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GEOCHEMISTRY AND MINERAGRAPY  
OF THE NAIRNE PYRITE DEPOSIT,  
BRUKUNGA, SOUTH AUSTRALIA.

by

JOHN A. NENKE, B.Sc.

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## A B S T R A C T

A mineralogical study of the mineralogy of tension gash veins at the Nairne Pyrite Deposit, has revealed the existence of boulangerite, stannite, ullmannite, freibergite, pyrargyrite and cubanite. Larger amounts of pyrite, pyrrhotite, galena, arsenopyrite, sphalerite and chalcopyrite were also observed.

Sulphur, iron and trace element geochemistry of the deposit has been studied in relation to the ore beds, waste beds and enclosing meta-shales. A statistical interpretation of the geochemical data was made using correlation coefficients and cluster analyses. Elemental ratios (Co/Ni, Cu/Zn, S/Se) were calculated. The results of carbon analyses add weight to the proposed theory of a sedimentary origin for the Nairne Pyrite Deposit.

## I N T R O D U C T I O N

1.

The Nairne Pyrite Deposit at Brukunga situated 29 miles east of Adelaide, South Australia, has been shown to be an example of a sedimentary iron sulphide deposit by Skinner (1958), LaGanza (1959a) and George (1967). Jensen and Whittles (1969) have proposed a bacteriogenic origin for the sulphur on the basis of sulphur isotope studies. Edwards and Carlos (1954) using S/Se ratios have called the Nairne Pyrite Deposit hydrothermal, but the majority of the field and laboratory evidence indicates a sedimentary origin.

LaGanza (1959a) has reported the occurrence of rare sulphide minerals and sulpho-salts as well as the major sulphide minerals, pyrite and pyrrhotite. The first aim of this study was to check the mineralogy using the modern reflectance, hardness, X-ray and electron microprobe techniques along with the qualitative methods used by LaGanza.

The second part of the project was to undertake a detailed geochemical study across the ore and waste beds at the quarries of Nairne Pyrites Limited to study any trends associated with a sedimentary iron sulphide deposit.

### GENERAL GEOLOGY

The Nairne Pyrite Member which has been traced for 65 miles along strike is found at the base of the Brukunga Formation. The Brukunga Formation of Cambrian age belongs to the Kanmantoo Group (Fig. 1a - in back pocket). The regional structure is controlled by a major N-S trending syncline plunging 30°S. Several large shear zones are present in the area of outcropping Nairne Pyrite beds (Mirams 1965).

At the quarries of Nairne Pyrites Limited, Brukunga, the Nairne Pyrite Member is divided into ore beds 1, 2 and 3 separated by waste beds A and B depending on sulphur contents (Fig. 1). At Shephard's

Hill the beds dip 70°E. This dip decreases further to the north and at Grass Fire Hill the beds dip 45 - 50°E. The mineralogy of the sequence has been formed under conditions of amphibolite facies metamorphism (George 1967, 1969b). The Nairne Pyrite Member consists of a dark grey fine grained meta-shales with some interbedded meta-siltstones and dolomites. The sulphides are found as disseminations, in thin layers parallel to the bedding or in veins formed during metamorphism. Below the No. 3 ore bed the sulphur content decreases. In this lower part of the Nairne Pyrite Member a thin (25 feet thick) muscovite-quartz rich layer was observed at Little Hill before the underlying Inman Hill Formation was reached. The Inman Hill Formation is characterized by an increase in grain size, feldspar content and is a lighter colour than the Nairne Pyrite Member. The general rock type is a biotite rich meta-arkose which commonly shows cross-bedding. Above the Nairne Pyrite Member the rock type is also a coarser grained, lighter coloured biotite rich meta-arkose.

MINERAGRA.PHY

This mineragraphic study of the Nairne Pyrite Deposit is concerned with the mineralogy of the sulphide veins classified as tension gashes by George (1967, 1969b). LaGanza and Ramdohr (LaGanza 1959) have identified in tension gash veins the following sulphides and sulphosalts as listed in order of decreasing abundance.

