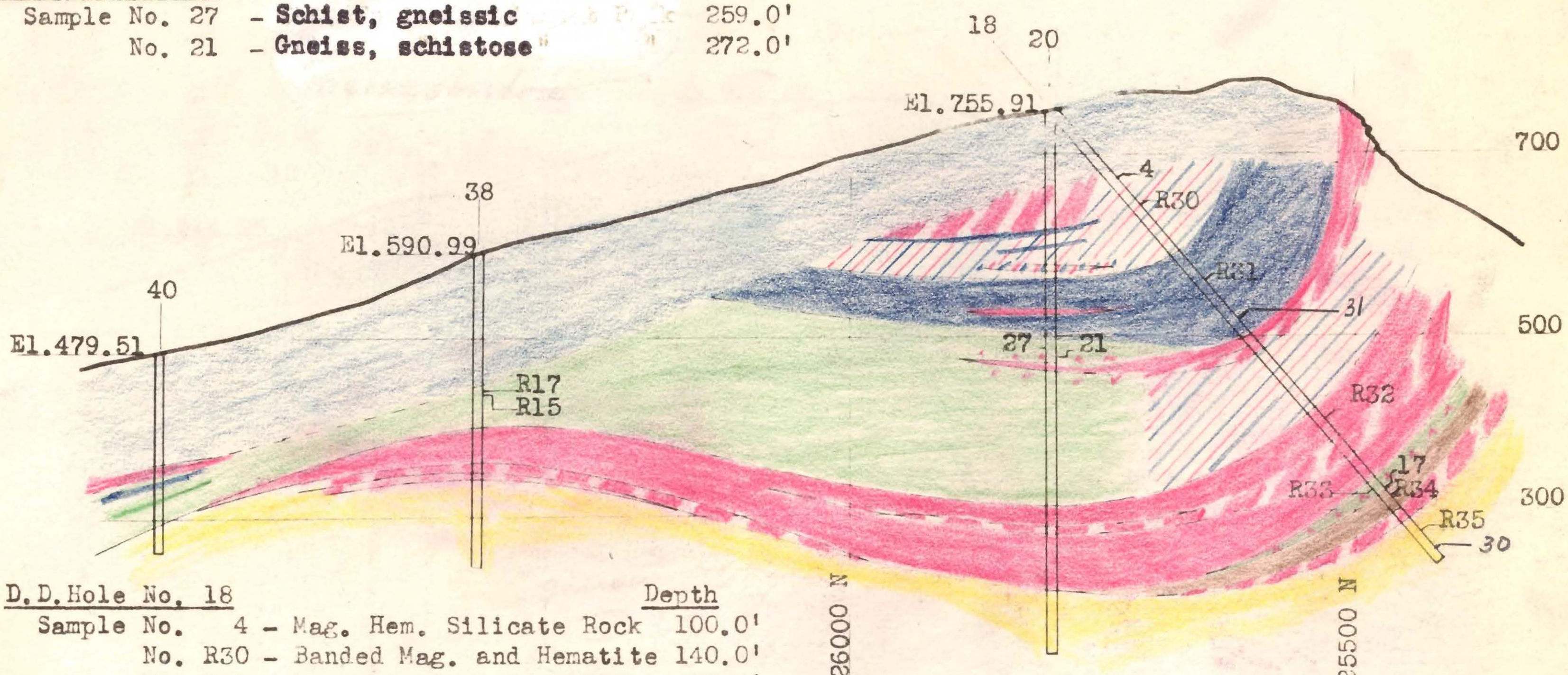
Scale 1" = 200'

D.D.Hole No. 38

		Depth
Sample No. R17	Chlorite Schist	150.0'
No. R15	" "	152.0'

D.D.Hole No. 20

Sample No. 27	**Schist, gneissic**	259.0'
No. 21	**Gneiss, schistose**	272.0'



D.D.Hole No. 18

		Depth
Sample No. 4	Mag. Hem. Silicate Rock	100.0'
No. R30	Banded Mag. and Hematite	140.0'
No. R31	Magnetic Iron Formation	250.0'
No. R32	Iron Ore	450.0'
No. R33	Chlorite Schist with Mag.	545.0'
No. 17	Mag. Chl. Amph. Serp. Carb. Pyrch. Rock	551.0'
No. R34	Mica and Granite Rock	560.0'
No. R35	Granite Gneiss	610.0'
No. 31	**Gneiss, qtz. & gr. mica**	**301.0'**
No. 30	**Granite with garnet&Biot.**	**639.0'**

Scale 1" = 200'

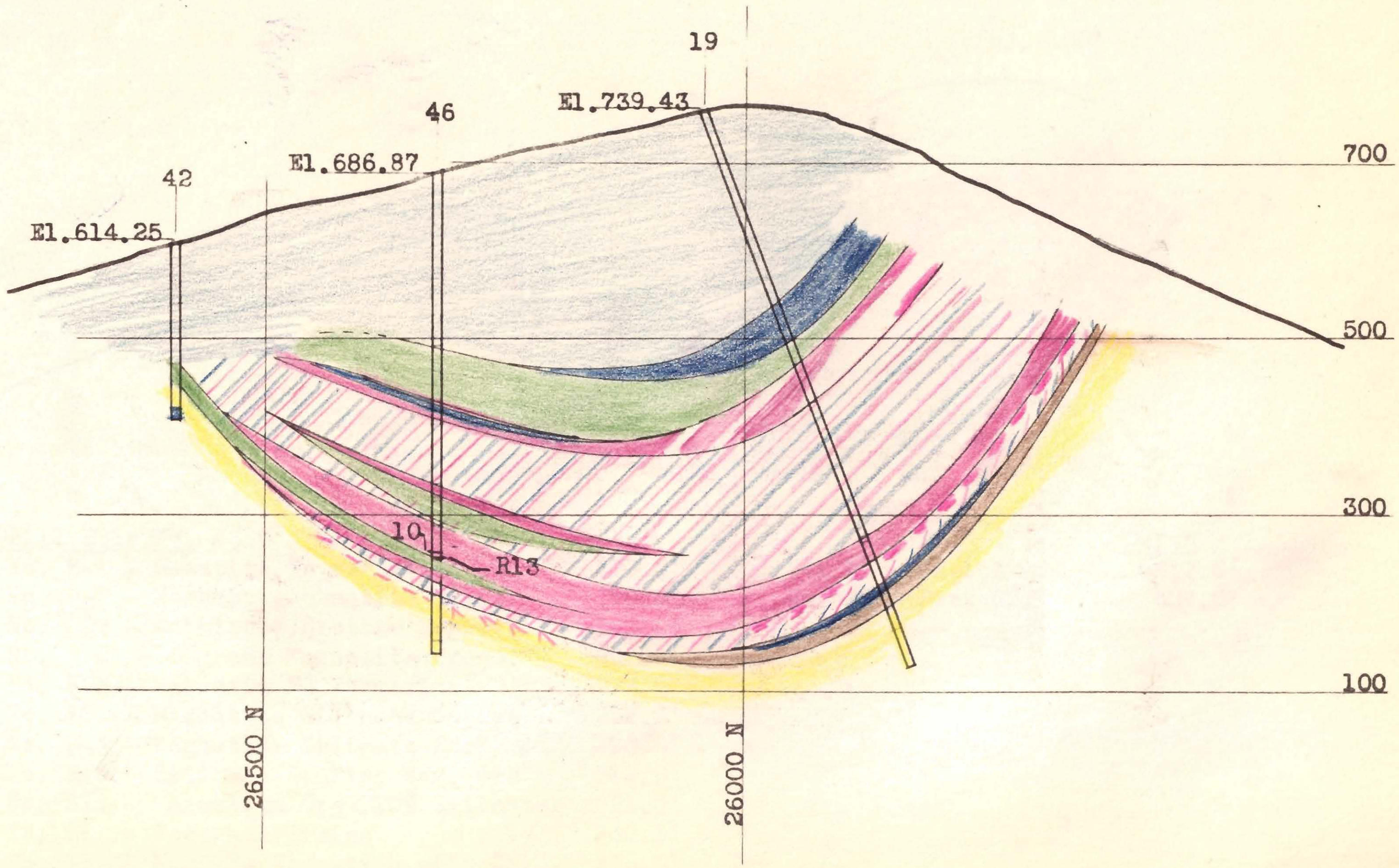
X-SECTION K'-K

No. 12

D.D. Hole No. 46 — Depth

Sample No. 10-Mag. Ore — 436.0'

No. R13-Iron Ore - Silicates < 10% — 442.0'



Scale 1" = 200'

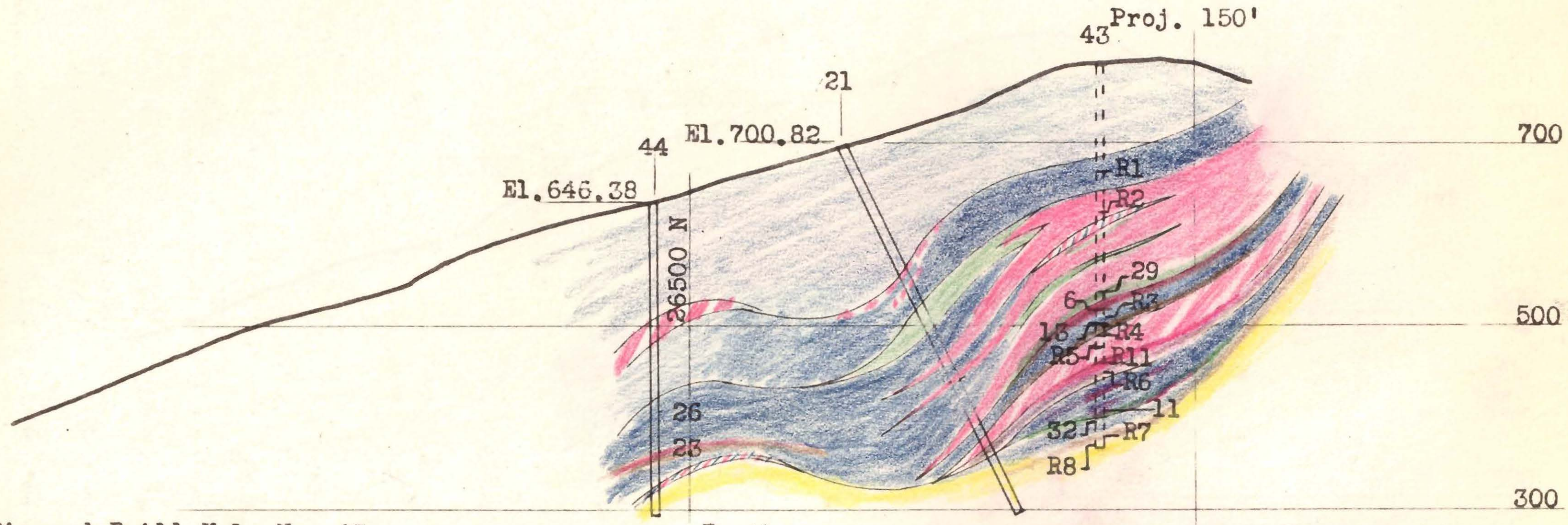
X-SECTION L'-L

No. 13

Diamond Drill Hole No. 44 — Depth

Sample No. 26 - Banded Magnetic Fe Form. 228.0'

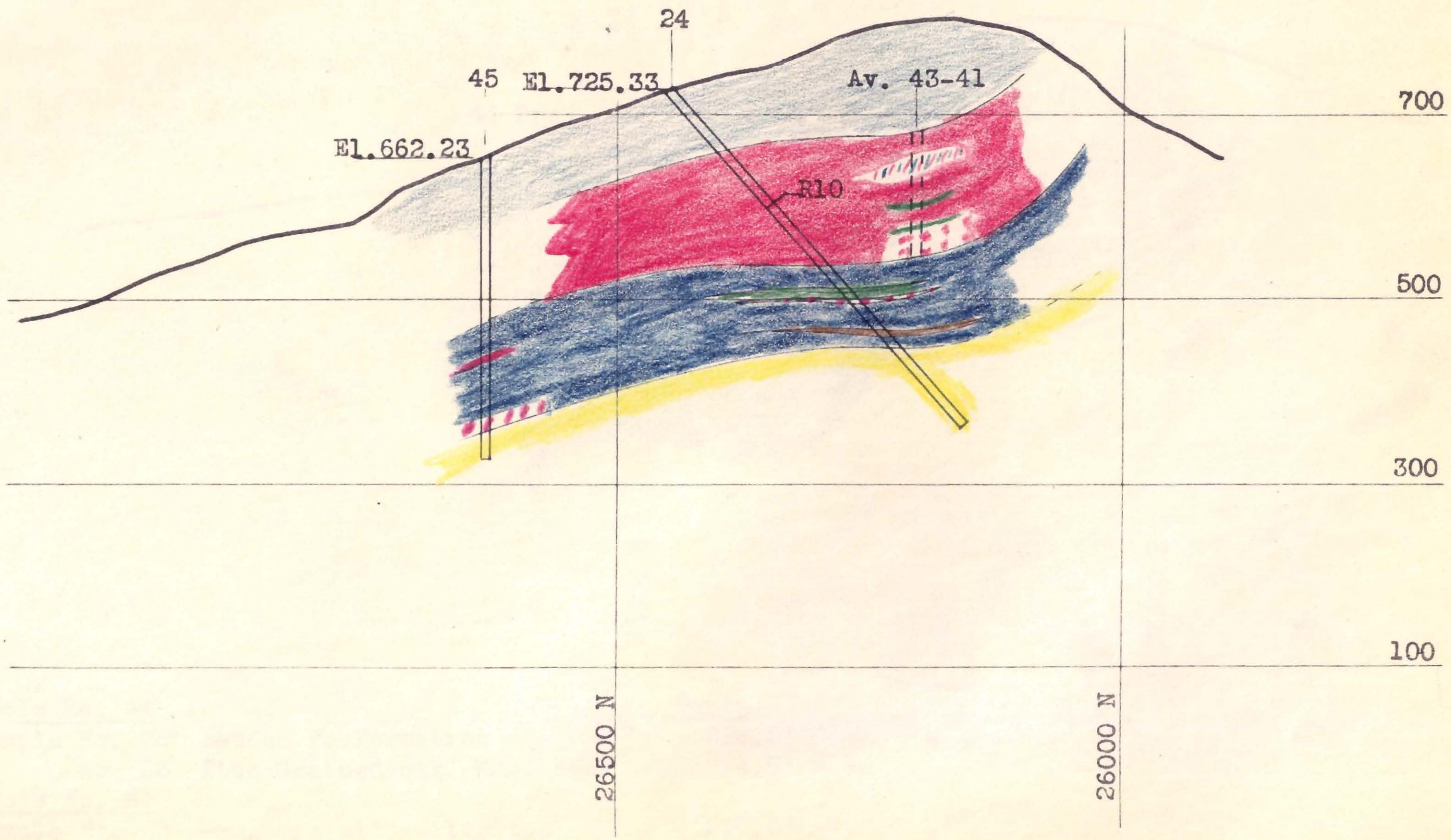
No. 23 - Fine Grained qtz. mag. gn. 274.5'



