TRIP D

ECONOMIC GEOLOGY OF INTERNATIONAL TALC AND BENSON IRON MINES

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ABSTRACT

Since 1964 International Talc Co. has mined commercial talc from its open pit at Fowler, New York. The minable product is tremolite-talc schist, a Grenville metasedimentary unit of the Balmat-Edwards district. Production of 80,000 tons annually accounts for 45 percent of New York State talc. The mineralogy of this complexly folded, Mg-rich unit is typical greenschist facies. The petrogenesis is complex and speculative, but replacement and/or isochemical metamorphism is suggested.

Iron ore, principally magnetite and hematite, are extracted by open pit methods at Benson Mines, New York. The 2.5 mile-long pit is located in the overturned eastern limb of a northerly-plunging syncline. Ore occurs disseminated in Grenville gneisses that average 23 percent iron. Average annual tonnage is 1.1 million, which yields a concentrate of 62 percent iron. A metasedimentary or replacement origin is postulated.

ACKNOWLEDGEMENT

We wish to thank Mr. Fred Totten and Mr. Peter Rocca of International Talc and Mr. Richard Harker and Mr. Grant Fleck of Jones and Laughlin for their continued cooperation and assistance in making this field trip possible.

STOP DESCRIPTIONS

Stop 1. International Talc Open Pit (Fig. 1) New York talc was originally discovered by Colonel Henry Palmer and in 1878 he opened the first commercial talc mine in New York at Talcville. Over the past 93 years talc has steadily grown in economic importance. Commercial talc from the Balmat-Edwards district is the only source in New York State and accounts for 22 percent of U.S. production or approximately 200,000 tons per year.

All of the producing and abandoned talc mines were underground operations until 1964 when International Talc started production from their open pit at Fowler. All mining operations in the district are confined to unit 13, a tremolite-talc schist that varies in thickness from 0 to 400 feet. It can be traced more or less continuously from Balmat to Edwards, some 10 miles.

Regional Geology

The Balmat-Edwards belt is a northeast - trending marble belt approximately 10 miles long and ½ to 2 miles wide. It is part of the Grenville metasedimentary sequence of northern New York. Within the marble belt 16 lithologic units have been identified (Brown and Engel, 1956). These stratigraphic units can be traced with a fair degree of accuracy, the entire length of the belt. They are numbered 1 to 16 with number 1 presumably oldest (Table 1, Fig. 2). All units have been extensively folded and there is abundant evidence of cross-folding, flowage, and intricate contortions. The interested reader is referred to Brown and Engel (1956), Buddington and Leonard (1962), and Lea and Dill (1968) for complete descriptions and detailed maps. The area has been subjected to regional metamorphism of the upper amphibolite and lower granulite facies. This high grade metamorphism is characteristic of the silicate gneisses that surround the Balmat-Edwards marble belt. However, the marble itself exhibits a mineralogy typical of greenschist and lower amphibolite facies.

Mine Geology

Structure

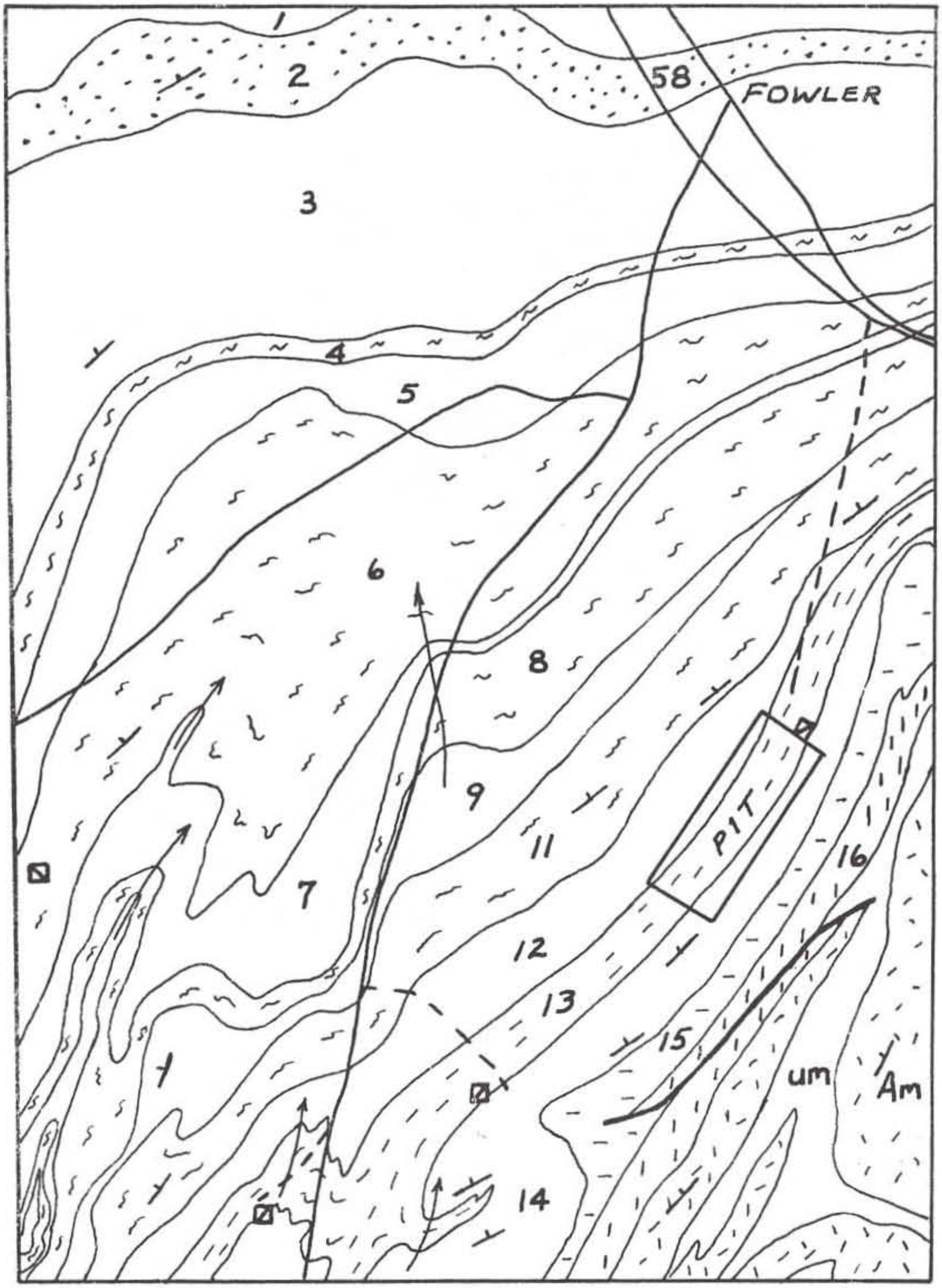
The International Talc Co. open pit is located in the tremolite-talc schist of unit 13 of the Balmat-Edwards district (Fig. 2). Initial stripping of overburden was begun in 1962 and production started in 1964. Since that time the pit has been expanded to its present size of 1200 x 450 feet with a depth of approximately 60 feet.

Unit 13 strikes northeast and is overturned to the southeast. Dips generally vary from 45 to 50 degrees. The tremolite-talc schist persists to a proven depth of at least 1000 feet and probably greater. Along strike to the south are remains of abandoned shafts to Wight, Woodcock and American mines and the producing Gouverneur Talc mine. There is evidence of fracturing, faulting, complex folding, and boudinage in many of the exposed surfaces. Minor and major folds plunge north at 15 to 50 degrees.

Mineralogy & Chemistry

Unit 13 is generally referred to as tremolite-talc schist, these being the major minerals present. All of the common minerals found in unit 13 are listed in Table 2. Mineral compositions of unit 13 are given in Table 3.

Figure 2.



GEOLOGY OF THE FOWLER AREA

(NUMBERS REFER TO UNITS OF TABLE 1)

After Brown and Engel 1956

0 1000 2000

FEET

N

Table 1. Stratigraphic units of the Balmat-Edwards district (pre sumably oldest at bottom).

16	-	Median gneiss
15	-	Rusty marble
14	-	Calcitic-dolomitic marble
13	-	Tremolite-talc schist
12	-	Dolomitic marble
11	-	Dolomitic-diopside marble
10	-	Anhydrite-gypsum marble (not exposed)
9	-	Dolomitic marble
8	-	Silicated dolomite
7	-	Dolomitic marble
6	-	Silicated dolomite
5	-	Dolomitic marble
4	-	Silicated dolomite
3	-	Dolomitic marble
2	-	Pyritic schist
1	-	Dolomitic marble

Table 2. Common minerals of unit 13.

Diopside	$CaMgSi_2O_6$
Tremolite	$Ca_2Mg_5Si_8O_{22}(OH)_2$
Anthophyllite	$Mg_7Si_8O_{22}(OH)_2$
Serpentine	$Mg_6Si_4O_{10}(OH)_8$
Talc	$Mg_3Si_4O_{10}(OH)_2$
Dolomite	$CaMg(CO_3)_2$
Calcite	$CaCO_3$
Quartz	SiO_2
Anhydrite	$CaSO_4$
Biotite	$K(MgFe)_3(AlSi_3)O_{10}(OH)_2$
K-feldspar	$KAlSi_3O_8$
Phlogopite	$K(Mg)_3(AlSi_3)O_{10}(OH)_2$
Pyrite	FeS_2

Table 3. Mineral composition of talc unit (volume %). (after Brown and Engel, 1956)

	1	2	3
Tremolite	38	47.6	84.8
Anthophyllite	7	38.4	4.5
Serpentine	12	4.1	4.2
Talc	24	5.4	3.2
Quartz	3.6	3.5	2.3
Calcite	14.4	3.0	0.2
Dolomite	tr	tr	-
Others	0.5	tr	0.8

1. Average of talc unit, 5th level, Woodcock Mine.
2. Commercial talc, Woodcock Mine.
3. Average of talc unit, Balmat zinc mine.

Table 4. Chemical analyses of channel samples across 5 commercial talc zones in the Balmat-Edwards district, (after Engel, 1962).