Pyrrhotite	FeS
Pyrite	FeS <sub>2</sub>
Galena	PbS
Sphalerite	ZnS
Arsenopyrite	FeAsS
Jamesonite	Pb <sub>4</sub> FeSb <sub>5</sub> S <sub>14</sub>
Chalcopyrite	CuFeS <sub>2</sub>
Tetrahedrite (Fahlerz)	(Cu <sub>2</sub> Ag <sub>2</sub> ) <sub>3</sub> Sb <sub>2</sub> S <sub>6</sub>
Bournonite	CuPbSbS <sub>3</sub>
Pyrargyrite	Ag <sub>3</sub> SbS <sub>3</sub>
Ullmannite	NiSbS
Breithauptite	NiSb
Gudmundite	FeSbS
Stibioluzonite	Cu <sub>3</sub> (Sb,As) <sub>4</sub> S <sub>4</sub>
Boulangerite	Pb <sub>5</sub> Sb <sub>4</sub> S <sub>11</sub>

In addition to the sulphides listed above, LaGanza (1959 a, b) has found marcasite, rutile, graphite and five different types of pyrite in unweathered samples of Nairne Pyrite. Recently Dr. J. Graham of the C.S.I.R.O. Perth (pers. comm.) has indicated the presence of minor amounts of monoclinic pyrrhotite, rare pyrophanite (MnTiO<sub>3</sub>) and alabandite (MnS). The one small grain of alabandite observed was associated with a small grain of chalcopyrite.

This study to re-examine the rare sulphosalts reported by LaGanza was made on LaGanza's polished sections, especially those of vein minerals (sections 8A, 10A, 82A, 83A, 84A) and several freshly prepared polished sections of tension gash sulphides. Three different types of pyrite plus pyrrhotite, galena, sphalerite, chalcopyrite, arsenopyrite, boulangerite, stannite, ullmannite, freibergite, pyrargyrite and cubanite were identified. The other rare minerals reported by LaGanza (1969a) were not observed in the available sections of LaGanza's or in the polished sections prepared.

#### MINERALOGY OF THE TENSION GASH VEINS

##### Pyrite FeS<sub>2</sub>

The pyrite in the veins was generally found as anhedral areas with an average diameter of 2.5 mm. This is in contrast to the primary pyrite found in the country rock which is sub-euhedral and smaller in size (.4 mm). Several of the larger pyrite areas were weakly anisotropic with a colour change from a pale orange to a bluish-green. This may be caused by lattice distortions due to the pressure of impurities or during polishing (Uytenbogaardt and Burke 1971). Concentric pyrite was also observed in the tension gashes. Concentric layers of fine grained pyrite separated by thin layers of gangue formed oval shaped bodies up to .7 mm long. The concentric pyrite was a duller colour than the normal vein pyrite which was due to the fine grain size and associated gangue. Melnicovite pyrite was found around the edges or as infillings of cracks through some areas of vein pyrite. The very small pyrite grains, mixed with gangue minerals often showed a colloform texture. Small areas of galena were situated in this type of pyrite. Anisotropism colours suggested the presence of marcasite along with the Melnicovite pyrite. This was confirmed by an X-ray powder photograph (Appendix 1).

##### Pyrrhotite FeS

LaGanza (1959) and George (1957) have reported that pyrrhotite

is the most common sulphide present in the tension gash veins. The pyrrhotite grains exhibit smooth irregular boundaries on contact with most of the other vein sulphides and sulphosalts. In some sections the pyrrhotite appeared to be of two types, with the central part of an area of pyrrhotite having a pitted surface surrounded by pyrrhotite grains with a smooth surface. The central core pyrrhotite was only weakly anisotropic compared with the typical strong anisotropism shown by the outer grains of pyrrhotite. Reflectance and hardness measurements (Appendix 1) and an X-ray powder photograph confirmed that the central core was pyrrhotite.