Diamond Drill Hole No. 43

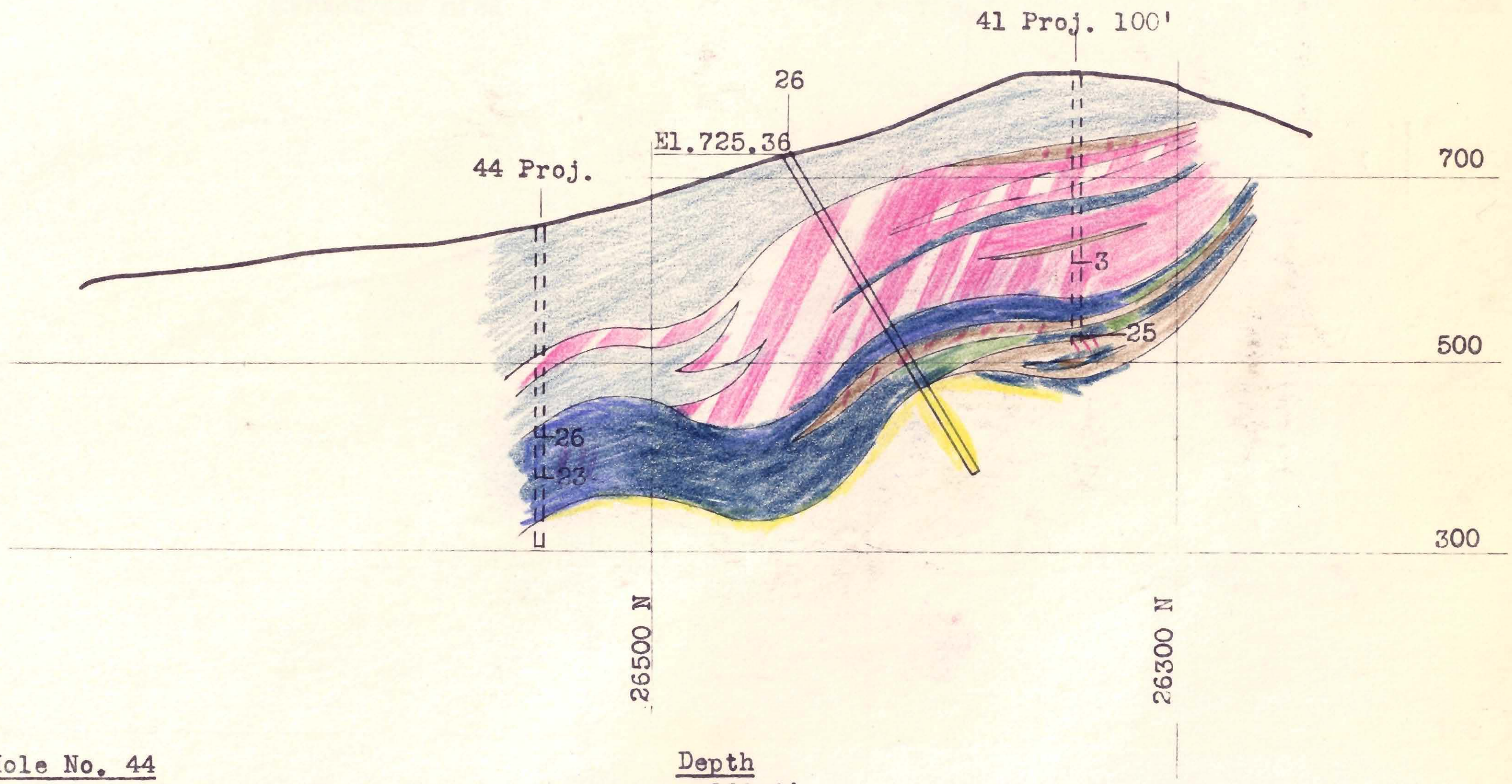
Sample No.	Description	Depth
No. R-1	Hematite Fe Formation	122.0'
No. R-2	Magnetite-Hematite Ore	170.0'
No. 29	Amphibole Biotite Schist	243.0'
No. 6	Hi-grade Magnetite Ore	263.0'
No. R-3	Magnetic Fe Formation	273.5'
No. 13	Magnetite Silicate Gneiss	282.0'
No. R-4	Magnetite Silicate Rock	290.0'
No. R-5	Silicate Bearing Mag. Ore	312.0'
No. R11	Magnetite Ore < 10% Silicates	321.0'
No. R6	Footwall Gneiss	340.5'
No. 11	Mag. Fe Formation with Chl.	376.5'
No. 32	Mag. Fe Formation	388.0'
No. R7	Gneiss	417.5'
No. R8	Pink Gr	429.0'

D. D. Hole No. 24 — Depth
R10 - Magnetite Ore — 166.5'



Scale 1" = 200'

X-SECTION 0'-0 No. 15



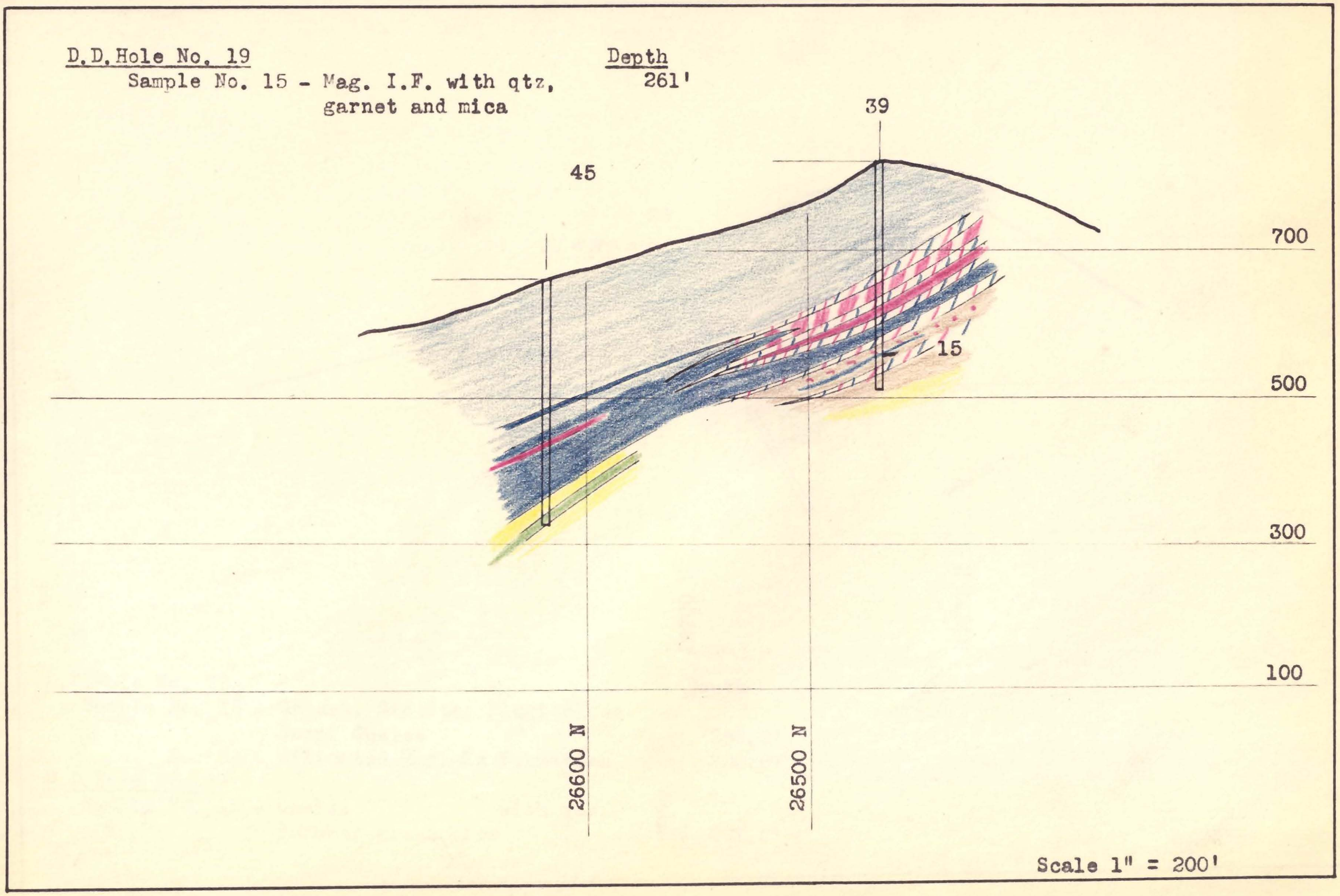
D.D.Hole No. 44 Depth

Sample No. 26	Banded Fe Formation		228.0'
No. 23	Fine Grained qtz. Mag. Rock		274.5'

D.D.Hole No. 41

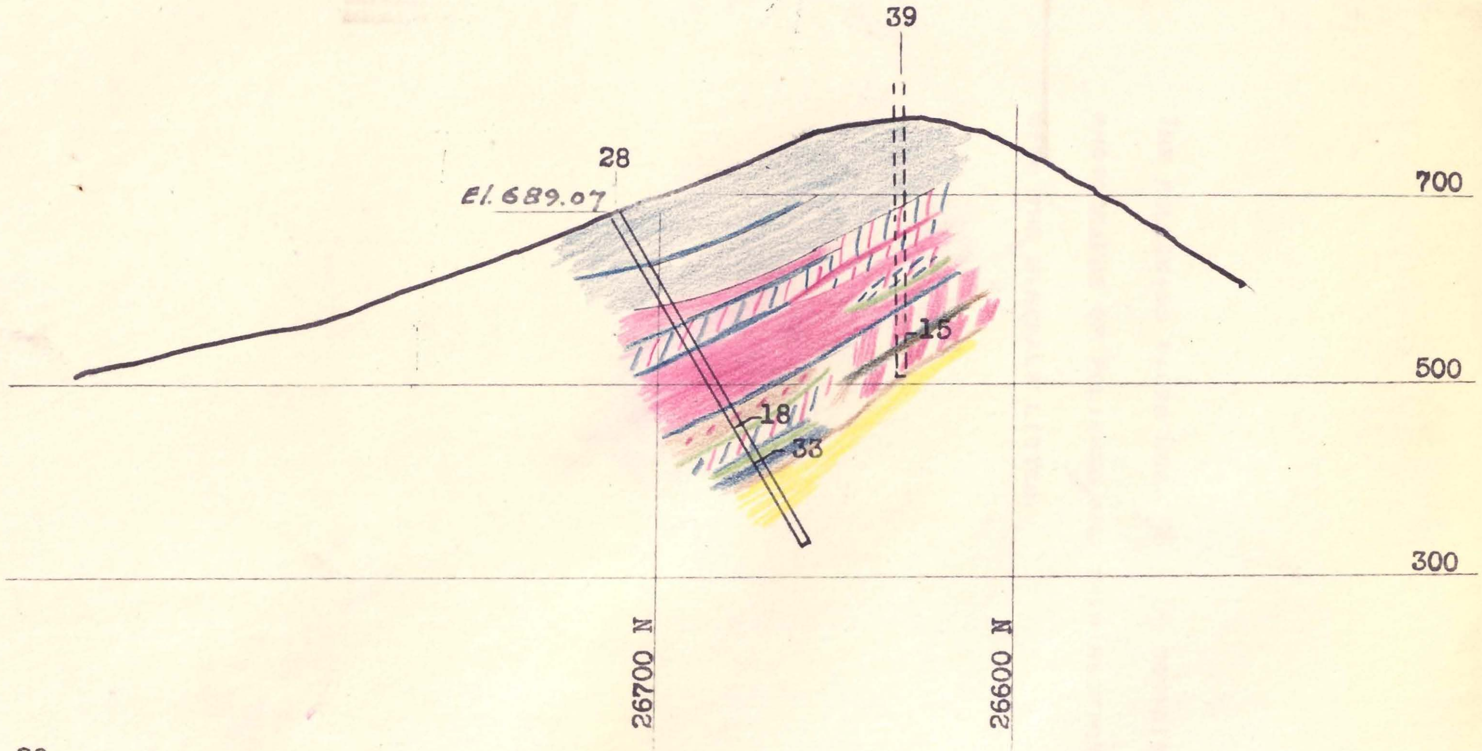
Sample No. 3	Mag. Ore with Silicates	212.0'
No. 25	Qtz., green-mica, garnet Rock	287.0'