	1	2	3	4	5	Average
SiO_2	57.46	57.58	59.40	59.40	66.13	60.07
Al_2O_3	1.14	0.57	0.74	0.57	1.05	0.81
Fe_2O_3	0.23**	0.03	0.02	0.05	0.13	0.09
FeO	0.05	0.09	0.12	0.15	0.22	0.12
MnO	0.51	0.31	0.20	0.39	0.16	0.31
MgO	29.18	28.65	30.09	27.25	25.71	28.91
CaO	6.50	6.86	4.94	6.80	2.26	5.49
H_2O-	0.34	0.54	0.47	0.44	0.25	0.41
H_2O+	3.98	5.39*	4.09*	4.75*	3.86	3.86
CO_2	0.29	1.28	0.31	1.18	0.56	0.72

* = Total loss on ignition (includes CO_2)

** = Contamination (?)

The mineralogy represents typical hydrous assemblages of the greenschist facies. Distinction between tremolite, anthophyllite, and fibrous talc generally requires x-ray diffraction and/or optical examination. Most mineral percentages vary greatly throughout the schist. In general, however, the footwall (east) is tremolitic with tan serpentine (antigorite?), and the hanging wall (west) is enriched in fibrous and scaly talc.

Chemical analyses of 5 channel samples are given in Table 4. SiO_2, CaO, MgO, and H_2O total more than 98 percent.

Pleistocene

Of interest to "The Friends" are some extraordinary glacial features exposed in the pit. A conglomeratic "cement" no more than ¼ inch thick is plastered over much of the polished and striated bedrock, even in places where the glaciated surface is vertical or overhanging.

On the northwest end of the pit the overburden is typically gravel, while at the southeast it consists of a thixotropic clay. This facies change is rather abrupt and needless to say presented difficulties during stripping operations. A more complete discussion of the Pleistocene at this locality can be found in the field Trip E guide.

Economic Geology

At the northern end of the pit are the remains of the old Arnold Mine. This underground operation had 15 levels, 45 to 65 feet apart, branching from a shaft that followed the dip for 850 feet (Engel, 1962). International Talc purchased the Arnold Mine property from Loomis Talc in 1956 and began production via open pit methods in 1964.

Mining methods are relatively simple. Talc ore is drilled, blasted, and truck-hauled to the jaw crusher, which is located just north of the pit. The Telesmith jaw crusher is 36 inches wide and 20 inches between adjustable jaws. At a 6 inch spread, the crusher has a maximum capacity of 500 tons per hour. Usual runs at the pit are approximately 100 tons per hour, or lower if smaller sizes are required.

The crushed ore is screened and separated usually at 4 inches with coarser material stored and the finer material hauled to the mill. The coarse-ground ore is trucked to the mill when supply warrants.

International's pit produces an average of 80,000 tons per year. This represents 45 percent of New York talc and 9 percent of U.S. production. The value varies depending on grade. Coarse commercial talc (80 percent less than 325 mesh or 44 microns) runs $30 per ton.

Top grade talc ore (average 1.4 microns) and fiber products sell at \$90 per ton. Most of the products go to the paint and ceramic industries.

Petrogenesis

The origin of the tremolite-talc schist represents a complex problem as does that of the zinc deposits so intimately associated with the schist. There are no definitive answers, but certain facts place limits on interpretations.

1. The Balmat-Edwards district is predominantly dolomite and associated Mg-silicates.

2. The stratigraphy is reliable throughout the length of the belt.

3. Associated anhydrite, gypsum, and halite suggest an evaporite sequence.

4. Metamorphic foliation and primary layering are generally in good agreement.

5. Tremolite-talc ore was present prior to deformation.

6. Commercial talc is only found in unit 13.

Engel (1962) suggests that the talc unit is a product of the replacement of a siliceous dolomite. He notes that relict carbonate layers and lenses in the talc support this interpretation. If such a replacement occurred it was remarkably selective since tremolite and talc are almost exclusively restricted to unit 13. No other units of presumably similar composition contain commercial tremolite and talc.

Any hypothesis regarding petrogenesis must consider original composition and the stability of the present assemblage. Major variables that must be considered are T, P_1, P_{H_2O}, and P_{CO_2}. Geothermometry in the district (Engel, 1962; Lessing and Grout, 1971) indicates metamorphic temperatures of approximately 500°C. Pressures are more difficult to determine, but P_{CO_2} was probably high as suggested by coexisting quartz and dolomite and lack of dissociated carbonate. Water is a minor phase suggesting low P_{H_2O}. The stability of anthophyllite at Balmat (Greenwood, 1963) also supports a low water pressure; perhaps only 2-3 bars. Load pressure is estimated at 2-4 kilobars.

The chemical composition of the schist is essentially a hydrous calcium-magnesium silicate. A replacement origin is certainly possible as Engel has suggested. However, the stratigraphic restriction of unit 13 may indicate a metasedimentary origin that was essentially isochemical. A possible parent material of siliceous dolomite with trapped connate water would provide the necessary chemistry. Metamorphism of this unit would require the loss of CO_2 while retaining H_2O. The separation of CO_2 and H_2O may be controlled by permeability and/or osmotic pressure.

Brown and Engel (1956) have pointed out a retrograde metamorphic sequence tremolite → anthophyllite → serpentine → talc. Elsewhere, Elberty and Lessing have noted the reaction diopside → serpentine and excellent examples of dedolomitization (Fig. 3) in which Mg has been removed from dolomite to make diopside, and leaving a selvage of calcite. This phenomenon is common in diopsidic dolomites. The characteristic greenschist assemblage is in large part due to retrograde metamorphism that did not noticeably affect the surrounding gneisses.

Stop 2. Benson Mines Iron Ore Deposit (Fig. 1). The Benson Mines magnetite-hematite deposit is located on the northwest slope of the Adirondacks in the Grenville province of the Canadian Shield. Knowledge of the deposit dates back to about 1810. Production of magnetite began around 1889 and the deposit was worked intermittantly until 1941 when it was leased by Jones and Laughlin Ore Company. In 1952, a merger formed the New York Ore Division of Jones and Laughlin Steel Company. At the present time, the plant facility has an annual production capacity of about 1,100,000 long tons of magnetite and 700,000 long tons of hematite concentrates. The deposit is 400 to 600 feet thick and about 2½ miles long making it the largest known deposit of its kind.

Much of the following information was obtained from Leonard and Buddington (1964); Crump and Buetner (1968) and Palmer (1970). The reader is referred to these sources for more detailed discussion.

Regional Geology

Magnetite and hematite ores are confined to a relatively narrow horizon within a sequence of paragneisses which are infolded into granitic rocks of the Adirondack Highlands. Figure 4 shows the general geology of the area around Benson Mines. Palmer (1970, p. 31) recognizes four major units in the paragneiss sequence.

1. Mixed garnet- and pyroxene-feldspar gneiss.
2. Garnet- and sillimanite-quartz-feldspar gneiss (ore and mineralized horizon)
3. Migmatitic plagioclase gneiss.
4. Pyroxene-quartz-feldspar gneiss.

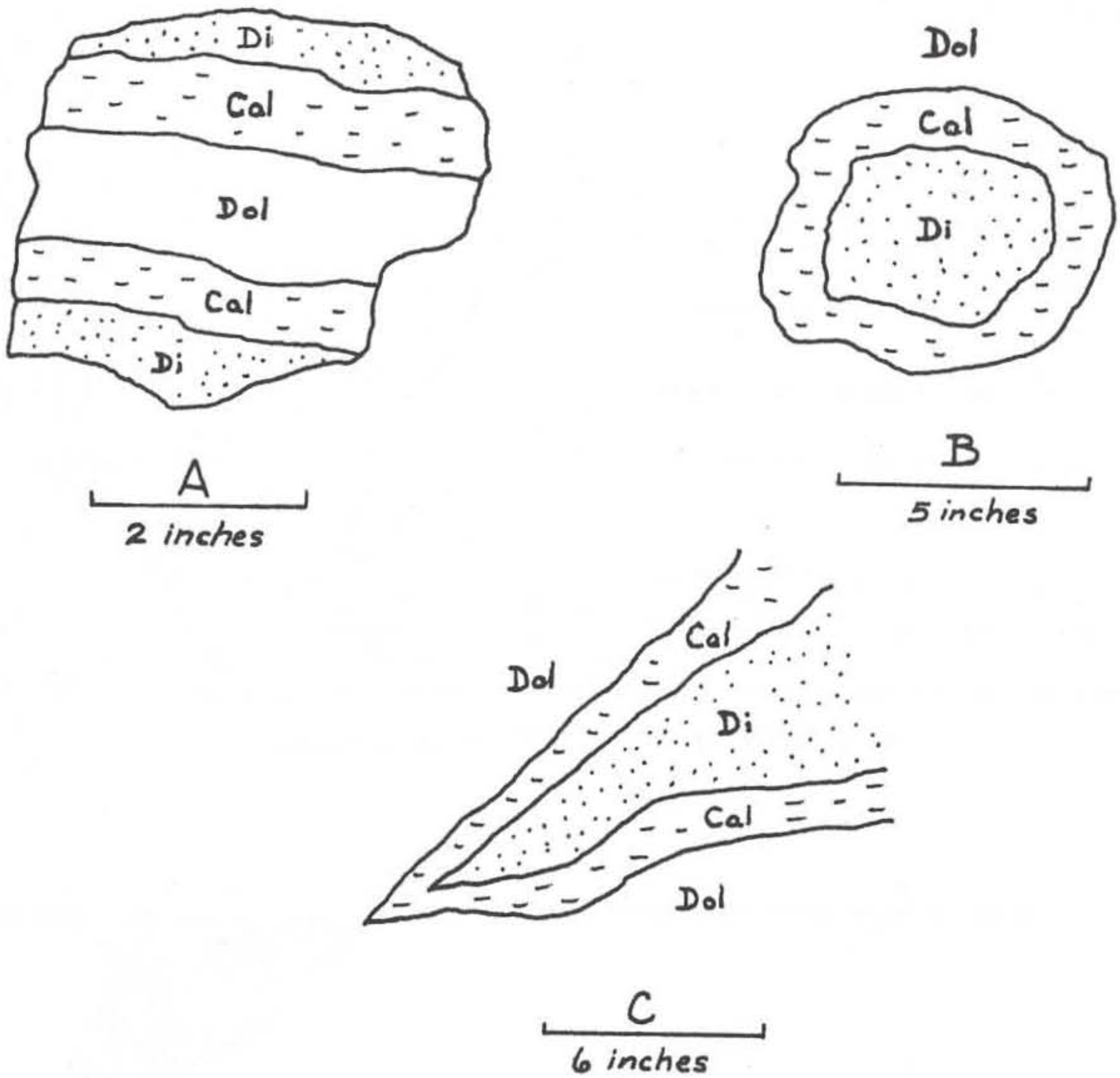
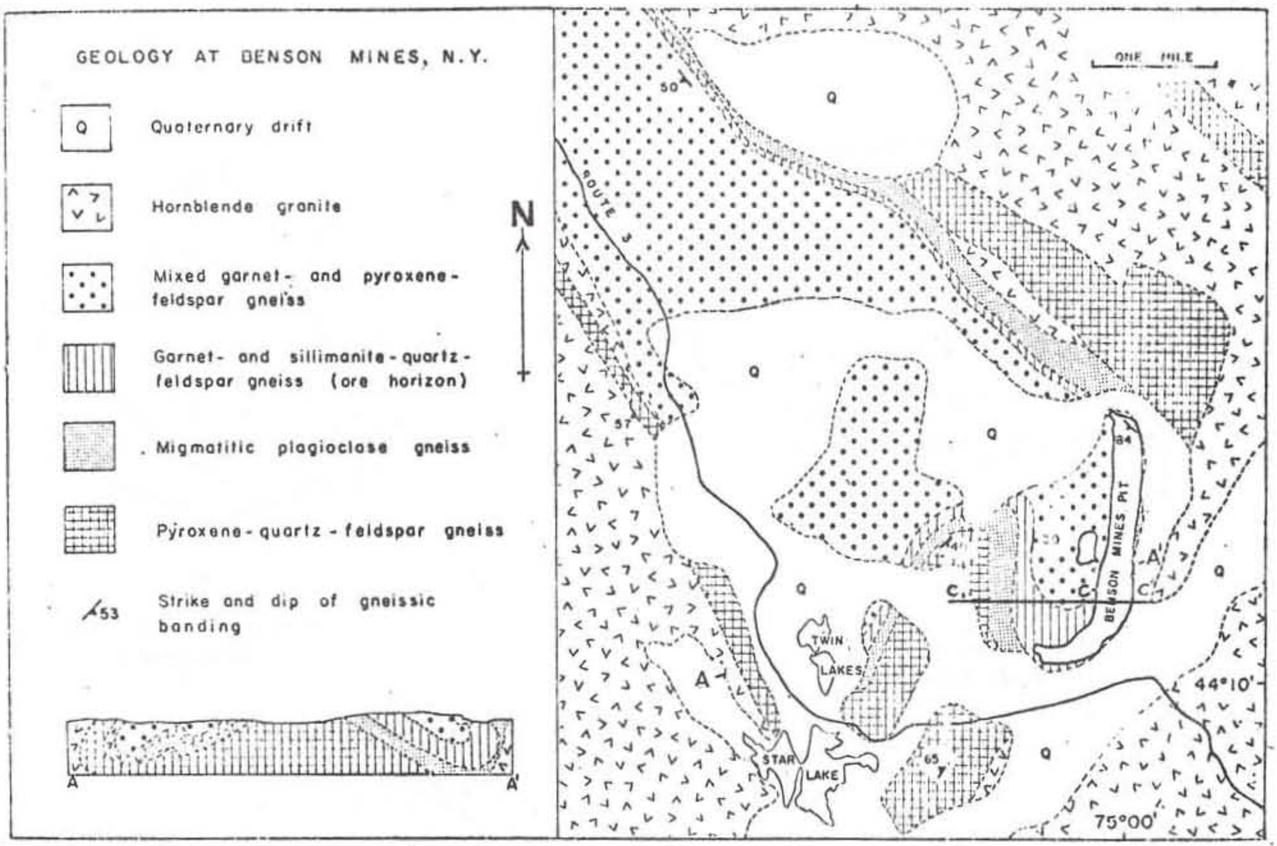