At Nairne the majority of the pyrrhotite is hexagonal but minor amounts of monoclinic pyrrhotite was observed with the use of a magnetic colloid (Appendix 1) along grain boundaries and cracks in pyrrhotite masses. The core of pyrrhotite discussed above was hexagonal as was the majority of the surrounding pyrrhotite, therefore the observed effects may have been caused during polishing.

#### Galena PbS

Commonly the galena occurred as large areas (1 - 3 mm wide) and was easily identified by its colour, cleavage and triangular pits. Galena was also found as small vein-like bodies through pyrite, arsenopyrite and pyrrhotite. In this environment the galena cleavage was rarely observed and because of the colour of the major minerals it appeared greenish and its identification was based on hardness and reflectance measurements. Galena is the host mineral to the rare sulphosalts.

#### Arsenopyrite FeAsS

Arsenopyrite was found as euhedral grains (.02 - .5 mm.) in a matrix of softer minerals (plate 1c) or as groups of grains with irregular grain shapes and boundaries with pyrite. In section 82A small arsenopyrite grains (.15 mm) exhibited some straight grain edges on one side with rounded hollows filled with the surrounding



PLATE I

a. Tension gash vein containing:

- (1) galena (g)
- (2) pyrrhotite (Po)
- (3) stannite (st)
- (4) boulangerite (b)
- (5) freibergite (F)
- (6) ullmannite (u)

Polished Section 8A.

Magnification of 495X. (In air).

b. Inter-relationships between galena (g), freibergite (F),  
boulangerite (b) and stannite (st).

Polished Section 10 A.

Magnification of 750X. (In oil).

c. A vein of sulphide minerals filling cracks in a large area  
of pyrite (py). The vein contains

- (1) chalcopyrite (cp)
- (2) galena (g)
- (3) sphalerite (sp)
- (4) stannite (St)
- (5) arsenopyrite (as)

Polished Section 8A.

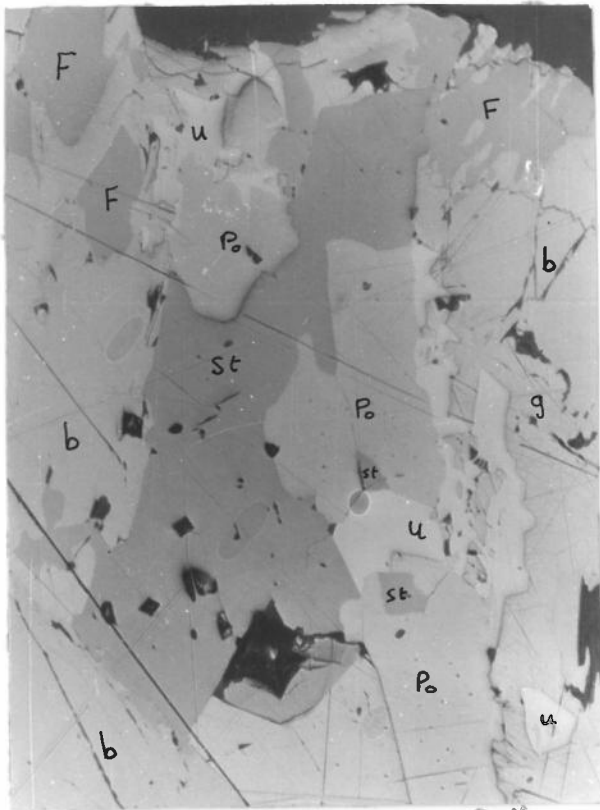
Magnification of 750X (In oil)

d. The relationship of pyrargyrite (pg) and cubanite (cb)  
with freibergite (F), and galena (g) and boulangerite (b).