Scale 1" = 200'


D.D. Hole No. 19
Sample No. 15 - Mag. I.F. with qtz, garnet and mica
Depth
261'
39
45
15
700
500
300
100
26600 N
26500 N
Scale 1" = 200'

X-SECTION N'-N

No. 17



D.D.Hole No. 28

		Depth
Sample No. 18 -	Garnet, Giotite, Plagioclose Serp. **Gneiss**	258.0'
No. 33 -	Silicated Mag. Fe Formation	300.0'

D.D.Hole No. 39

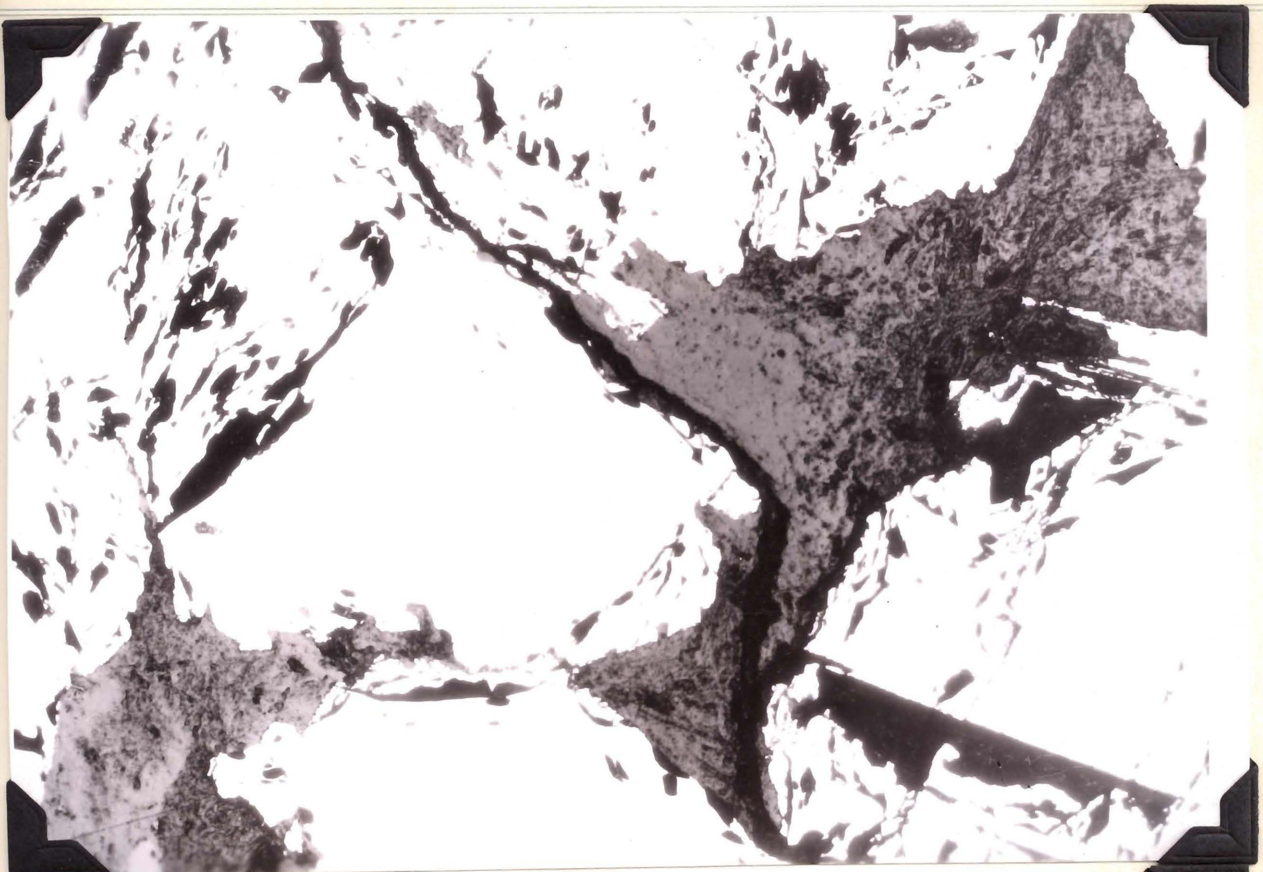
Sample No. 15 -	**Gneiss** with qtz., garnet, green mica	261.0'

Scale 1" = 200'

THE FOLLOWING PAGES NOS. 38 - 65 CONTAIN PHOTOGRAPHS OF POLISHED AND THIN SECTIONS WITH THE MINERALS LISTED.

No. 1 Coarse Magnetite Ore
Magnetite (white)
Anthophyllite (dark)
68.92% Fe, 1.92% SiO_2
Polished section X77
x-section D'-D, Drill Hole 36, Depth 338'.

No. 11 Coarse Magnetite Ore
Magnetite (white)
Anthophyllite (dark)
Polished section X77
x-section L'-L, Drill Hole 43, Depth 263'.



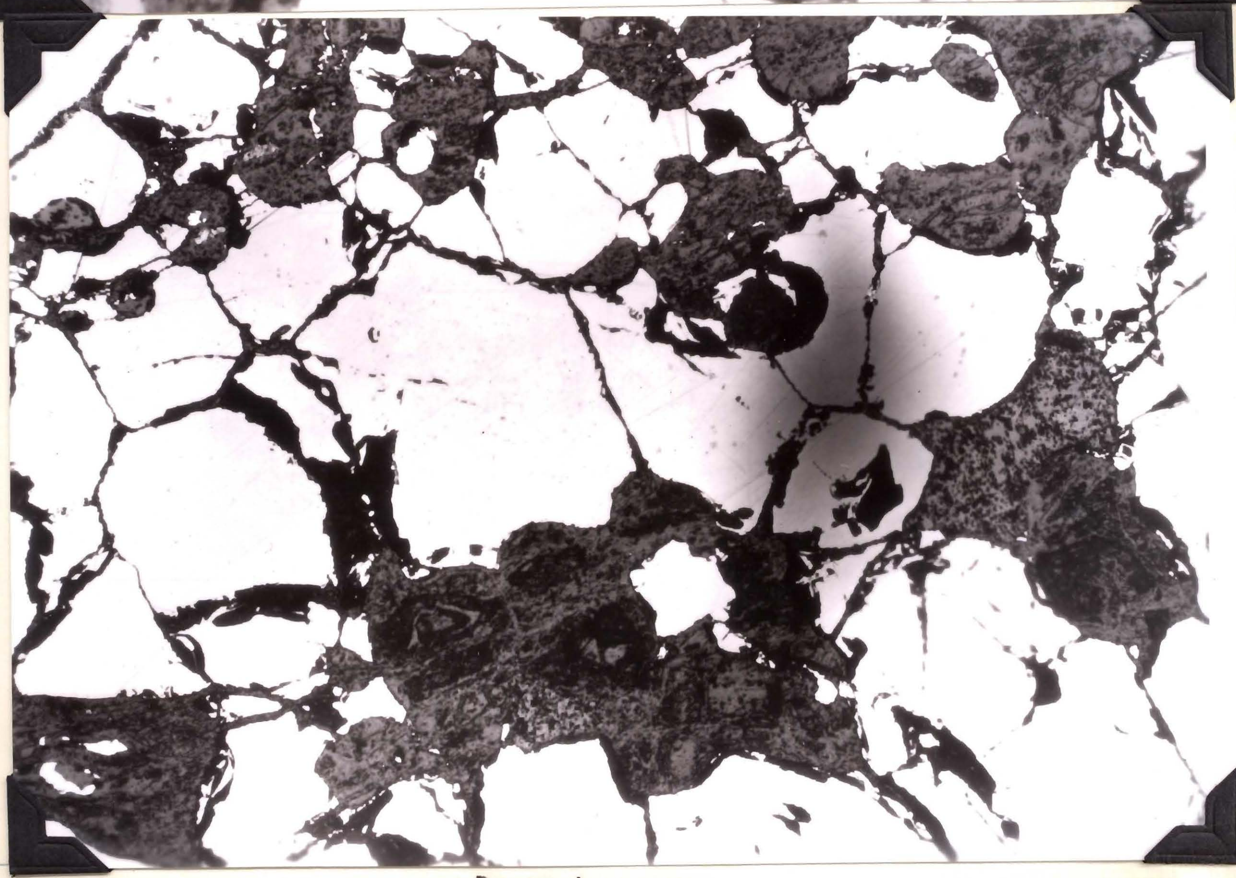


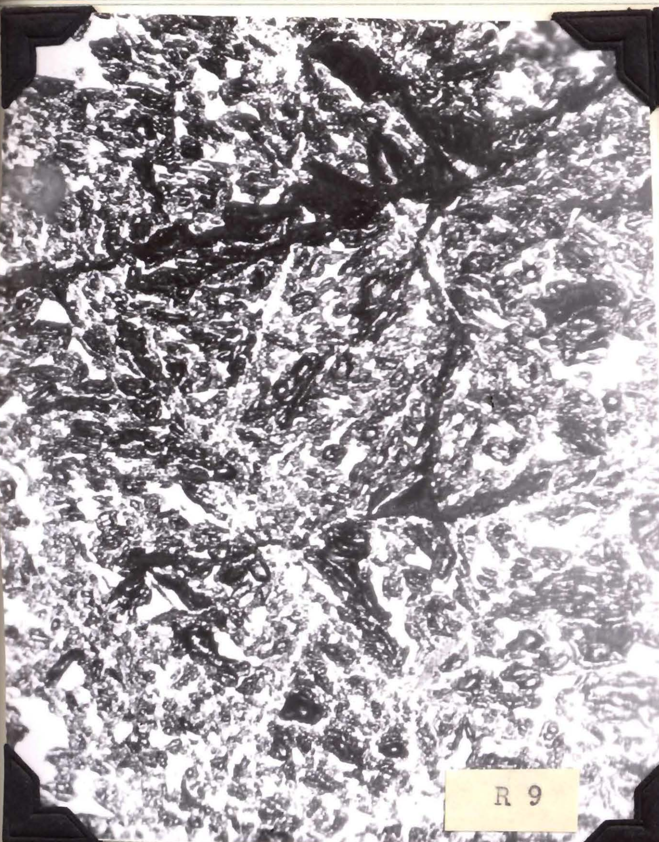
PLATE I

No. R9 Magnetite Ore
It is in the high grade ore zone and 10 feet above sample No. 1
64.96% Fe, 4.76% SiO_2.
Polished section X68
x-section D'-D, Drill Hole 36, Depth 318'.

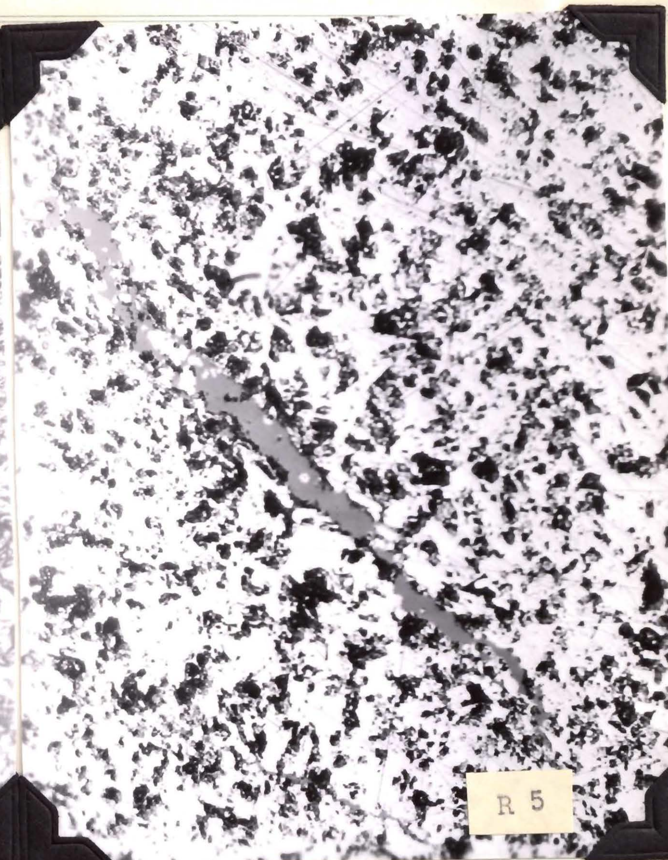
No. R5 Magnetite Ore - Silicate bearing
Magnetite (white)
Anthophyllite (gray)
Prochlorite (dark)
Polished section X68
x-section L'-L, Drill Hole No. 43, Depth 312'.

No. R13 Magnetite Ore
Magnetite (white)
Anthophyllite (gray)
Polished section X68
x-section K'-K, Drill Hole 46, Depth 402'.

No. R11 Magnetite Ore - lense in a magnetic iron formation zone below the high grade ore.
Magnetite (white)
Cummingtonite
Anthophyllite
Chlorite
Polished section X68
x-section L'-L, Drill Hole 43, Depth 321'.