Figure 3. Examples of dedolomitization. A - layering, B - knots, C - pinchouts



SECTION OF MAJOR STRUCTURE

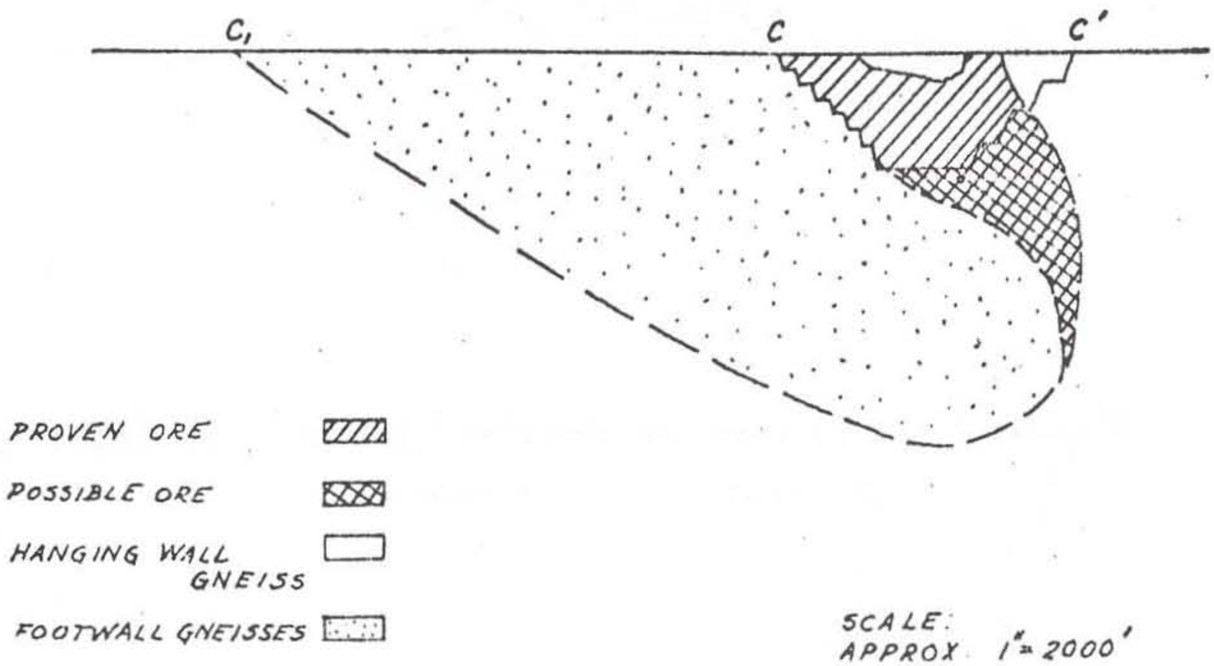


Fig. 4.- General geology of Benson Mines (after Palmer, 1970) and section showing the mine with respect to the major structure.

The surrounding crystalline rocks consist of alaskite and hornblende granites and their gneissic equivalents.

Mine Geology

The paragneisses comprise a large, structural synform overturned to the west and plunging north about 20° in the vicinity of the mine. The paragneisses are subdivided into six lithologic units: 1) hanging-wall gneiss, 2) disseminated-garnet gneiss, 3) sillimanite gneiss, 4) ferromagnesian gneiss, 5) blotchy garnet gneiss, and 6) biotite gneiss. Important concentrations of ore are confined to units 2, 3, and 4, and some ore is found in unit 5. Thicknesses, mineral composition, and appearance of the units vary considerably. Sequence is an important aid to identification within the mine. Rocks similar to those exposed in the Benson Mine have been traced approximately 8 miles along the strike.

Hanging-wall gneiss. An extremely heterogeneous unit composed of a variety of different rock types including diopside, marble, quartzite, and hornblendite in bands 5 to 50 feet thick. Most of the unit consists of pink or gray hornblende and/or pyroxene gneiss. A pink, microcline pegmatite marks the immediate hanging wall throughout the deposit. Hornblendite and diopside rock are encountered in drill holes. Minerals include quartz, orthoclase, microcline, perthite, oligoclase, biotite, muscovite, hornblende, pyroxene, chlorite, with local garnet and sillimanite near the ore contact. Common accessory minerals are apatite, zircon, leucoxene, magnetite, and hematite.

Disseminated-garnet gneiss. Largely a potash feldspar-quartz gneiss with disseminated grains of garnet. Quartz with magnetite and disseminated garnet and biotite characterize the contact with the hanging-wall gneiss. Other minerals are pyroxene, hornblende, chlorite, muscovite, sillimanite, biotite and accessory apatite, zircon, pyrite and sphene. The ore is largely magnetic and the highest-grade ore in the southern half of the ore body was concentrated in this unit. The unit varies in thickness from zero to 350 feet.

Sillimanite gneiss. This unit is generally composed of orthoclase or microcline with low quartz and ferromagnesian content. Sillimanite is a common constituent of many sections, but there are thick sections exposed in the pit and in drill cores which do not contain sillimanite. The unit averages 350 feet thick with a maximum of 650 feet. It is absent locally in the northern end of the pit. Sillimanite gneiss contains most of the non-magnetic ore and the nature of the gneiss changes with the ratio of magnetic to non-magnetic ore. Biotite, chlorite, muscovite, and accessory apatite, zircon, sphene and leucoxene may be present.

Biotite-garnet gneiss. A light-gray, coarse-grained, orthoclase-quartz-biotite rock with knots or blotches of garnet. The rock is similar to the disseminated garnet gneiss and forms the footwall of the Benson Mines ore body. Pyrite, pyrrhotite, sillimanite, magnetite, apatite and zircon are present.

Ferromagnesian gneiss. This unit contains the high-grade magnetic ore of the northern part of the mine. It is lens-shaped with a strike length of about 3300 feet, an average width of 200 feet, and it pinches out in depth. The rock contains orthoclase and quartz with the quantity of hornblende, biotite, and pyroxene varying inversely to the quantity of magnetite. Other minerals present, in more or less abundance, are garnet, pyrite, pyrrhotite, sillimanite, and accessory zircon, spinel, and apatite.

Biotite gneiss. A medium- to fine-grained quartz-feldspar gneiss with biotite and local disseminations of garnet, sillimanite, chlorite, and hornblende.

There are no sharp boundaries between any of the above units. Units containing important concentrations of ore minerals may be traced for considerable lengths. Magnetic and non-magnetic ore are generally confined to specific lithologic units (Crump and Beutner, 1968, p. 66).

Assuming some potassium metasomatism as evidenced by the presence of K-feldspar pegmatites, Palmer (1970, p. 37-38) postulates "illitic siltstones, calcareous silt or sandstone and carbonate lenses with either graywacke or soda shale" as original sediments.

In addition to the minerals mentioned in the description of the gneiss units, copper occurs rarely as native copper, chalcopyrite, chalcocite, bornite, covellite, azurite and malachite. Molybdenite occurs in pegmatite dikes and disseminated in some ore zones (Crump and Beutner, 1968, p. 61). Fluorite is present in some pegmatites.