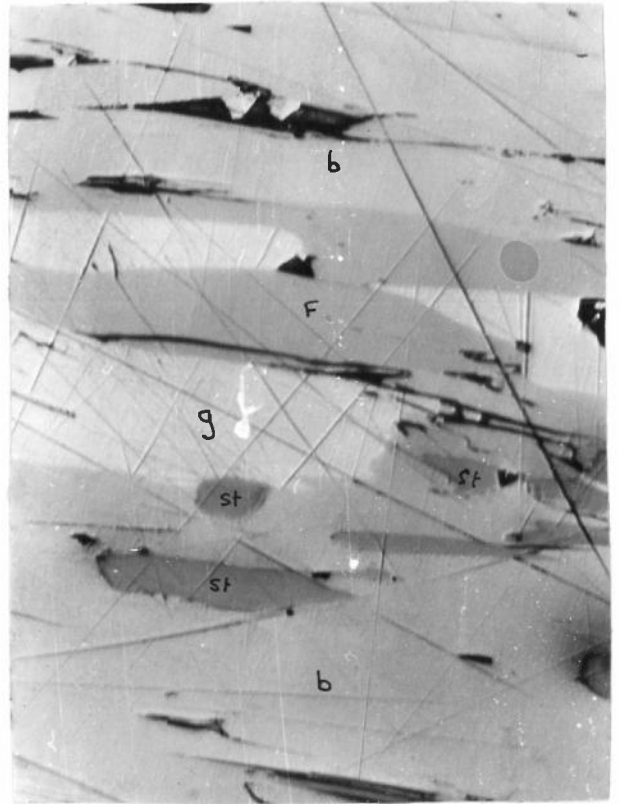
Polished Section 10A

Magnification of 1800X (In oil).

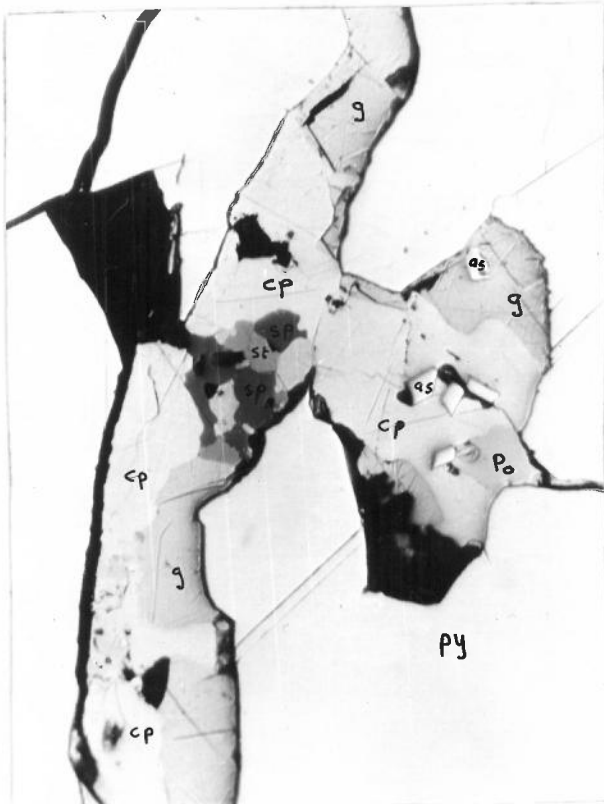
PLATE I



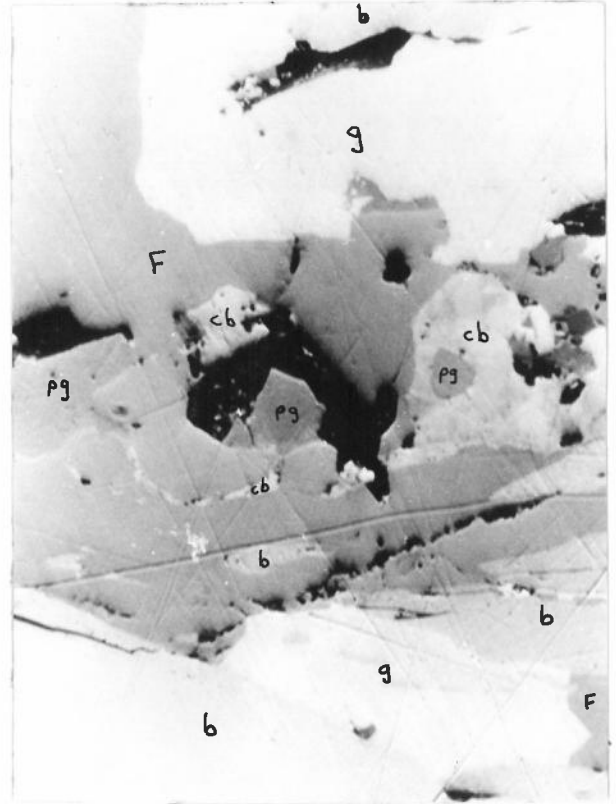
a (8A)