R 9



R 5

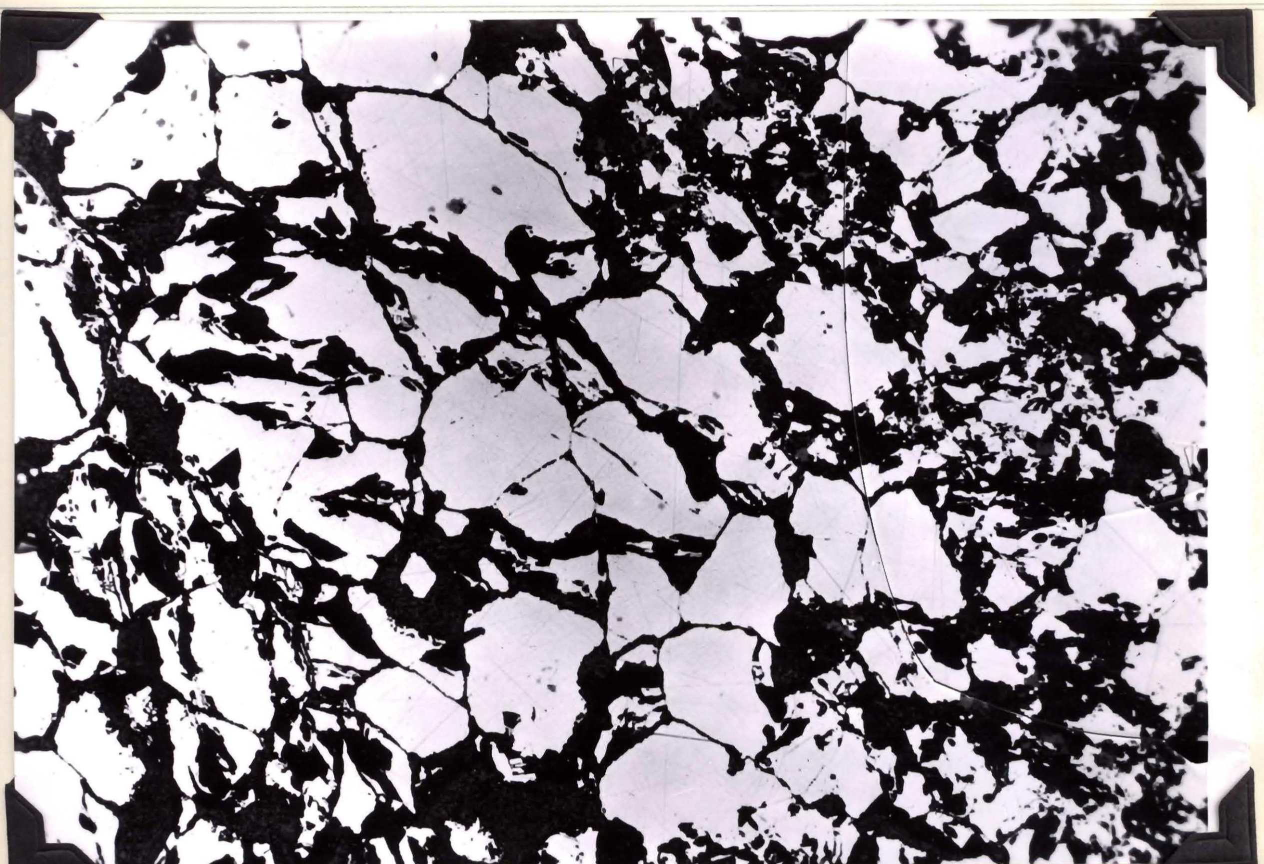
R 13

R 11

PLATE 2

No. 3 Magnetite Ore - with silicates
Magnetite (white)
Anthophyllite (gray)
Chlorite, slight
Pyrite, a few minute crystals
Polished section X77
x-section O'-O, Drill Hole 41, Depth 212'.

No. 2 Magnetite Ore - with Silicates
Magnetite (white)
Anthophyllite (gray)
Chlorite (dark gray)
Below the high grade ore zone; assays range:
53.28 to 63.34% Fe and 15.06 to 6.88% SiO_2
Polished section X77
x-section H'-H, Drill Hole 23, Depth 458'.



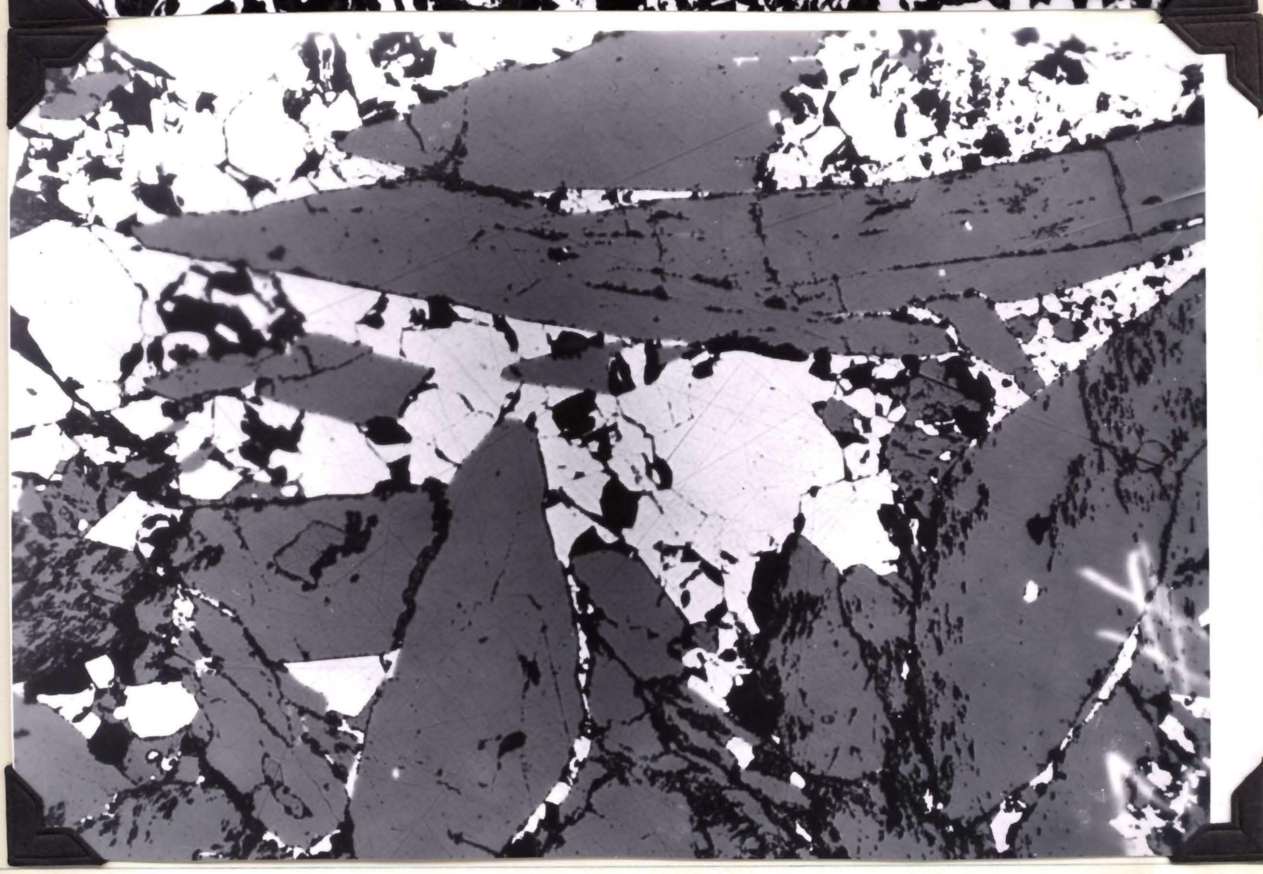


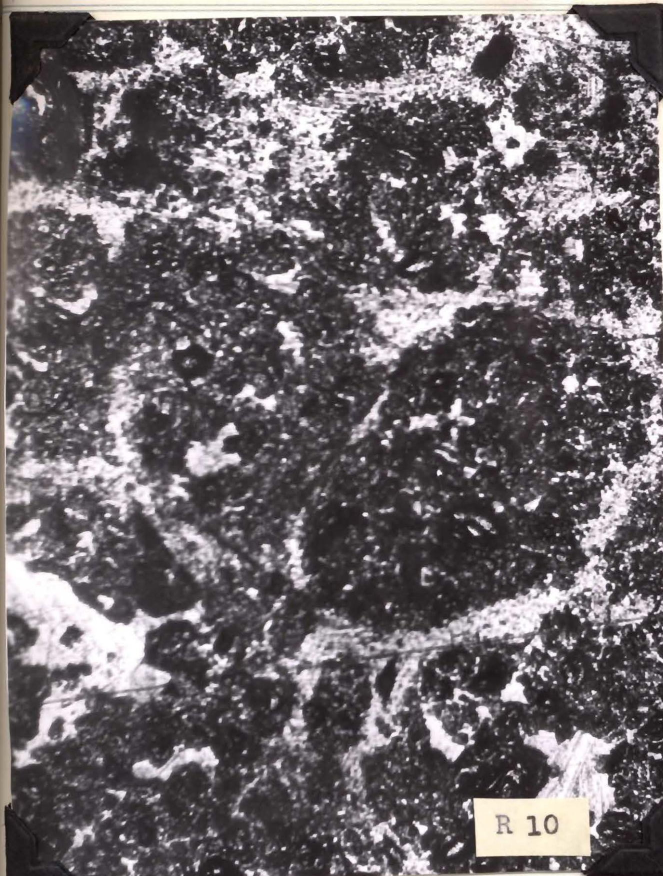
PLATE 3

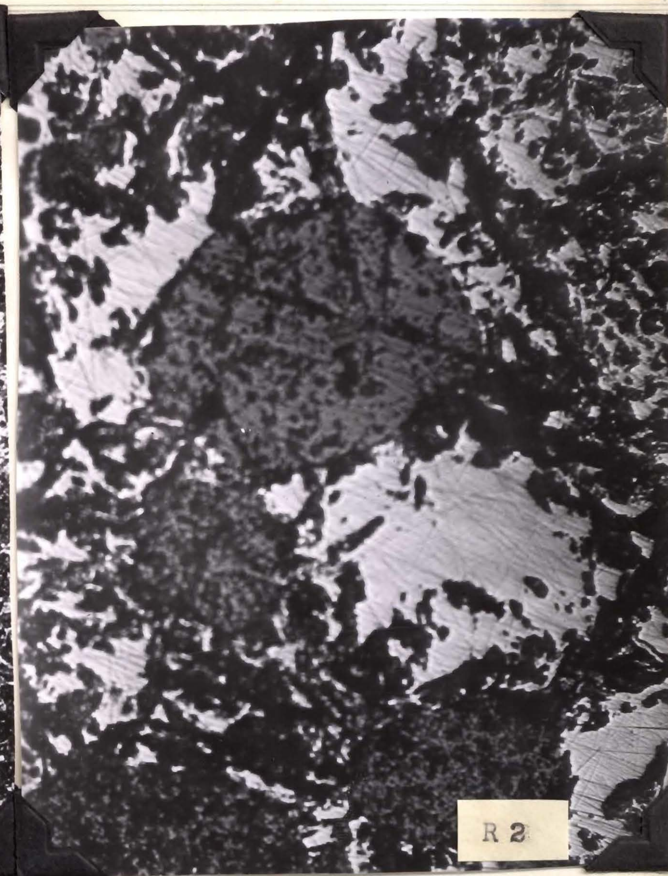
No. R10 Magnetite Ore - fine grained
Magnetite (white)
Anthophyllite (gray)
In the center of a 200' thick ore bed assaying from 61 to 69% Fe.
Polished section X68
x-section M'-M, Drill Hole 24, Depth 166'.

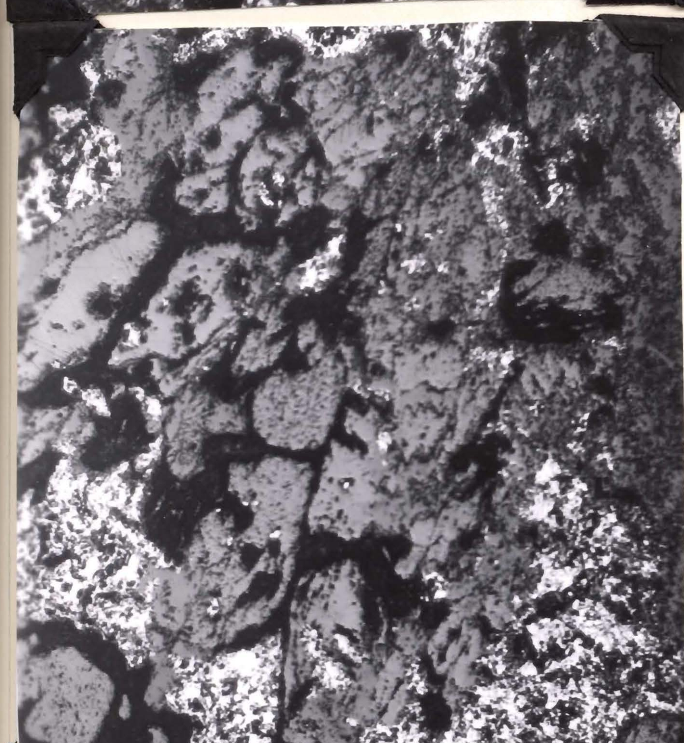
No. R2 Magnetite, Hematite Ore (30' below I.F.)
Hematite
Magnetite
Rose quartz
Anthophyllite
Chlorite
The ore zone is very porous.
Polished section X68
x-section L'-L, Drill Hole 43, Depth 470'.

No. R12 Hematite-Magnetite Ore with Silicates in a 65' thick high grade ore zone.
Hematite
Magnetite (white)
Anthophyllite (gray)
Chlorite
Total Fe is 54.56%; the magnetic Fe is 24.33%.
Polished section X68
x-section H'-H, Drill Hole 17, Depth 407'.