A generalized plan and section of the major structure is given in Fig. 4 and a more detailed plan of the mine showing the distribution of the various units in Fig. 5. The ore body is located on the eastern limb of a synform, the Benson Syncline, which is overturned towards the west and plunges 20° to N30°E. Smaller folds plunge 12° to S30°W and form an anticline and syncline in the overturned east limb of the Benson Syncline. They are of economic significance because they more than double the volume of ore-bearing rock. The Amoeba pit (Fig. 5) is interpreted as the bottom of one of the subsidiary synclinal rolls developed in the eastern limb of the Benson Syncline (Crump and Beutner, 1968, p. 53-54). It is the only place where the blotchy garnet gneiss (unit 5) has been found to contain sufficient iron mineralization to constitute ore.

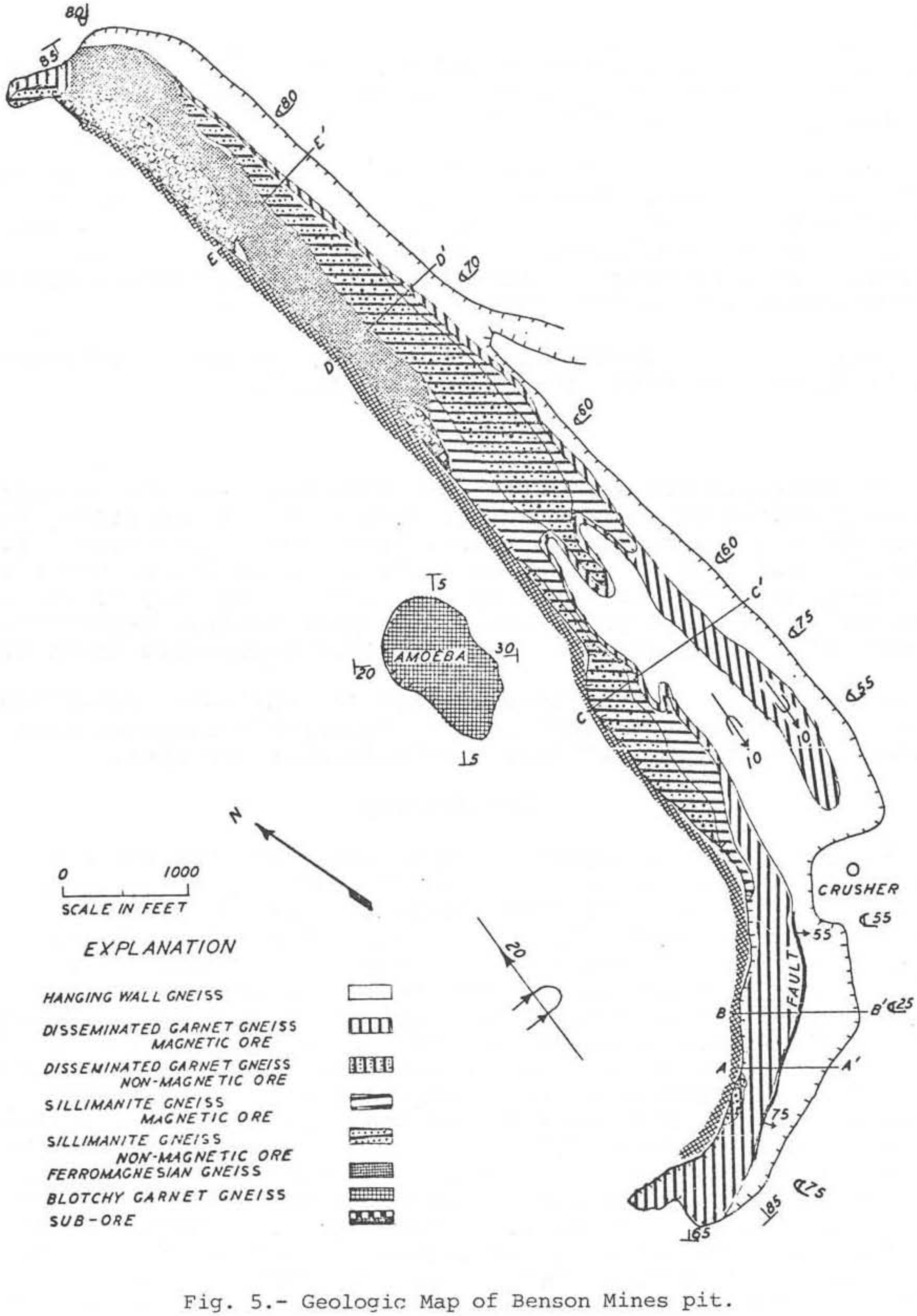


Fig. 5.- Geologic Map of Benson Mines pit.

Palmer (1970, p. 32) recognizes two stages of folding. Flow folding is shown by thickening and axial-plane schistosity in fold hinges, with accompanying mineral lineations. The latter were deformed by flexure-slip folding.

Ore is found where the stratigraphic footwall is overturned to form the structural hanging-wall. Ore stops at both the northern and southern ends of the pit where this hanging-wall relation ceases. Drilling, however, has penetrated 35 feet of ore-grade rock, resting on "hanging-wall" gneiss where there is no overturning (Crump and Beutner, 1968, p. 54).

Many of the relationships discussed above are illustrated in Fig. 6-10, with section lines given in Fig. 5.

Ore

Ore minerals are magnetite and hematite. The ore is classified as magnetic if 80 per cent or more of it is magnetite, and non-magnetic if magnetite comprises less than 80 per cent. Average grade is a function of economics. The distribution of the magnetic and non-magnetic ore is shown in Fig. 5 and a summary of their characteristics is given in Table 5. Table 6 gives representative analyses of the two kinds of ore and their respective concentrates.

Although the Benson Mines deposit is considered non-titaniferous, there is enough TiO_2 present in the concentrate obtained from the Humphrey spirals to constitute a metallurgical problem.

Ore Genesis

Palmer (1970) discusses three possible origins for the magnetite-hematite ore in the Benson Mines deposit, 1) as a product of metamorphic differentiation, 2) as an epithermal replacement in the metasediments, and 3) as a metamorphosed iron-rich sediment. Each of these origins can explain the confinement of the ore to a restricted lithologic horizon; the fact that the ores have apparently been present during deformation and recrystallization of the host rock (Hagni, et al., 1968; Palmer, 1970); the presence of hematite and magnetite in different areas of the ore deposit; etc. Leonard and Buddington (1964), Buddington (1966), and Crump and Beutner (1968) favor a hydrothermal origin, because of the lithologic heterogeneity of the host rocks; the presence of skarn; a low-angle, cross-cutting relation between the ore and the host rocks; and the presence of veins of fluorite, calcite, quartz, and other minerals typically associated with hydrothermal activity. Palmer (1970) rejects both metamorphic differentiation and hydrothermal replacement in favor of a syngenetic, metasedimentary origin. Palmer feels that the confinement of the ore to a specific horizon within the paragneiss sequence; the relatively great lateral continuity of this horizon; the lack of any evidence of replacement of the host

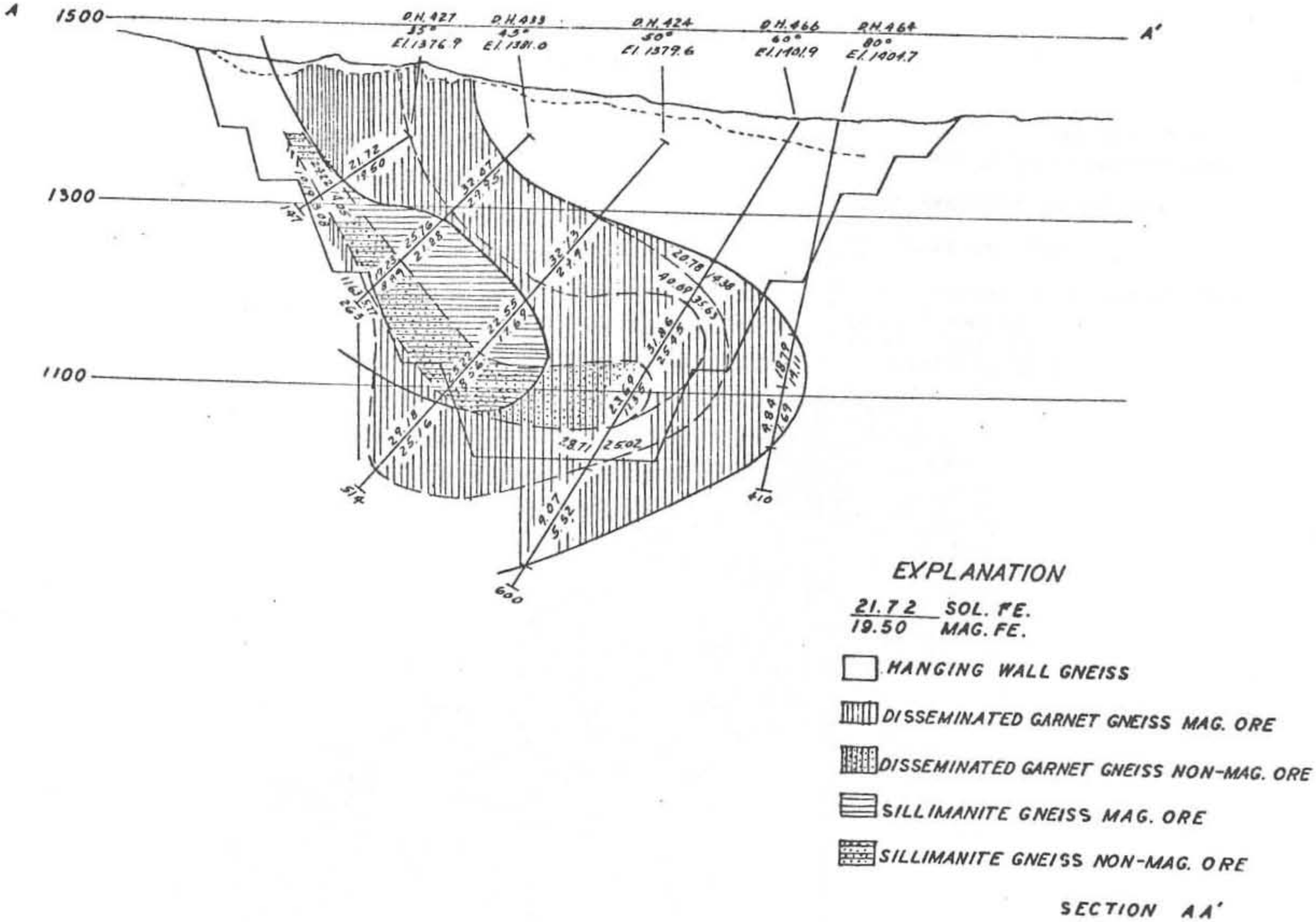


Fig. 6.- Section A-A'