b (10A)



c (2A)



d (10A)

boulangerite on the other. This texture may have developed by growing arsenopyrite crystals in a softer matrix or by replacement of arsenopyrite by boulangerite. Most of the arsenopyrite showed typically strong anisotropism colours but some grains of similar colour, reflectance and hardness were only weakly anisotropic (blue-grey to yellowish green colour change). Spot electron microprobe analyses showed Fe, As, S to be the major elements present. An X-ray powder photograph also identified these grain as arsenopyrite. This implies that the grains were cut in a direction in which the anisotropic effects are weaker.

#### Sphalerite ZnS

Sphalerite occurs as dark grey, irregularly shaped areas (.2 mm.) associated with pyrrhotite and galena. Dr. J. Graham (pers. comm.) had indicated that the sphalerite has high iron and manganese contents. The high iron content accounts for the dark grey colour of the sphalerite.

#### Chalcopyrite CuFeS<sub>2</sub>

Chalcopyrite was found as small blebs (.1 mm.) on the edges of pyrite, and pyrrhotite masses. Small areas of chalcopyrite were also found in veins cutting through the larger areas of pyrite and pyrrhotite (Plate 1c.)

#### Boulangerite 5PbS. 2Sb<sub>2</sub>S<sub>3</sub>

LaGanza (1959a) has tentatively identified one grain of boulangerite in galena. He also has reported that jamesonite is the most common of the sulphosalts. This study has identified boulangerite as the major sulphosalt present, generally as elongate areas (.5 mm. x .1 mm.) intergrown with galena and the other sulphosalts (Plate 1 a, b.) Boulangerite was distinctly bireflectant, grey to a light green-grey and was distinguished from galena mainly by its lack of cleavage and its strong anisotropism colours (dark green, brown with a green tint and a light brown-grey). The mineral had a reflectance range of 30.6 to 39.5% and an average Vickers Hardness Number with a 50 gm.

Load (VHN 50) of 145. Of these physical properties the VHN was more characteristic of boulangerite, than jamesonite and other Pb,Sb,S minerals (e.g. geocronite, robinsonite) whose other properties are very similar to those of boulangerite.

Three spot electron microprobe analyses, reported as nominal concentrations, averaged,

Pb	53.88
Sb	18.47
As	1.08
Cu	0.06
Fe	0.04
S	17.10
<u>Total</u>	<u>90.63</u>

The percentages were not corrected for mass absorption (Appendix 1) <sup>(also *fluorescence and at 1000°C*)</sup> and hence the low total. An approximate mineral formula of  $Pb_5Sb_3S_{10}$  (o.f.  $Pb_5Sb_4S_{11}$  of boulangerite) was calculated from the above data. X-ray powder photographs also identified the mineral as boulangerite.

#### Stannite $Cu_2SnFeS_4$

Stannite was found associated with galena and boulangerite (Plate 1a, b). In several of the sections studied small areas of stannite (.1 mm.) were situated at galena pyrrhotite boundaries. Stannite was identified from the following properties;

- colour - olive grey (darker than boulangerite).
- bireflectance - weak, observed under oil at grain boundaries.
- anisotropism - strong, light violet to dark reddish brown.
- reflectance - 26.9-29.3 percent.
- VHN 50 - 220.

Qualitative electron microprobe analyses showed Cu, Fe, Sn and S to be the major elements present with rare Mn, Ag and Co.