No. R4 Magnetite Silicated Rock below the high grade ore.
Magnetite (white)
Anthophyllite
Chlorite
Polished section X68
x-section L'-L, Drill Hole 43, Depth 290'.


R 10


R 2


R 12

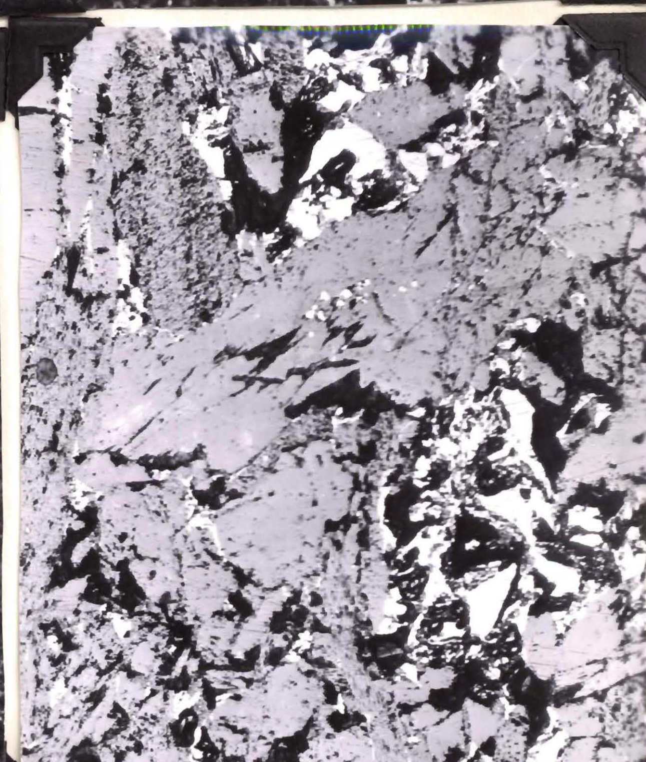

R 4

PLATE 4

<u>No. R3 Magnetic Iron Formation</u> - below high grade ore zone.
Magnetite (white)
Quartz
x-section L'-L, Drill Hole 43. Depth 273'.
Polished section X68.

<u>No. R1 Hematite Iron Formation</u> - above the ore.
Hematite
Magnetite
Orthoclase
Aglbite
Cordierite
Quartz
Altered and porous.
Polished section X68.
x-section L'-L, Drill Hole 43. Depth 273'.

<u>No. R6 Gneiss</u> - footwall.
Magnetite
Biotite
Quartz
Polished section X68.
x-section L'-L, Drill Hole 43. Depth 340'.

<u>No. R7 Gneiss</u> - footwall
Magnetite
Orthoclase
Biotite
Albite
Microline
Quartz
Polished section X68.
x-section L'-L, Drill Hole 43. Depth 417'.

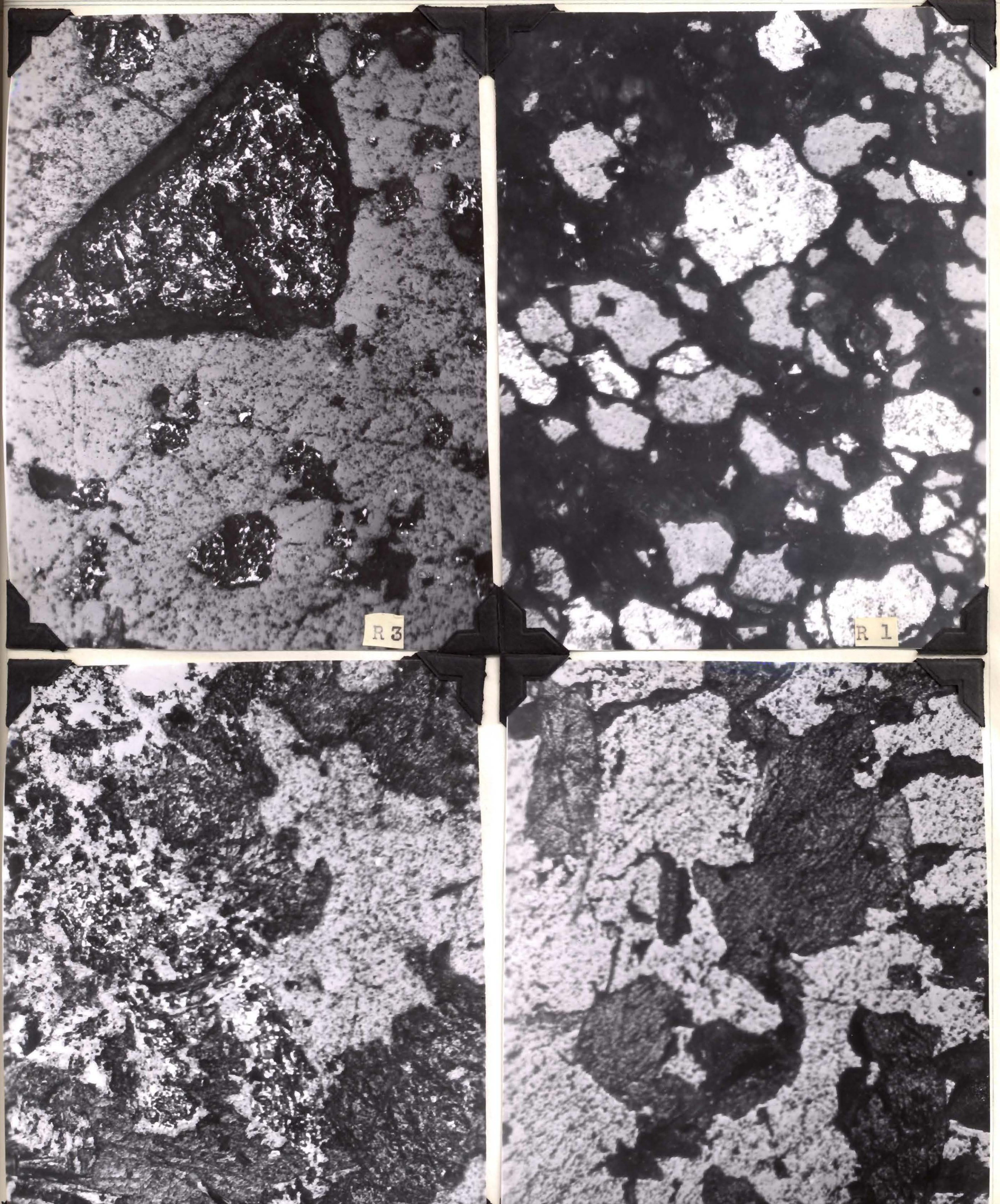


PLATE 5

Thin Sections

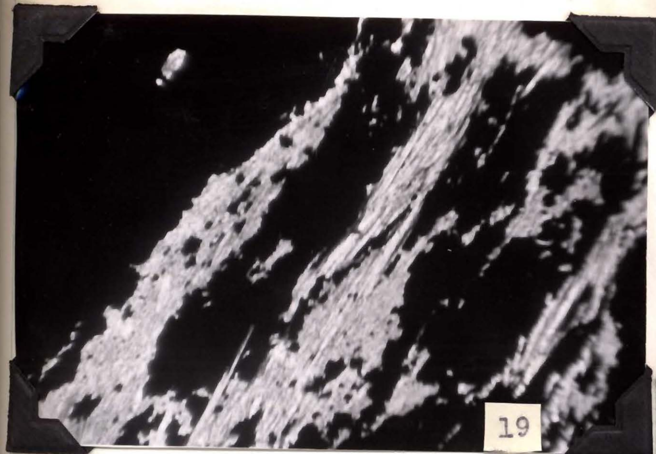
<u>No. 19 Magnetite Ore with Silicates</u>
Magnetite (black)
Anthophyllite (gray fibrous)
This is a silicate zone under high grade ore.
X180, one nicol.
x-section A'-A, Drill Hole 25, Depth 273'.

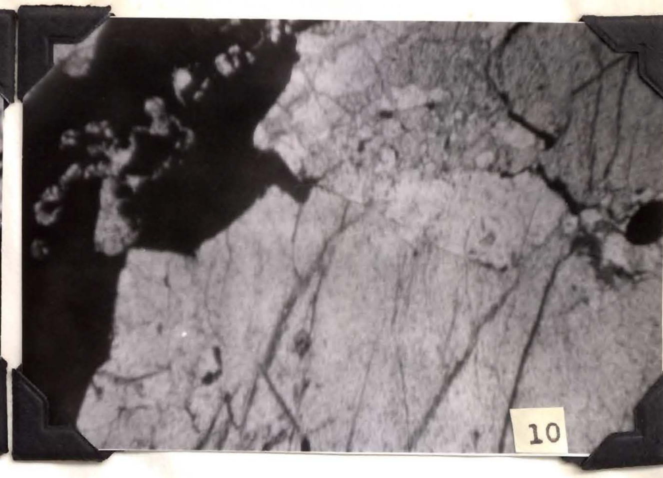
<u>No. 10 Magnetite Ore</u>
Magnetite (black)
Albite (gray large mass)
Anthophyllite (gray) in magnetite.
X180, one nicol.
x-section K'-K, Drill Hole 46, Depth 436'.

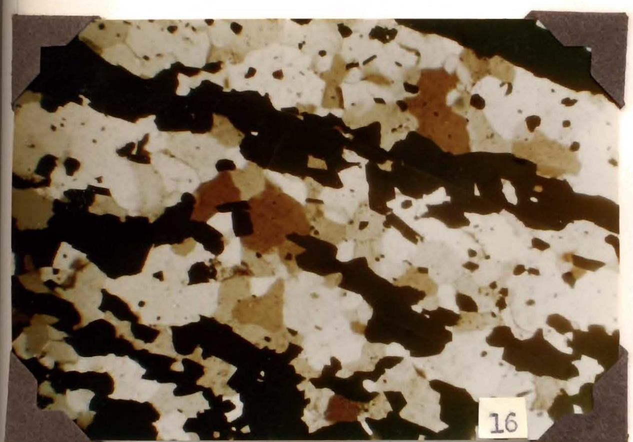
<u>No. 16 Hematitic Iron Formation</u>
Hematite and magnetite (black)
Cordierite with muscovite (tan to light)
Albite
Quartz
(Metamorphism has started out in form of recrystallization, beginning of replacement near, due to presence of small amount of muscovite).
X132, x-nicols.
x-section B'-B, Drill Hole 16, Depth 291'.

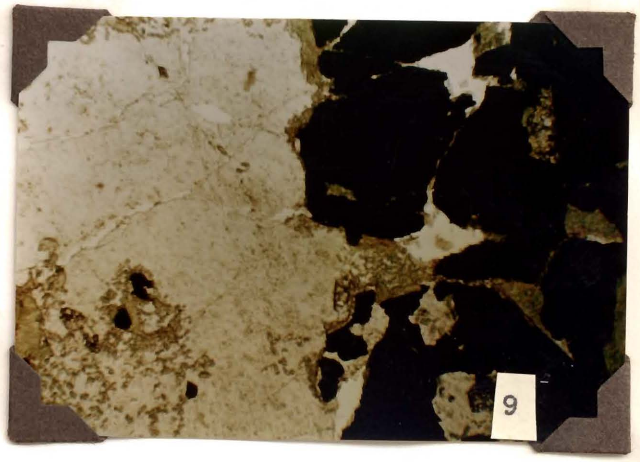
<u>No. 9 Hematitic Iron Formation</u>
Hematite and magnetite (black)
Quartz (white)
Cordierite
Chlorophyllite with muscovite and serpentine (light with specks)
Chlorite1penninete (green)
Albite
X132, one nicol
x-section D'-D, Drill Hole 36, Depth 183'.

<u>No. 22 Hematitic Iron Formation</u>
Hematite and magnetite (black)
Albite
Quartz
x-nicols
x-section A'-A, Drill Hole 22, Depth 175'.









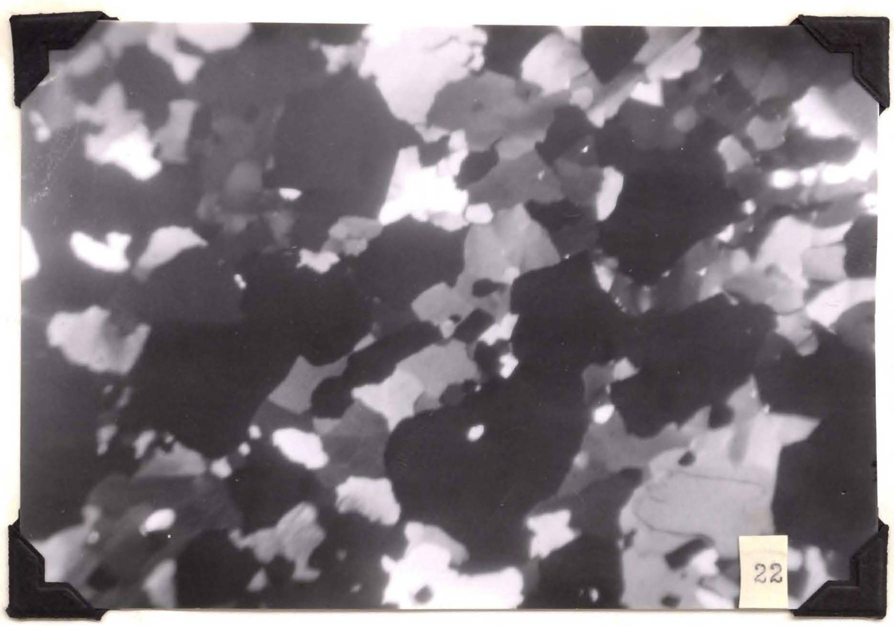


PLATE 6

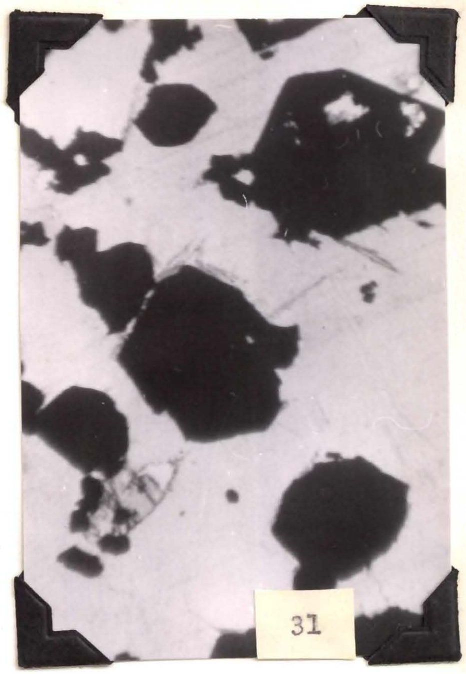
50

Thin Sections

No. 12 Magnetic Iron Formation
Magnetite (black) crystal
Quartz (light)
Muscovite (specks in quartz)
Chlorite (fibrous) at contact of magnetite and quartz.
X180, one nicol.
X-section , Drill Hole 34, Depth 154'.