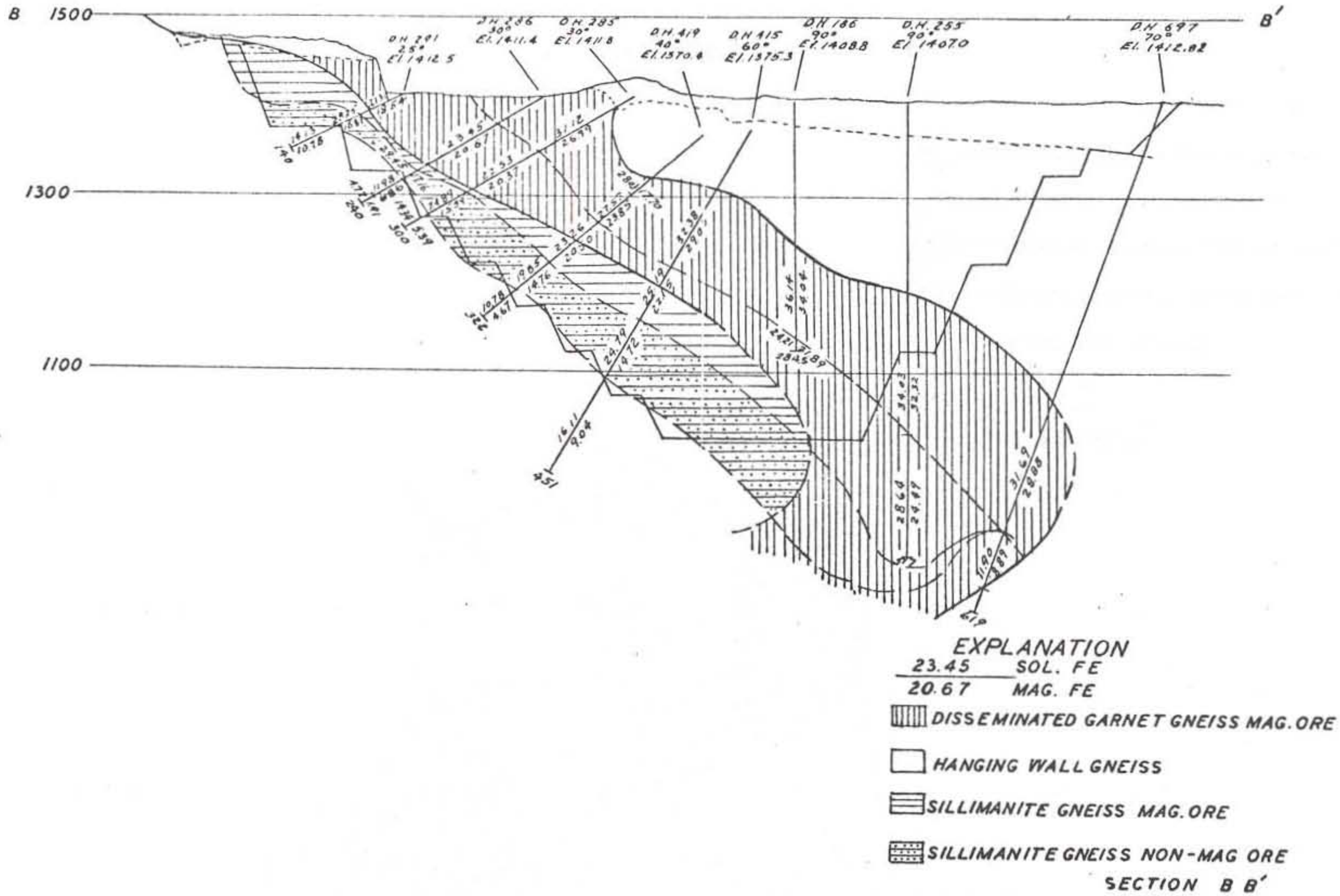


Fig. 7.- Section B-B'

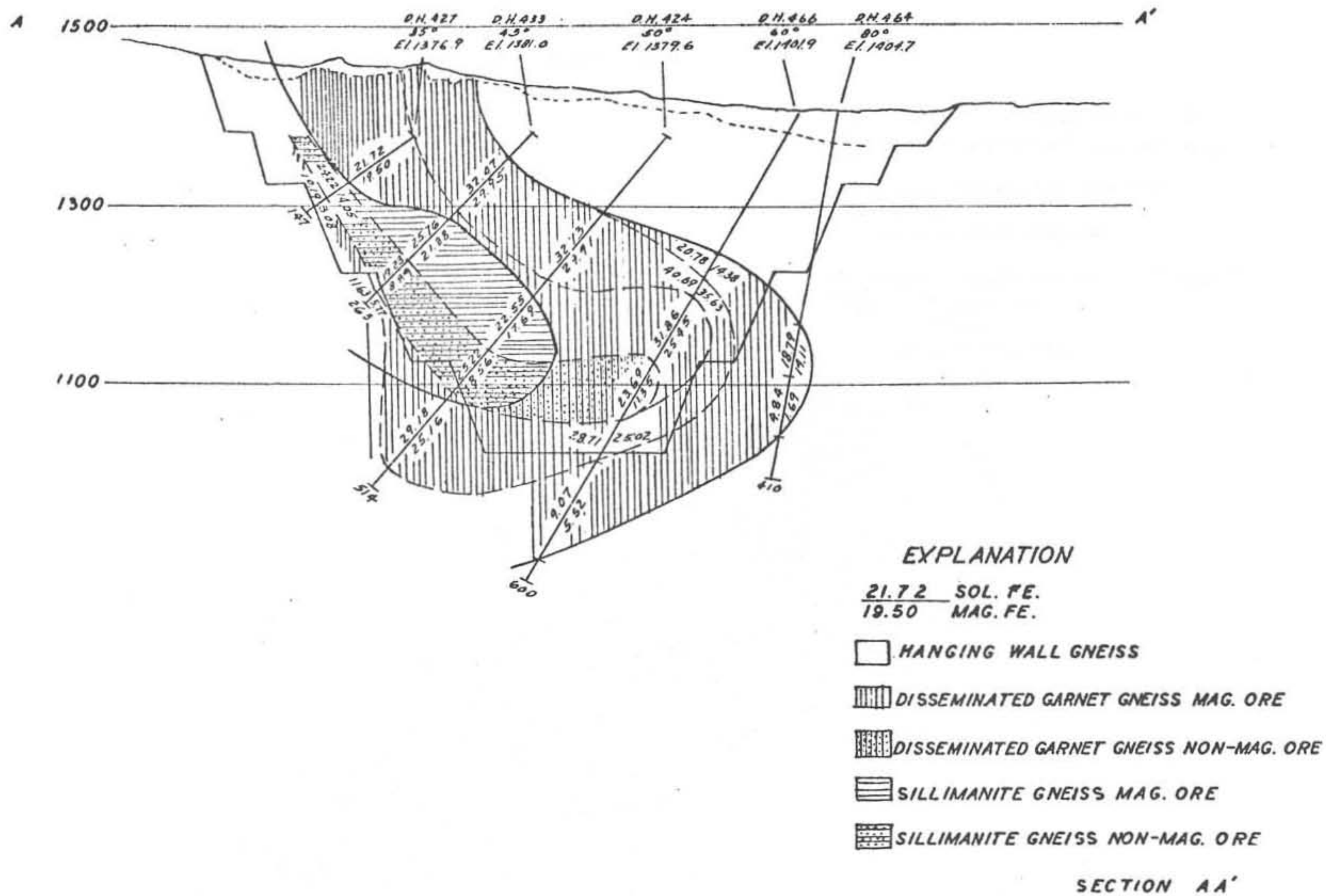


Fig. 6.- Section A-A'

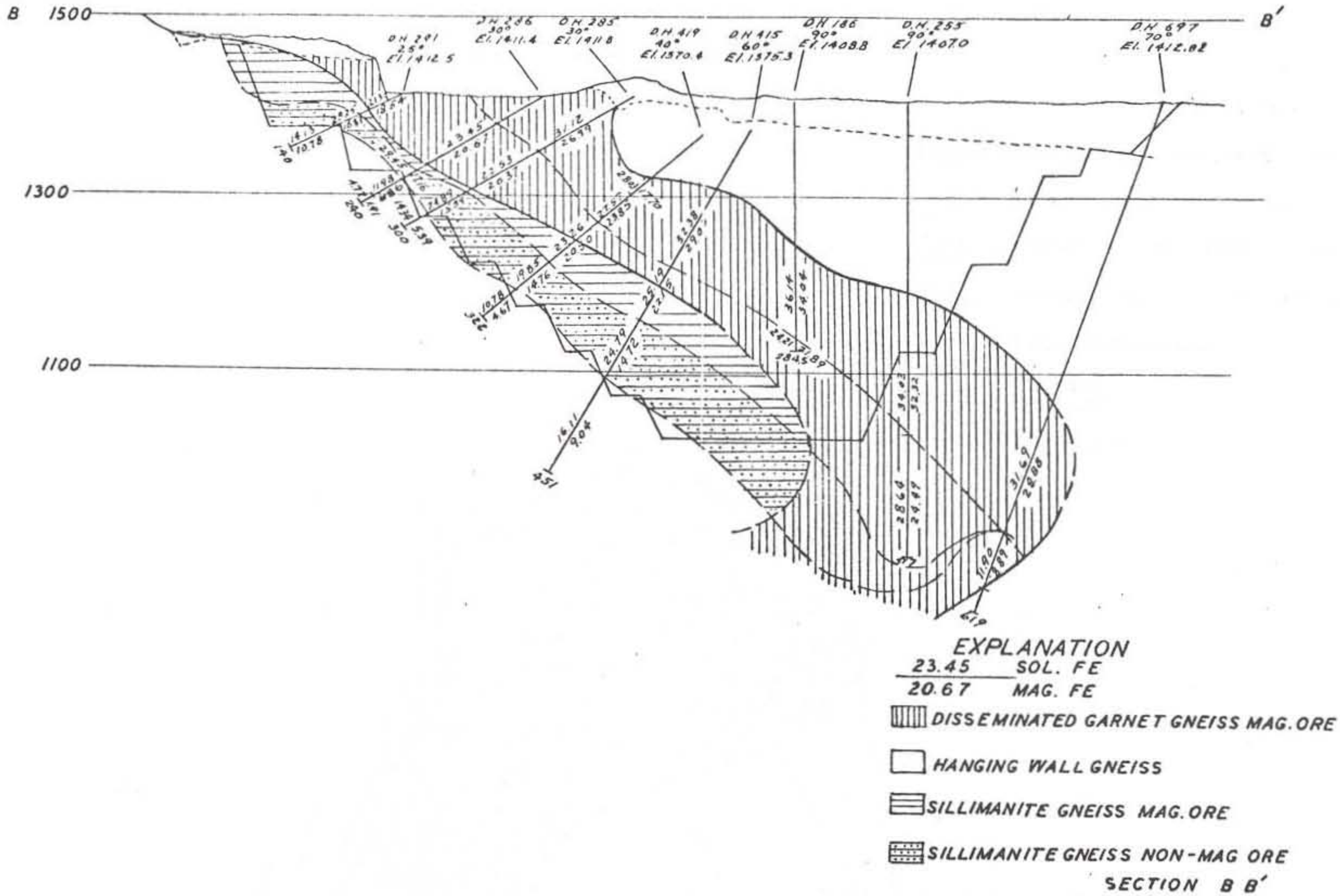


Fig. 7.- Section B-B'