Freibergite (Cu,Fe,Ag)<sub>12</sub>Sb<sub>4</sub>S<sub>13</sub>

The freibergite observed as small irregular shaped areas (less than 0.2 mm long), was associated with galena, boulangerite and stannite assemblages (Plate 1a, b). This grey mineral with a greenish tint (darker than boulangerite) was weakly bireflectant and isotropic. Reflectance measurements ranged from 30.7 to 32.2 percent and an average VHN<sub>50</sub> of 293 was obtained. These properties identified the mineral as tetrahedrite. The average values of three spot electron microprobe analyses, reported as nominal concentrations of elements are

Pb	0.11
Sb	21.17
Ag	22.31
As	1.22
Cu	7.93
Fe	6.19
S	18.48
<u>Total</u>	<u>77.41</u>

The low total suggests that one or more elements have not been analysed for. The general formula for tetrahedrite indicates the presence of Zn which has not been reported in the above analysis. Another reason for a low total is that mass absorption corrections were not made on this analysis. The high weight percent of silver implies that the mineral is freibergite, a silver rich form of tetrahedrite.

Ullmannite NiSbS

The mineral later identified as ullmannite was observed as a white, with a pinkish tint, isotropic mineral. This mineral formed irregularly shaped areas less than 0.1 x 0.05 mm in sections con-

taining galena and other sulphosalts (Plate 1a). The reflectance range measured of 45.5 to 45.9 percent and the average VHN<sub>50</sub> of 415 did not clearly identify the mineral. The average of five spot electron microprobe analyses used to identify the mineral as ullmannite is listed below as the nominal concentration of the elements. This analysis has not been corrected for mass absorption etc.

Pb	0.11
Sb	49.47
As	2.56
Ni	17.06
Cu	0.06
Fe	0.09
S	12.17
<u>Total</u>	<u>81.52</u>

Pyrargyrite 3Ag<sub>2</sub>S. Sb<sub>2</sub>S<sub>3</sub>

A rare bluish grey mineral (.07 mm) was located in sections containing sulphosalts and galena (Plate 1d). This mineral was weakly bireflectant, strongly anisotropic (light to dark brown-grey) and showed strong red internal reflections. This soft mineral (VHN<sub>50</sub>: 99.2) had a reflectance of 27.1 to 29.0 percent. These properties were unable to distinguish between pyrargyrite and proustite and so an electron microprobe analysis was done. The following analysis corrected for mass absorption is the average of six spot analyses.

Sb	25.01 wt. percent.
Ag	59.49 wt. percent.
As	0.28 wt. percent.
S	17.32 wt. percent.
<u>Total</u>	<u>102.1 wt. percent.</u>

When these results were converted to atom percent, a mineral formula

$Sb_4Ag_{11}S_{11}$  was obtained. This implied that the mineral was pyrargyrite.

Cubanite  $CuFe_2S_3$

A fine grained (.01 mm), strongly bireflectant (yellow to brown) mineral was associated with pyrargyrite (Plate 1d). This mineral was strongly anisotropic showing a colour change from blue to brown. The reflectance varied from 36.1% when the mineral was brown to 38.2% when it was in the yellow bireflectance position. The grain size was too small for hardness measurements to be taken. As an average of three spot analyses corrected for mass absorption,<sup>etc</sup> the electron microprobe identified the following elements:

Sb	1.23 wt. percent.
Ag	2.48 wt. percent.
As	0.22 wt. percent.
Cu	20.8 <sup>a</sup> wt. percent.
Co	0.09 wt. percent.
Fe	37.04 wt. percent.
S	33.47 wt. percent.
<u>Total</u>	<u>95.40 wt. percent.</u>

This analysis gives an approximate mineral formula of  $CuFe_2S_3$ , which is cubanite. The low reflectance range measured, compared with the range given by Uytendogaardt and Burke (1971) of 39.2 to 40.4 percent, may be due to the fine grain size and/or polish of the cubanite.

CONCLUSIONS

The sulphide minerals of tension gash veins identified in this study agreed with those reported by LaGanza (1959a) but several differences were found in the mineralogy of the sulphosalts.