No. 31 Magnetic Iron Formation (over ore, near bottom of I.F.)
Magnetite (black)
Quartz (white)
Chlorite is present elsewhere on the thin section.
X180, X-nicols.
X-section J'-J, Drill Hole 18, Depth 301'.

No. 28 Magnetic Iron Formation (over ore near bottom I. F.)
Magnetite (black)
Quartz and cordierite (white and gray).
Chlorite (fibrous)
Muscovite
Albite
Orthoclase
X-nicols
X-section A'-A, Drill Hole 29, Depth 120'.



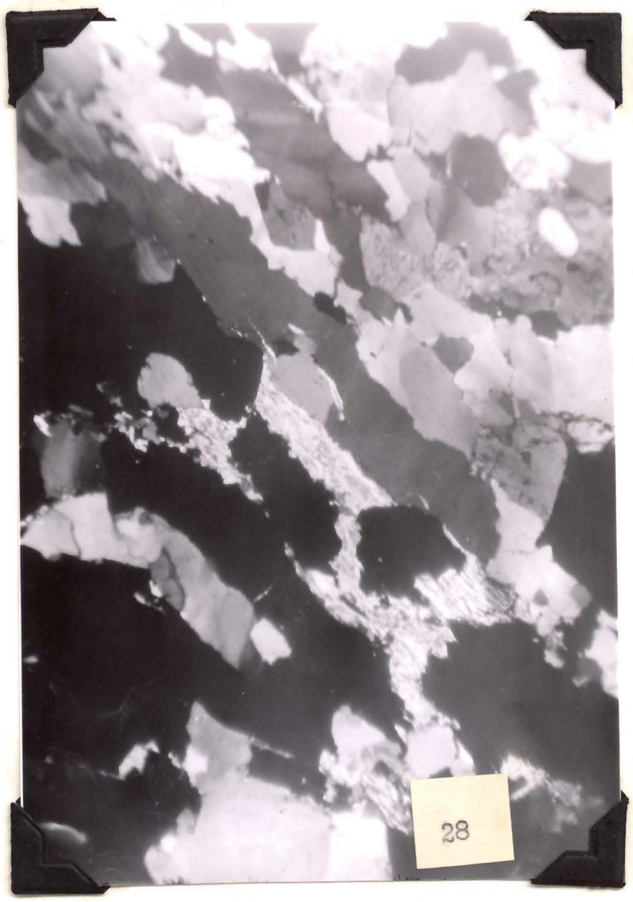


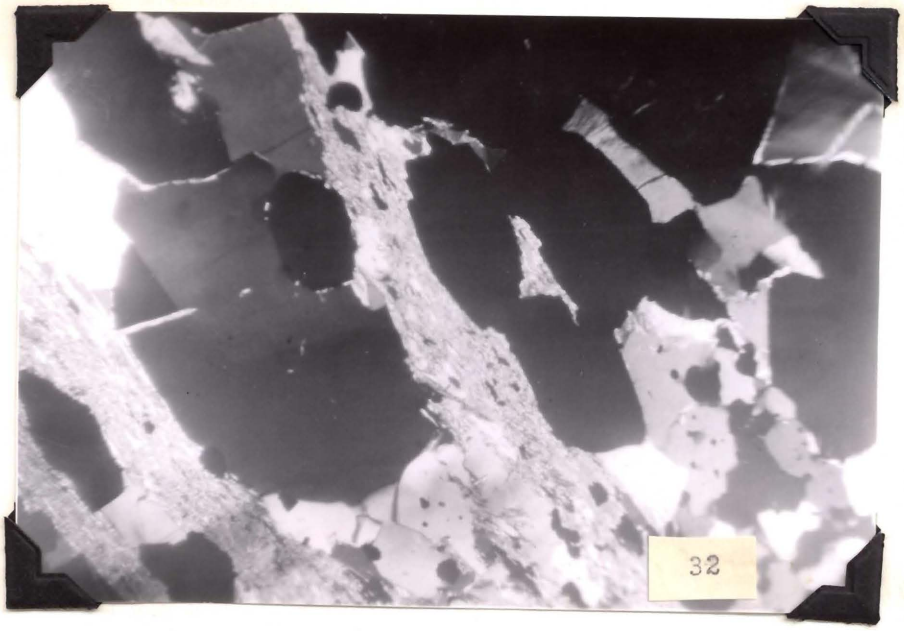
Plate 7

Thin Sections

No. 32 Magnetic Iron Formation (under ore)
Magnetite (black) euhedral to subhedral
Quartz (light to gray) well defined crystals
Chlorite (fibrous) replacing quartz
x-section L'-L, Drill Hole 43, Depth 388'.

No. 26 Magnetic Iron Formation (some ore higher up)
Magnetite (black) euhedral to subhedral
Quartz (light)
Chlorite (fibrous)
Same as sample No. 32.
X150, x-nicols
x-section L'-L, Drill Hole 44, Depth 228'.

No. 11 Magnetic Iron Formation (under ore)
Magnetite (black)
Quartz
Chlorite
Same as above.
X180, x-nicols.
x-section L'-L, Drill Hole 43, Depth 376'.



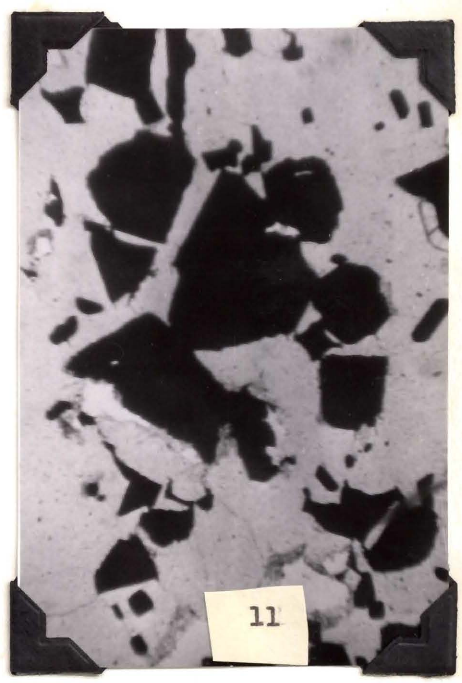


PLATE 8

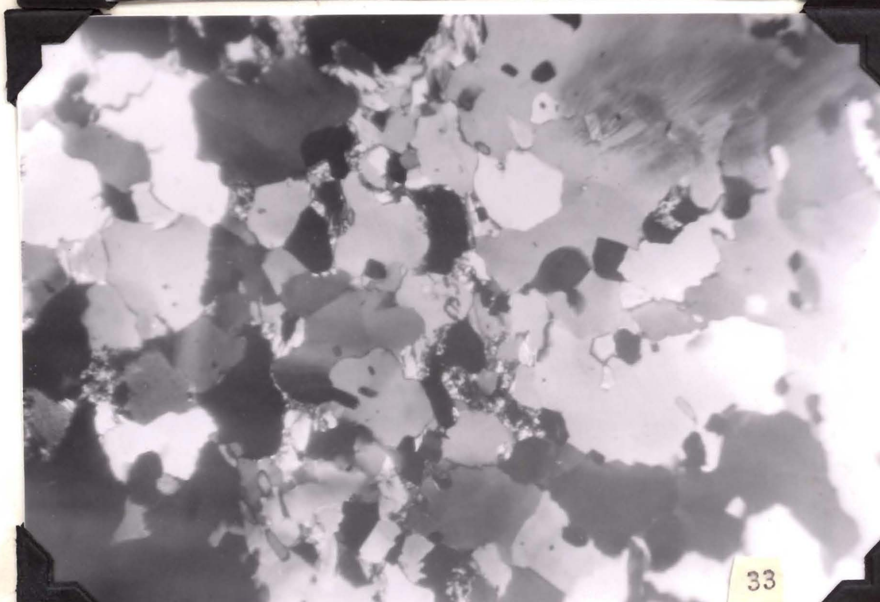
Thin Sections

No. 24 Magnetic Iron Formation (under Ore)
Magnetite (black)
Quartz (white)
Muscovite - a few isolated crystals.
Recrystallization has occurred but no replacement of minerals.
x-nicols
On East End, Drill Hole 31, Depth 561'.

No. 33 Magnetic Iron Formation (under ore)
Magnetite (black)
Quartz (white)
Hornblende (gray)
Cummingtonite
Chlorite (fibrous)
The hornblende is replacing magnetite and chlorite is replacing the hornblende. See also Sample No. 18 photo in a zone above this.
x-nicols
x-sections N'-N, Drill Hole 28, Depth 300'.

No. 23 Magnetic Iron Formation (under ore)
Magnetite (black)
Quartz
Albite
Muscovite
Banded like jasper
One nicol
x-section L'-L, Drill Hole 14, Depth 274'.

24



33

23

PLATE 9

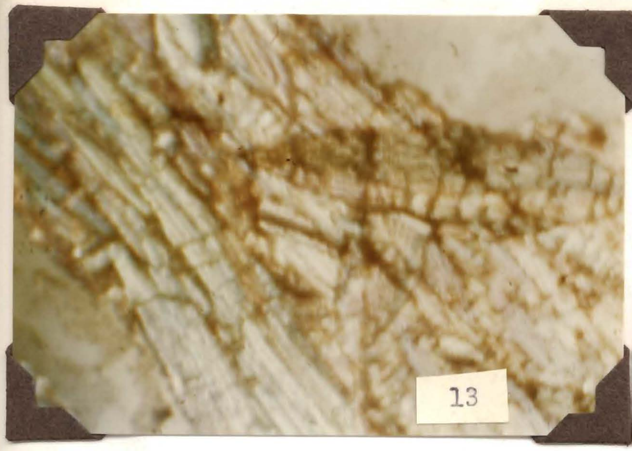
Thin Sections

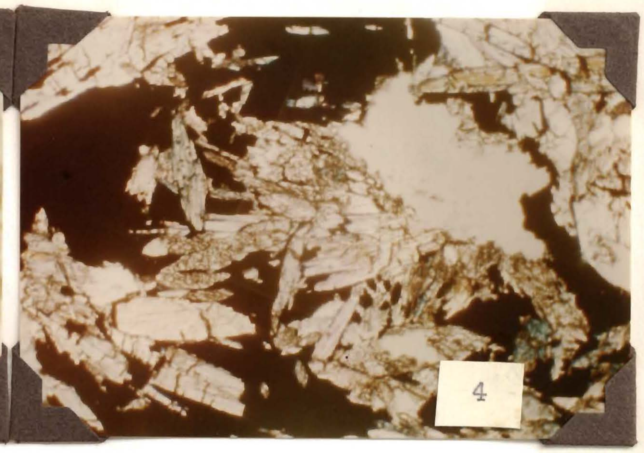
No. 13 Gneiss (Under Ore)
Magnetite, in corroded bands.
Albite
Cummingtonite
Muscovite
Chlorite
X132, x-nicols
x-section L'-L, Drill Hole 43, Depth 282'.

No. 14 Magnetite and Silicates
Magnetite, broken crystals
Cummingtonite
Anthophyllite
Chlorite
Quartz
X132, x-nicols
x-section J'-J, Drill Hole 18, Depth 100'.

No. 36 Gneiss (above ore)
Magnetite (black)
Quartz
Microline
Albite
Garnet
Biotite
Cummingtonite
Chlorite
One nicol.
X-section F'-F, Drill Hole 35, Depth 258'.

No. 34 Gneiss (above ore)
Pyrrhotite after magnetite
Biotite
Cummingtonite
Chlorite
Sericite
Quartz
One nicol
x-section H'-H, Drill Hole 23, Depth 328'.