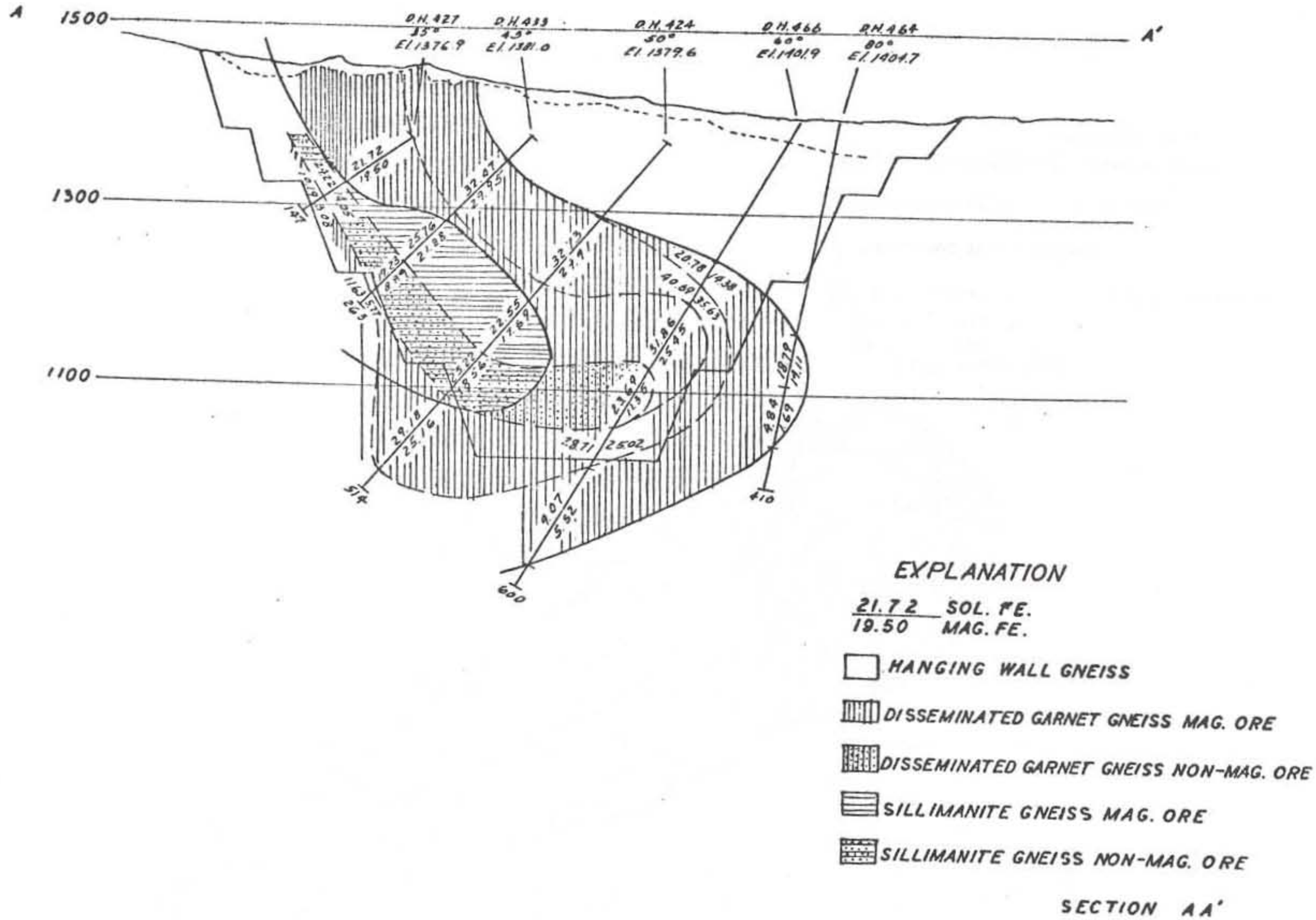


Fig. 6.- Section A-A'

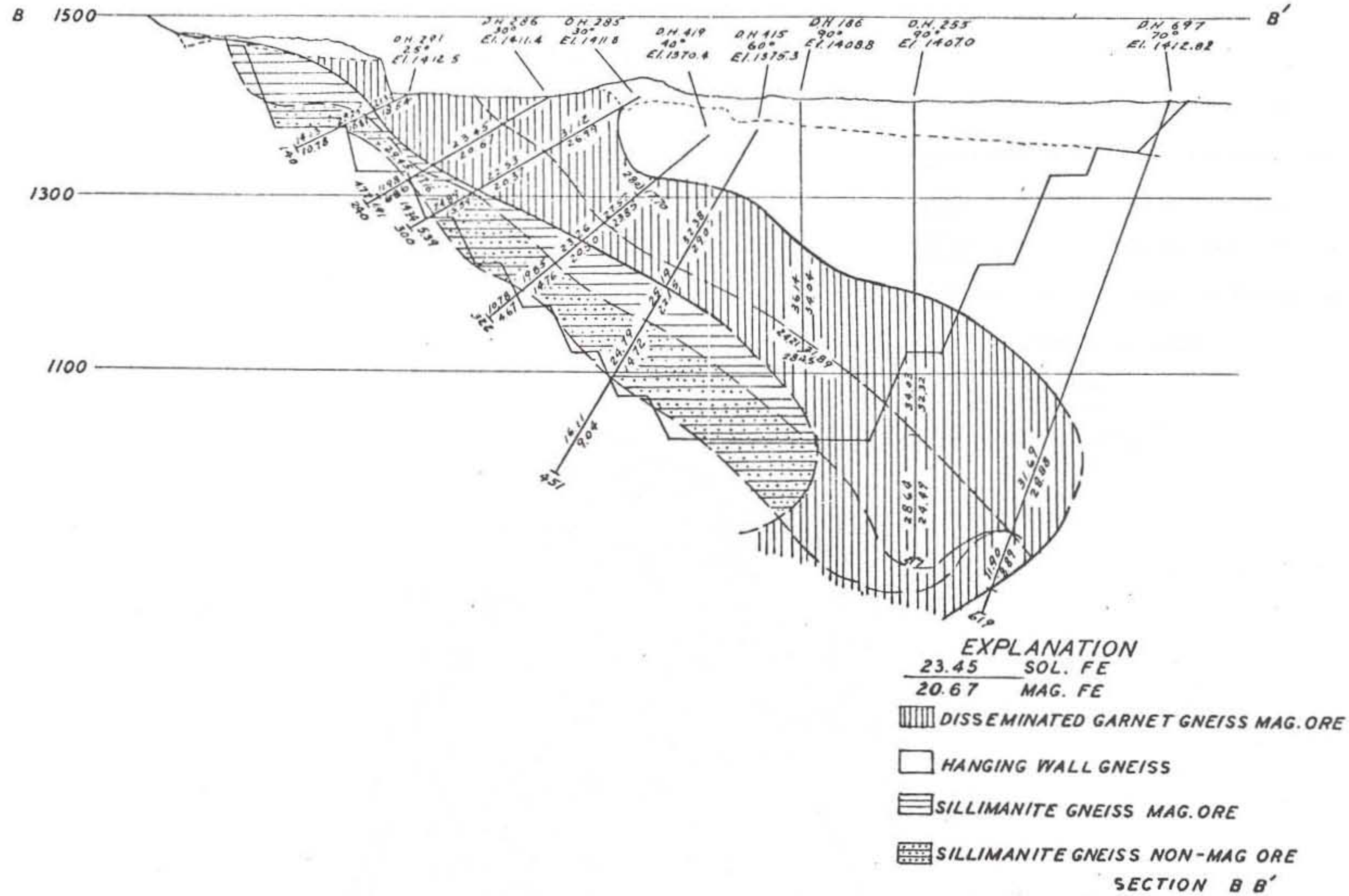


Fig. 7.- Section B-B'