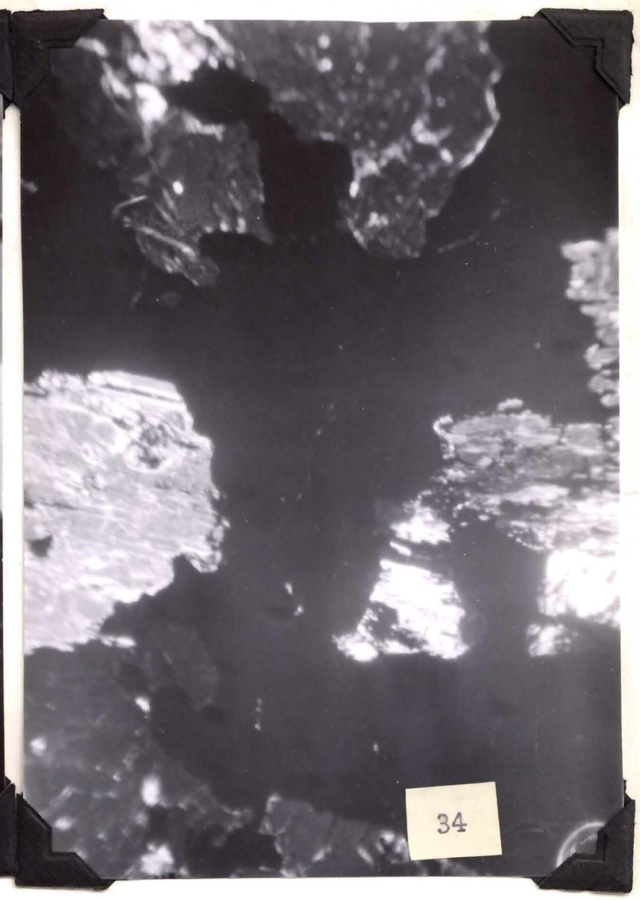


PLATE 10

Thin Sections

No. R 6 Gneiss (Under Ore)
Magnetite
Orthoclase
Albite
Biotite, Prochlorite
Quartz - 2 intergrowths
X180, x-nicols
x-section L'-L, Drill Hole 43, Depth 340'.

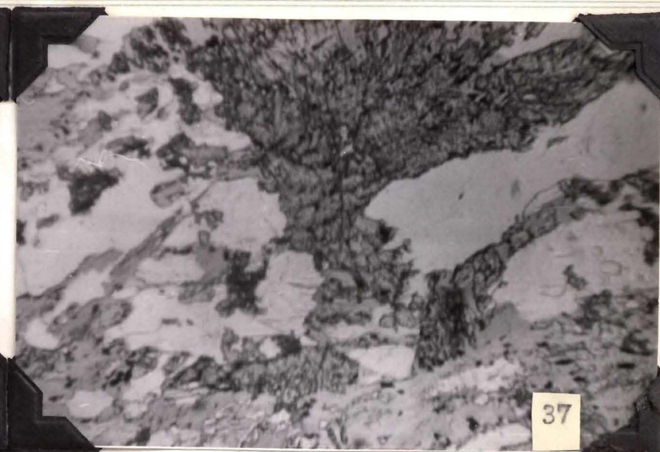
No. 37 Gneiss (Under Ore)
Magnetite
Quartz
Biotite
Chlorite
X180, one nicol
x-section B'-B, Drill Hole 27, Depth 365'.

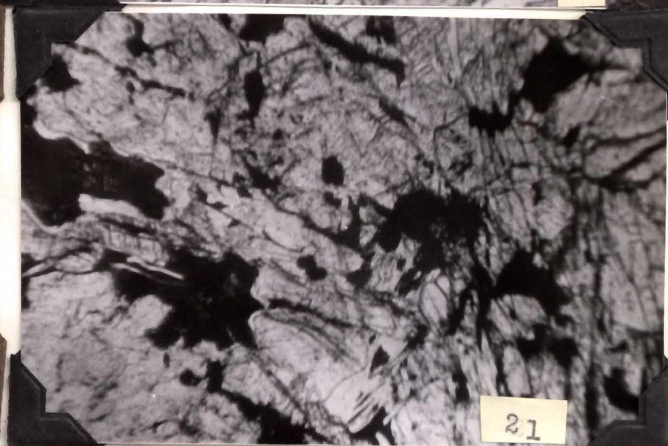
No. 15 Gneiss (Under Ore)
Magnetite (black)
Garnet
Biotite
Chlorite
Quartz
x-section P'-P, Drill Hole 39, Depth 261'.

No. 21 Gneiss (Under Ore)
Magnetite
Quartz
Albite
Biotite
Green Mica
Chlorite
X180, one nicol
x-section J'-J, Drill Hole 20, Depth 272'.

No. 18 Gneiss (Under Ore)
Garnet
Biotite
Albite
Chlorite
Serpentine
Quartz
x-section N'-N, Drill Hole 28, Depth 258'.

No. 25 Gneiss (Under Ore)
Magnetite (black)
Quartz (white-gray)
X , one nicol
x-section P'-P, Drill Hole 41, Depth 287'.





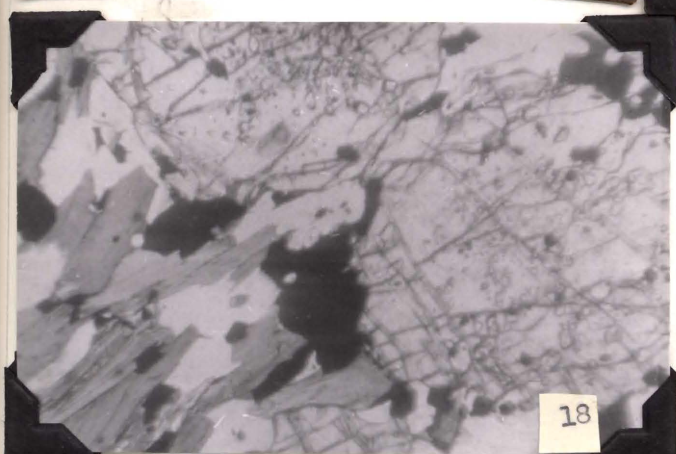


PLATE 11

THIN SECTIONS

<u>No. R20 SCHIST</u>
MAGNETITE
CUMMINGTONITE
GREEN MICA
CHLORITE
QUARTZ - MOSTLY GREEN ISOTROPIC
X180, X-NICOLS
X-SECTION D'-D, DRILL HOLE 36, DEPTH 250'.

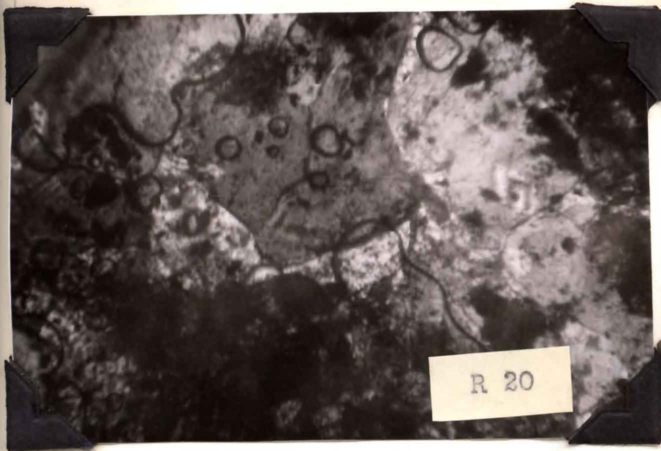
<u>No. 8 SCHIST</u>, GNEISSIC
MAGNETITE
QUARTZ
CUMMINGTONITE
CHLORITE
PYRITE IN THE MAGNETITE
X132, ONE NICOL
X-SECTION D'-D, DRILL HOLE 36, DEPTH 259'.

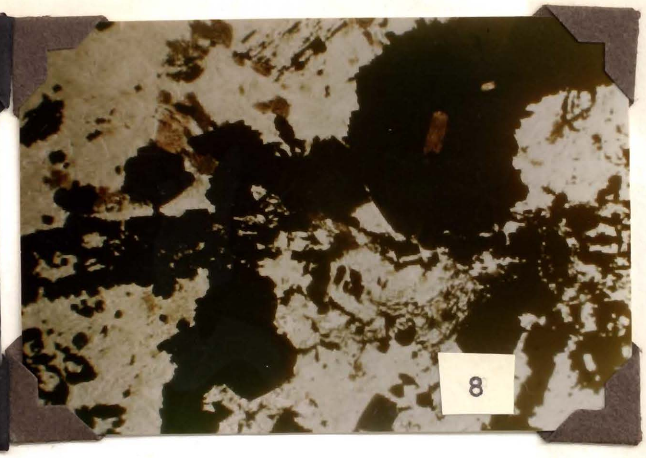
<u>No. R16 SCHIST</u>
MAGNETITE
QUARTZ
CUMMINGTONITE
CHLORITE
X180, X-NICOLS
X-SECTION H'-H, DRILL HOLE 17, DEPTH 281'.

<u>No. 14 SCHIST</u>
QUARTZ
BIOTITE
CUMMINGTONITE
CHLORITE
SERPENTINE
X132, ONE NICOL
X-SECTION H'-H, DRILL HOLE 17, DEPTH 295'.

<u>No. 20 SCHIST</u>
HEMATITE
QUARTZ
BIOTITE
EPIDOTE
CHLORITE
SERPENTINE
X180, ONE NICOL
X-SECTION A'-A, DRILL HOLE 22, DEPTH 222'.

<u>No. R19 SCHIST</u>
MAGNETITE, REMAINDER MOSTLY GREEN
X180, X-NICOLS
X-SECTION B'-B, DRILL HOLE 27, DEPTH 290'.


R 20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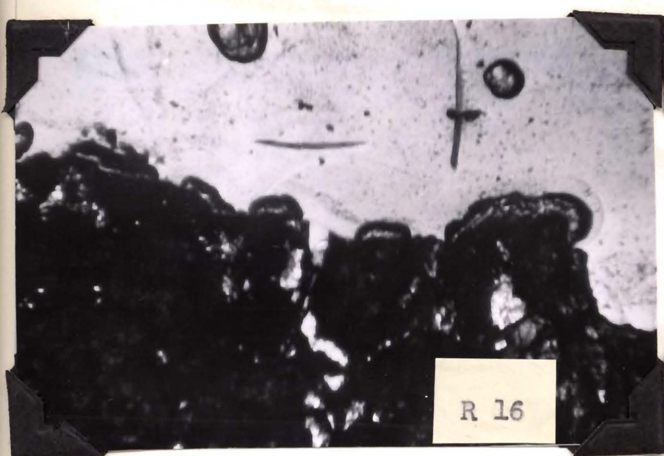
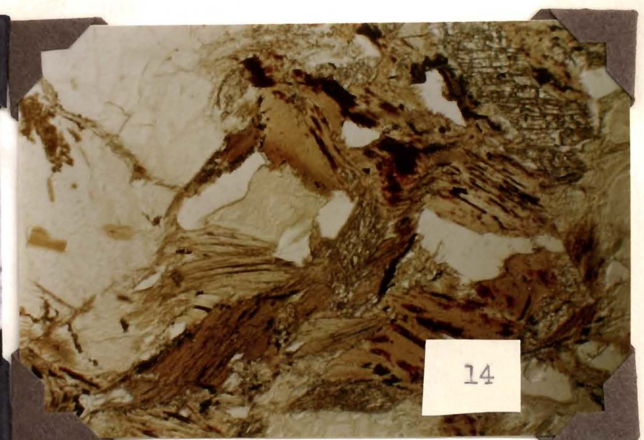

R 16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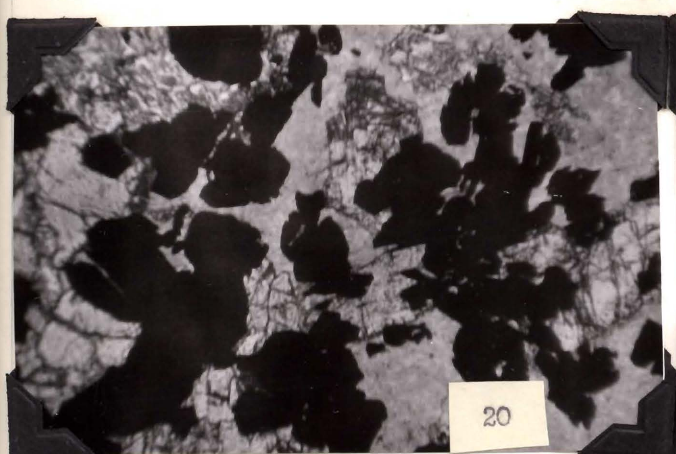
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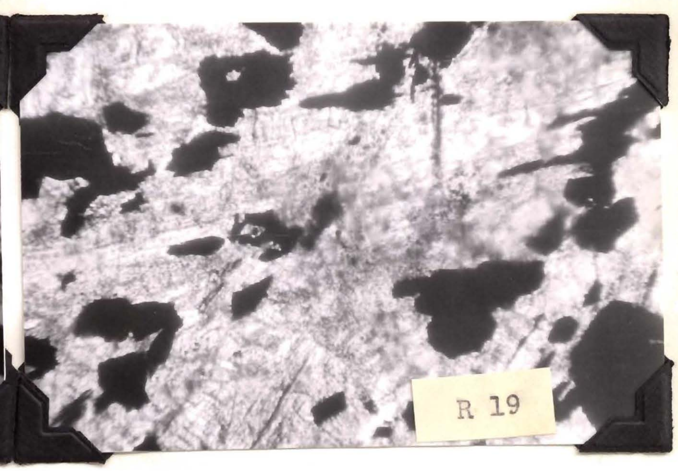

R 19

PLATE 12

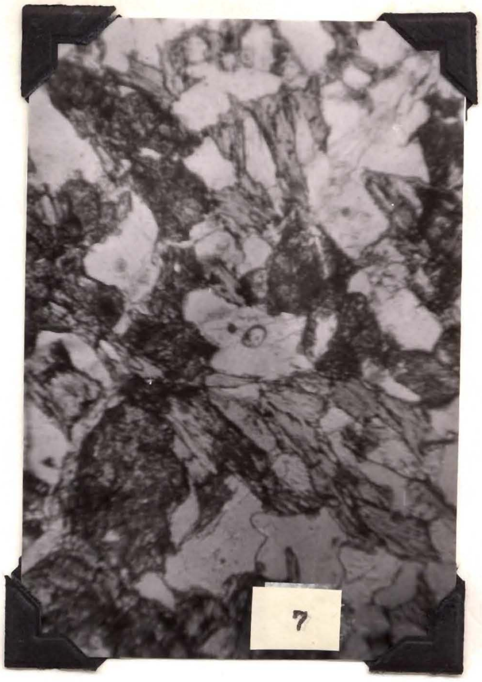
Thin Sections

<u>No. 7 Schist, gneissic</u>
Quartz
Biotite
Epidote
Cummingtonite
Chlorite
Serpentine
X180, one nicol
x-section H'-H, Drill Hole 23, Depth 168'.