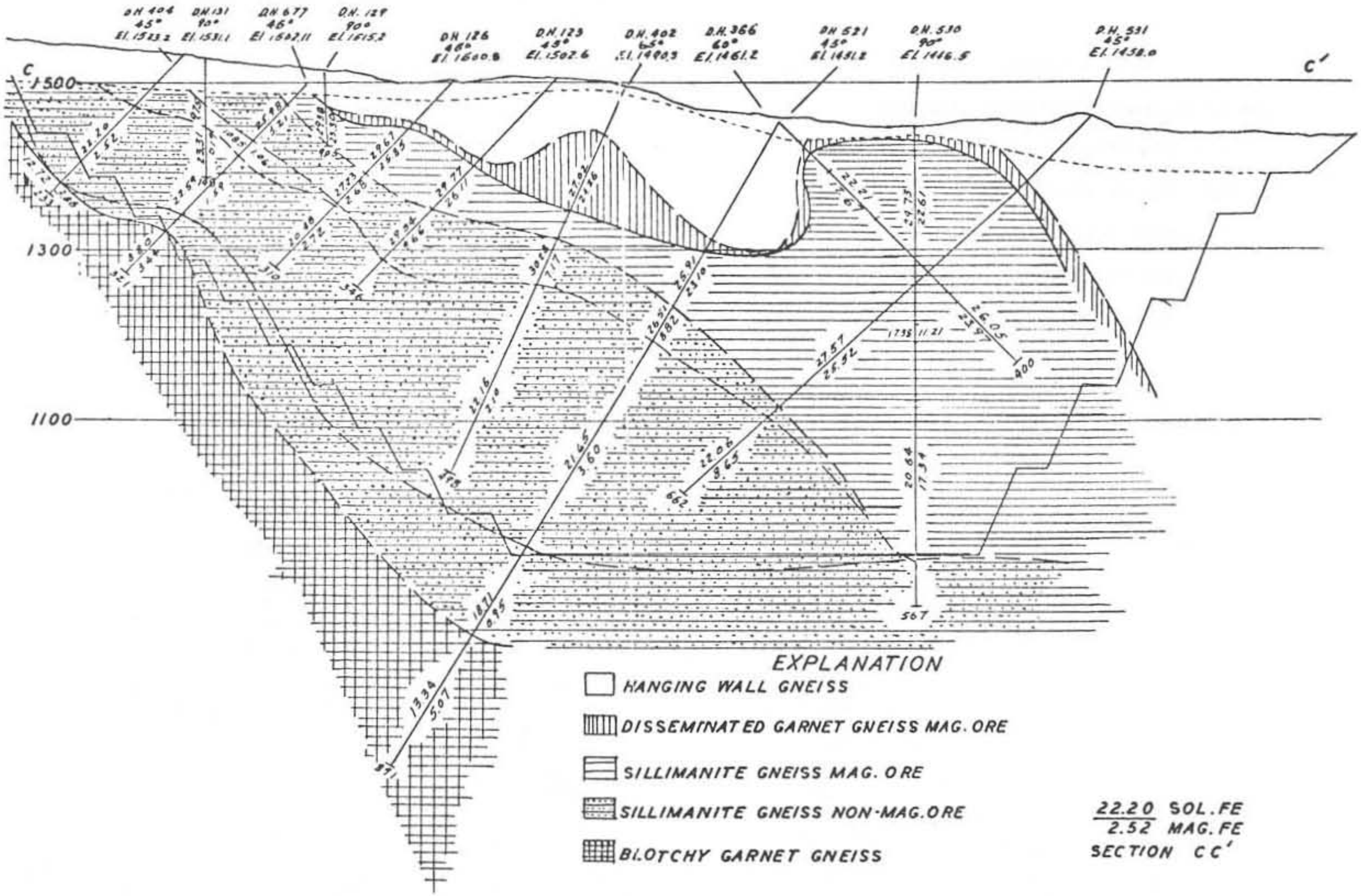


Fig. 8.- Section C-C'

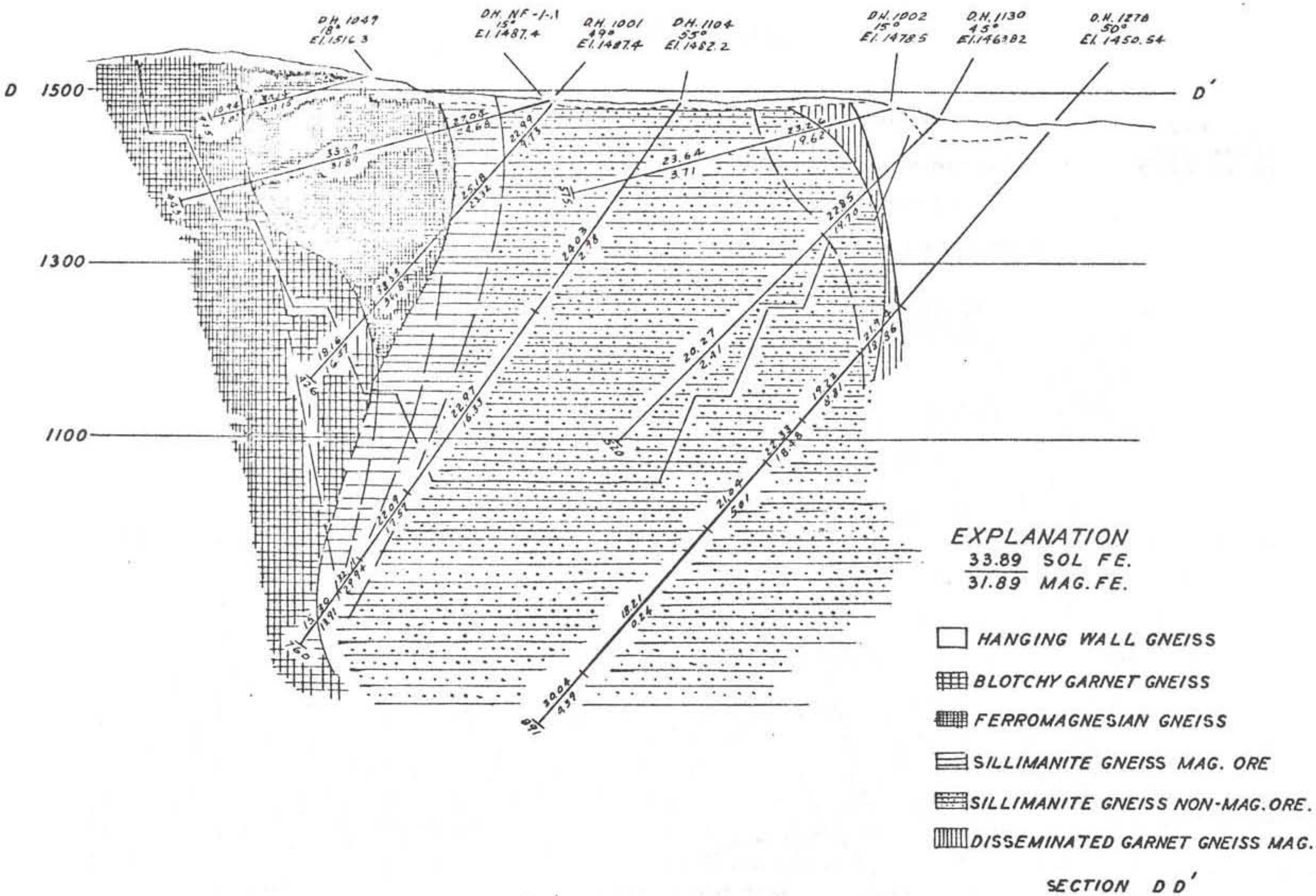


Fig. 9.- Section D-D'

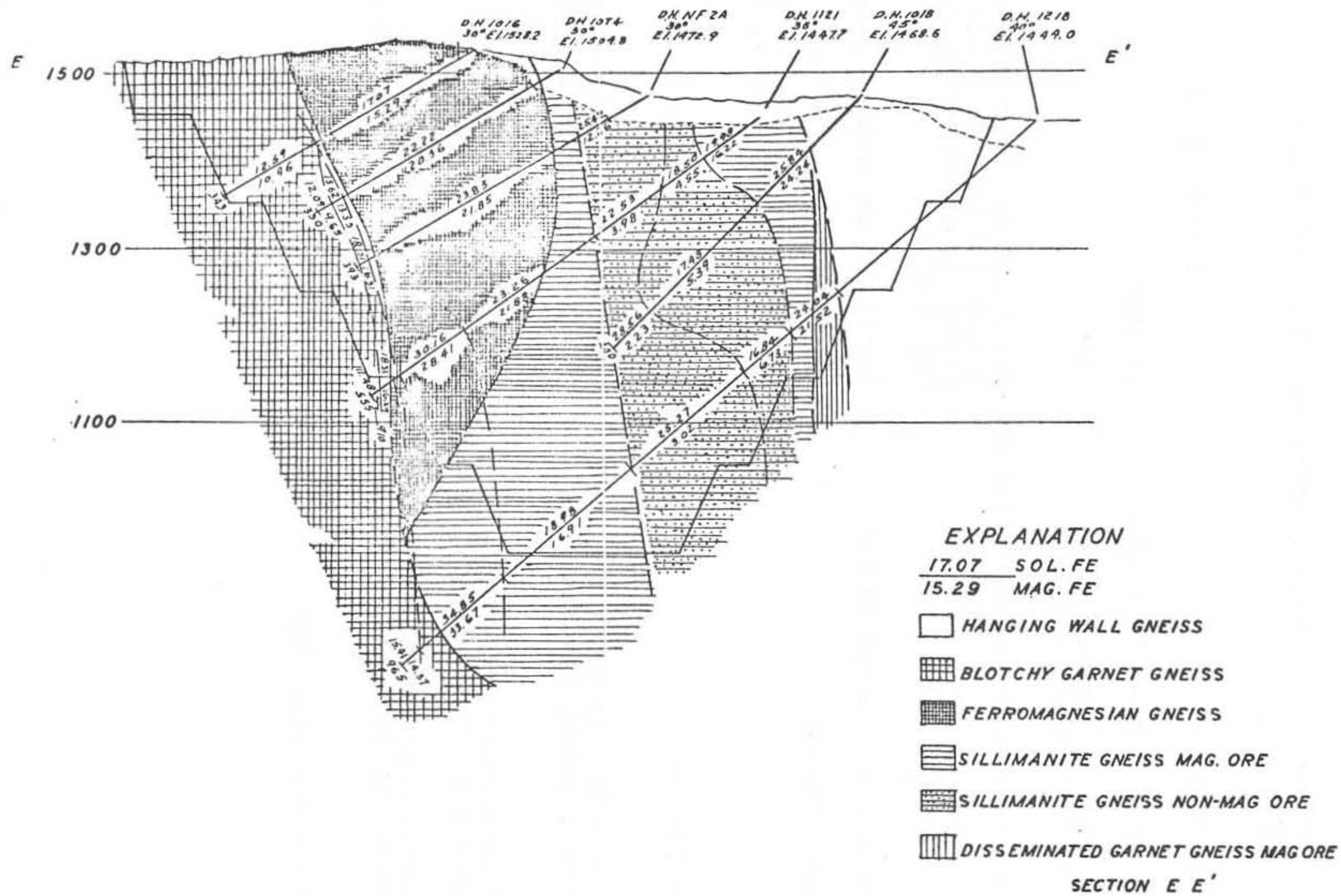


Fig. 10.- Section E-E'

Table 5. Summary of ore characteristics (after Crump and Beutner, 1968)

	MAGNETIC	NON-MAGNETIC
1)	Generally difficult to crush	Friable
2)	Distribution generally confined to lithologic horizons	Same
3)	Occurs in all lithologic horizons	Not found in ferromagnesian gneiss and only to minor extent in disseminated garnet gneiss
4)	Generally high quartz gangue	Generally low quartz gangue
5)	Sulfides present	Sulfides absent but with many limonite-filled vugs of a size corresponding to sulfides
6)	Sphene present	No sphene but some leucoxene
7)	Contains green or colorless, untwinned, potash feldspar	Contains pink or colorless, twinned and strained, potash feldspar
8)	Rare labradorite grains in ferromagnesian gneiss ore	No plagioclase
9)	Has fairly uniform gneissic structure and texture	Ptygmatic folding and pegmatitic lenses are quite common
10)	Average grain size 1mm	Same

Table 6. Representative chemical analyses
(after Crump and Beutner, 1968 and Palmer, 1970)

MAGNETITE

	Crude	Conc.	Crude	Conc.	A*
Fe	25.80	63.62	20.80	63.04	
FeO	12.35	-	1.74	-	28.40
SiO	42.28	5.44	46.28	4.35	49.45
MnO^2	0.45	0.338	0.10	-	-
P_2O_5	0.506	0.067	0.55	1.008	0.3
CaO	1.07	0.210	0.83	-	1.3
Al_2O_3	9.56	3.53	12.78	3.51	9.90
MgO	0.79	0.314	0.44	0.45	1.45
NiO	0.02	0.01	0.009	-	-
C_2O_3	tr	tr	0.012	-	-
V_2O_5	0.018	-	0.027	-	-
TiO_2	0.61	0.725	0.55	1.88	0.83
S	0.70	0.262	0.028	0.078	-
CuO	0.066	-	0.016	-	-
Alkali	5.45	-	6.97	-	7.19

* Average of 8 whole rock analyses of ore (Palmer, 1970).

rock by magnetite or hematite; and the apparent presence of ore prior to deformation and metamorphism is best explained by metamorphism of iron-rich sediments.

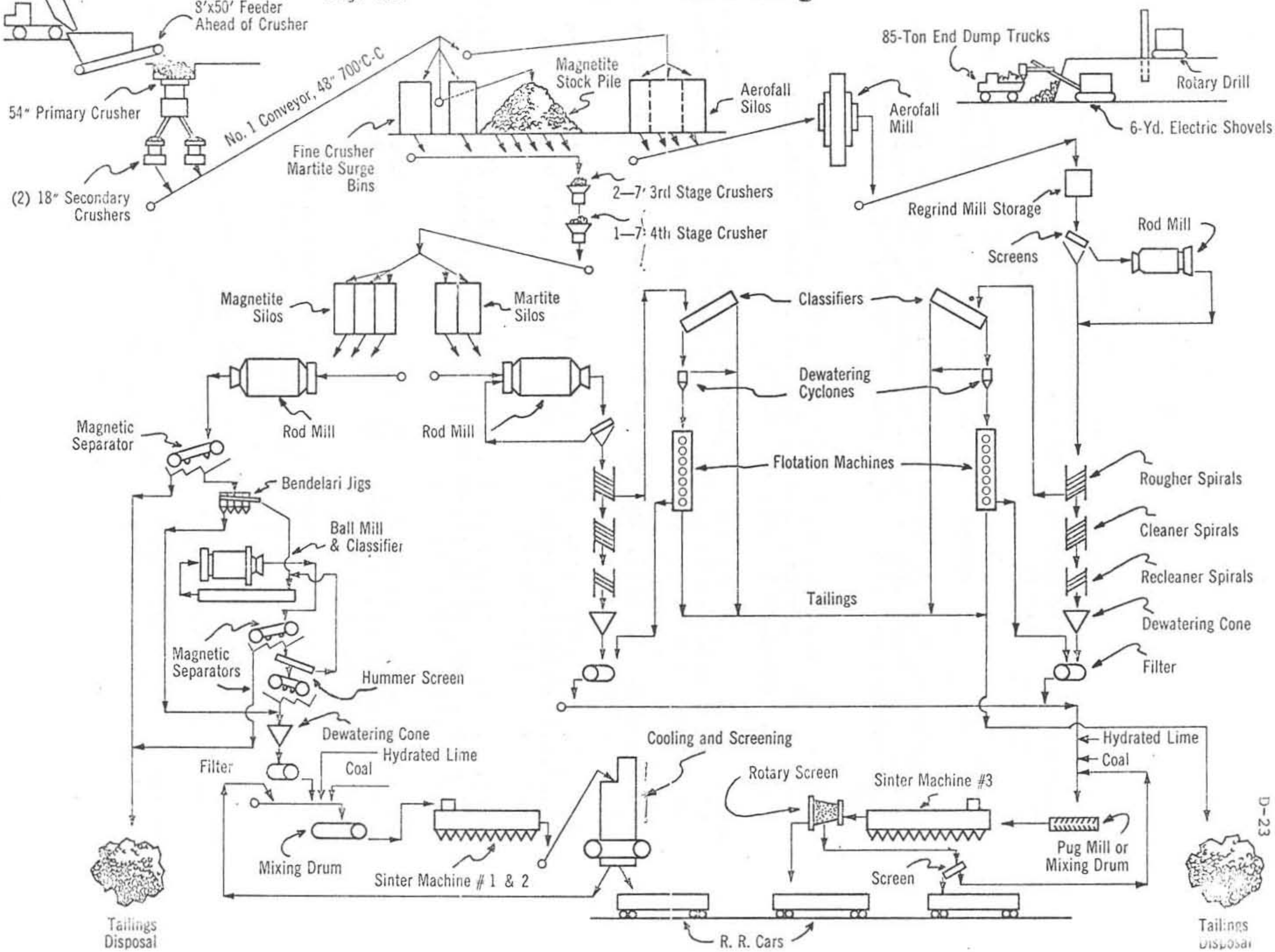
Mining and Processing

Mining is carried out by open-pit methods. Magnetic and non-magnetic ores are differentiated by diamond drilling and are mined selectively. Operating faces are generally about 50 feet high. Blast-hole drilling is done with rotary drills. Ammonium nitrate explosives are used. Crude ore is loaded by 6-yard, electric shovels into 85-ton dump trucks for transport to the primary crusher. The plant is capable of handling 16,000 tons of ore per day.

Figure 11 illustrates by flow diagram the methods used to concentrate the magnetic and non-magnetic ores. Magnetic ore is concentrated by magnetic separators, with the final concentrate (minus 20 mesh) containing 63 to 65 percent iron. Non-magnetic ore is concentrated by gravity methods with auxiliary magnetic separation to collect magnetite, or by flotation to collect hematite and magnetite fines (minus 100 mesh). The concentrates are transported to the sintering plant where they are thoroughly mixed with fine anthracite coal, lime, and sinter fines in the ratio of 64 per cent concentrate: 5 per cent anthracite: 1 per cent lime: 30 per cent sinter fines. The sintering cycle takes about 11 minutes.

Sinter is shipped by rail to the Jones and Laughlin steel plants at Pittsburgh and Aliquippa, Pa. and Cleveland, Ohio.

Fig. 11.- Benson Mines Flow Diagram



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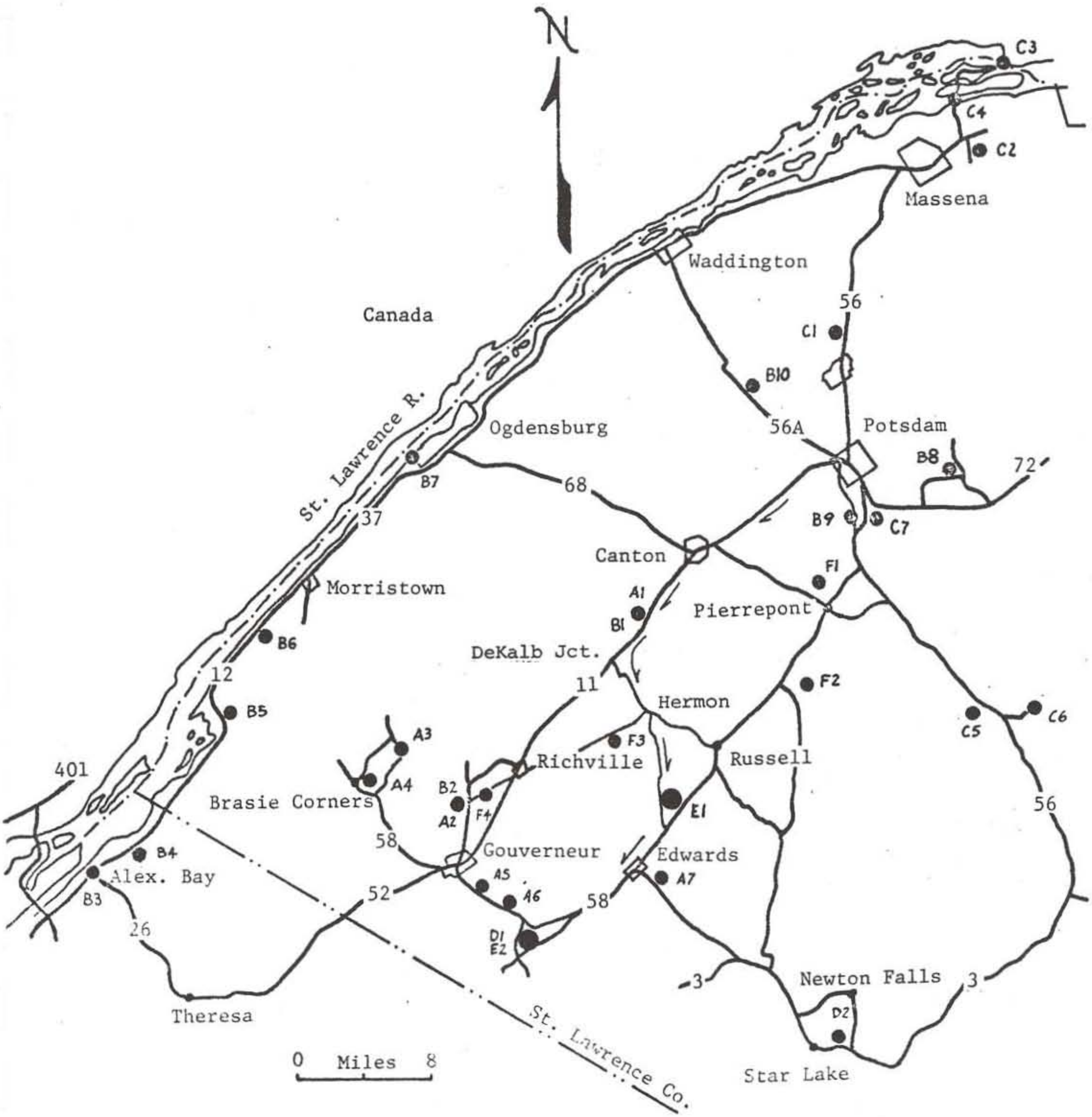

Figure 1. STOP MAP FOR TRIP E

Large dots indicate stops for this trip
and arrow show route.
Stops for other trips in guidebook
are indicated by smaller dots.