<u>No. R17 Schist</u> - weathered
Magnetite
Quartz
Cummingtonite
Chlorite
Pyrite
X180, one nicol
Elevation 735
Co-ordinate 25,100 N, 19,900 E.

<u>No. 27 Schist, gneissic</u>
Magnetite
Pyrite after magnetite
Quartz
Biotite
Cummingtonite
Prochlorite
X132, x-nicols
x-section J'-J, Drill Hole 20, Depth 259'.

<u>No. 29 Schist</u>
Magnetite
Quartz
Hornblende
Biotite
Chlorite
X132, x-nicols
x-section L'-L, Drill Hole 43, Depth 243'.



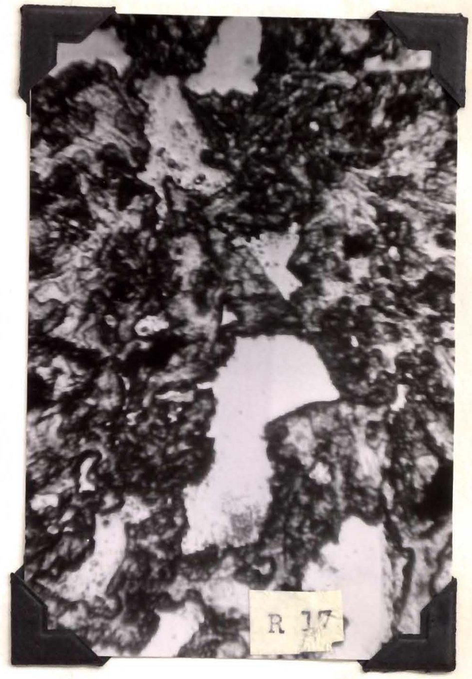


PLATE 13

No. 30 Granite (Pink)
Quartz
Orthoclase
Microline
Albite
Muscovite
Biotite
Chlorite
Serpentine
Sericite
X180, one nicol
X-section J'-J, Drill Hole 18, Depth 639'.

No. R 8 Granite
Quartz
Albite
Microline
Muscovite
Sericite
X180, one nicol
X-section L'-L, Drill Hole 43, Depth 129'.

No. 35 Pink Gneissic Granite
Quartz
Oligoclase
Muscovite
Albite
Orthoclase
Chlorite - penninite
Sericite (most recent)
X180, X-nicols
East End, Drill Hole 31, Depth 97'.


30


R 8


35

PLATE 14

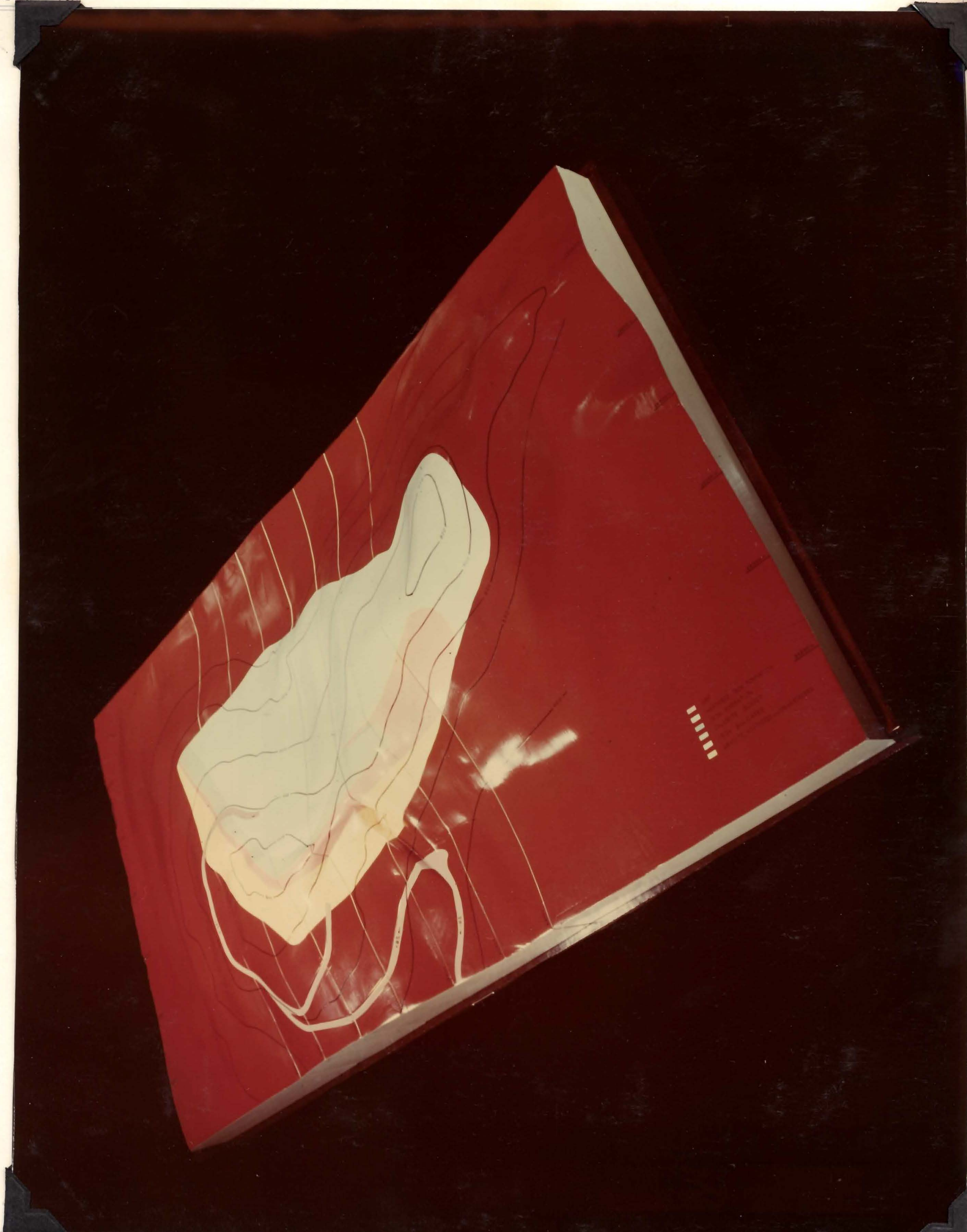


PLATE 15

PLATE 16

Bibliography Cited

1. Bell, Gordon L.: Geology of the Pre-Cambrian Metamorphic Terrane Farmington Mountains, Utah. P. 9-43. A thesis. Printed in the Guidebook to the Geology of Utah, 1948.

2. Fitzhugh, E. F. Jr.: Iron Ores of Bomi Hill, Skillings Mining Review, 1952, and Personal Communication on Silica, 1954.

3. Gillies, Donald: Oral Communication, 1953, Mining Consultant Republic Steel Corporation, Cleveland, Ohio.

4. Gruner, J. W.: General Geology of the Vermillion Range. Unpublished Paper, 1951.

5. Gruner, J. W.: Oral Communication, 1954.

6. Gruner, J. W.: The Origin of the Sedimentary Iron Formation: The Biwabik Formation of the Mesabi Range, Econ. Geol., Vol. 17: P.407-460.

7. Lerch Brothers Laboratories, Hibbing, Minnesota, Assays for U.S.G.S., 1945: Personal communication, S. G. Lawrence, Vice Pres.

8. Liberia Mining Company: 70 Pine Street, New York, N. Y. Bomi Hill Mining Plan by: R. I. Erickson, 1952.

9. Mackin, J. Hoover: Guidebook to the Geology of Utah, 1947.

10. Moore, E. S. and Maynard, J. E.: Solution, transportation and precipitation of silica. Econ. Geol., 24:p.272-303; 365-402; 506-572, 1929.

11. Newhouse, W. H., Thayer, T. P., and Butler, A. P.: Report on the Geological Mission to Liberia, 1945, Open File, Not Published, U.S.G.S. Washington, D. C.

12. Textor Laboratories, Cleveland, Ohio.

13. Thayer, T. P.: Iron Ore Deposits of Liberia, Geological Society of America, Vol. 63, December 1952, p. 1303.

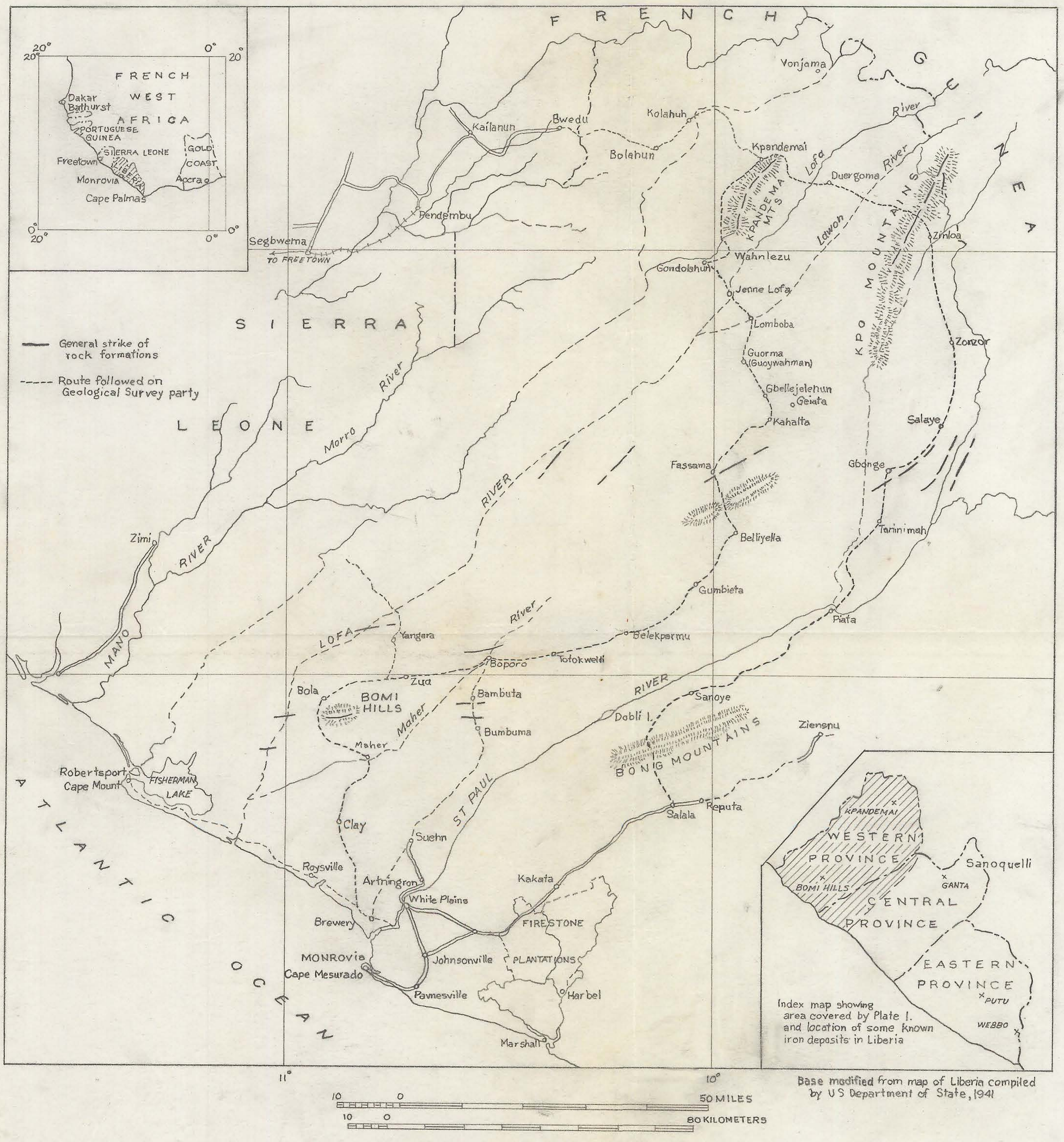
DRAWING No. 1


DISTANCE FROM EXISTING R.R. YARD
TO PROPOSED NEW MILL SITE 18800 FT.
[TRIL TRACK IS ADDITIONAL]
EAST DUMP No 1 6 000 000 CU. YD.
SOUTH TOE OF EAST DUMP No 1
SOUTH LIMIT OF FE FORMATION
PROPOSED NEW MILL
SHEET No 1
LIBERIA MINING COMPANY LTD.
ENGINEERING DEPARTMENT
PLAN OF EXISTING AND FUTURE ROADS
ALSO PROPOSED NEW MILL SITE AND RAILROAD TO THE MILL
DRAFT
DRAWN
APPROVED
SEEN

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
REPUBLIC OF LIBERIA

PLATE 1



MAP OF THE WESTERN PART OF LIBERIA, SHOWING THE PRINCIPAL IRON DEPOSITS, THE STRIKE OF THE ROCK FORMATIONS, AND THE ROUTE FOLLOWED BY THE GEOLOGICAL SURVEY PARTY