1. The major sulphosalt reported as jamesonite by LaGanza was identified as boulangerite. The presence of jamesonite can not be discounted because of the small number of grains analysed by the electron microprobe and identified from X-ray powder photographs.
2. The properties as described by LaGanza (1959a) of ~~boulangerite~~ <sup>bournonite</sup> are the properties of the mineral identified as stannite.
3. LaGanza predicted a high silver content of the tetrahedrite from its greenish colour. This was confirmed by the electron microprobe analysis which indicated a silver content high enough for the mineral to be called freibergite.
4. The presence of ullmannite and pyrargyrite was confirmed.
5. The yellow mineral associated with pyrargyrite thought to be stibioluzonite by LaGanza and Ramdohr (LaGanza 1959a) was identified as cubanite.



GEOCHEMISTRYSAMPLE LOCATION

Samples were collected two diamond drill holes, DD9 and DD10 cutting across the ore and waste beds of the Nairne Pyrite Deposit. The position of DD9 and DD10 is shown in figure 1. The drill holes sampled were selected on the condition and availability of the core. Six inch samples were taken at ten foot intervals from DD9. To ensure sufficient coverage of the ore and waste beds, forty four samples were taken. DD10 was sampled in more detail to show any geochemical variations within an ore bed. Twenty five, six inch core samples were collected at five foot intervals from Wastebody A, across Crebody 2, to Wastebody B.

ELEMENTS ANALYSED

For both DD9 and DD10 sulphur, selenium, arsenic, iron, nickel, copper, cobalt, lead, zinc, manganese, chromium and vanadium analyses were done on all the samples collected. Sulphur, selenium and arsenic were analysed by X-ray fluorescence (X.R.F.) methods (Appendix II). Iron and the trace elements listed above were analysed for "total" metal content by atomic absorption methods. The "sulphide" Fe, Ni, Co, Cu, Pb, Zr and Mn contents were also analysed (Appendix II). Selected samples from DD9 were analysed for carbon using an induction furnace. (Appendix II).

PRESENTATION OF ANALYTICAL DATA

All of the data collected is listed in Appendix III. The spot sampling method used involved sampling errors, therefore rolling means were calculated to smooth out, and make the data more representative of the sections studied. The rolling means of the

analytical data for DD9 and DD10 are plotted as profiles in figures 2 to 10. The rolling means were obtained by plotting the average of three adjacent assays in the position of the central sample. No values are plotted for the first and last sample of each drill core. The rolling mean representation of the data has some disadvantages. For one high metal value in the raw data, the rolling mean data indicates high values for three samples. The height of an anomaly is also reduced. When samples from both ore and waste beds are averaged the contrast between them is reduced. The advantages of smoothing out of the data and making any trends present more obvious ~~outways~~ the disadvantages.

Two or three adjacent samples from DD9 were combined to give samples for carbon analyses. The raw data for carbon assays was plotted (fig. 2), because of this prior grouping of samples.

The position of ore beds 1, 2, and 3 and waste beds A and B as shown on the profiles were taken from the South Australian Department of Mines, Mining Review, No. 95 (p. 100, 101). This was confirmed by the sulphur assays done by X.R.F.

#### SULPHUR ANALYSES

The results of the sulphur analyses of DD9 are shown in fig. 2. The sulphur content defines the ore and waste beds. Ore beds 1 and 2 have an average sulphur content of 11%, waste beds A and B contain 5% sulphur and ore bed 3 has an average of 7.5% sulphur. Below ore bed No. 3 the meta-shales contain approximately 1000 p.p.m. sulphur. The variation in sulphur content across ore bed No. 2 is shown in Fig. 7. The profile indicates a thin (15 ft.) barren bed towards the base of the ore bed. This drop in sulphur may be due to sampling but because three samples show this anomaly it was probably due to changing conditions of deposition. The sulphur content of sample 69 rises to 9.42%. This suggests that it is in ore bed No. 3 but the Mines Department assays indicate that this sample is still in wastebed B. Therefore the rise in

DD 9 S, C, As

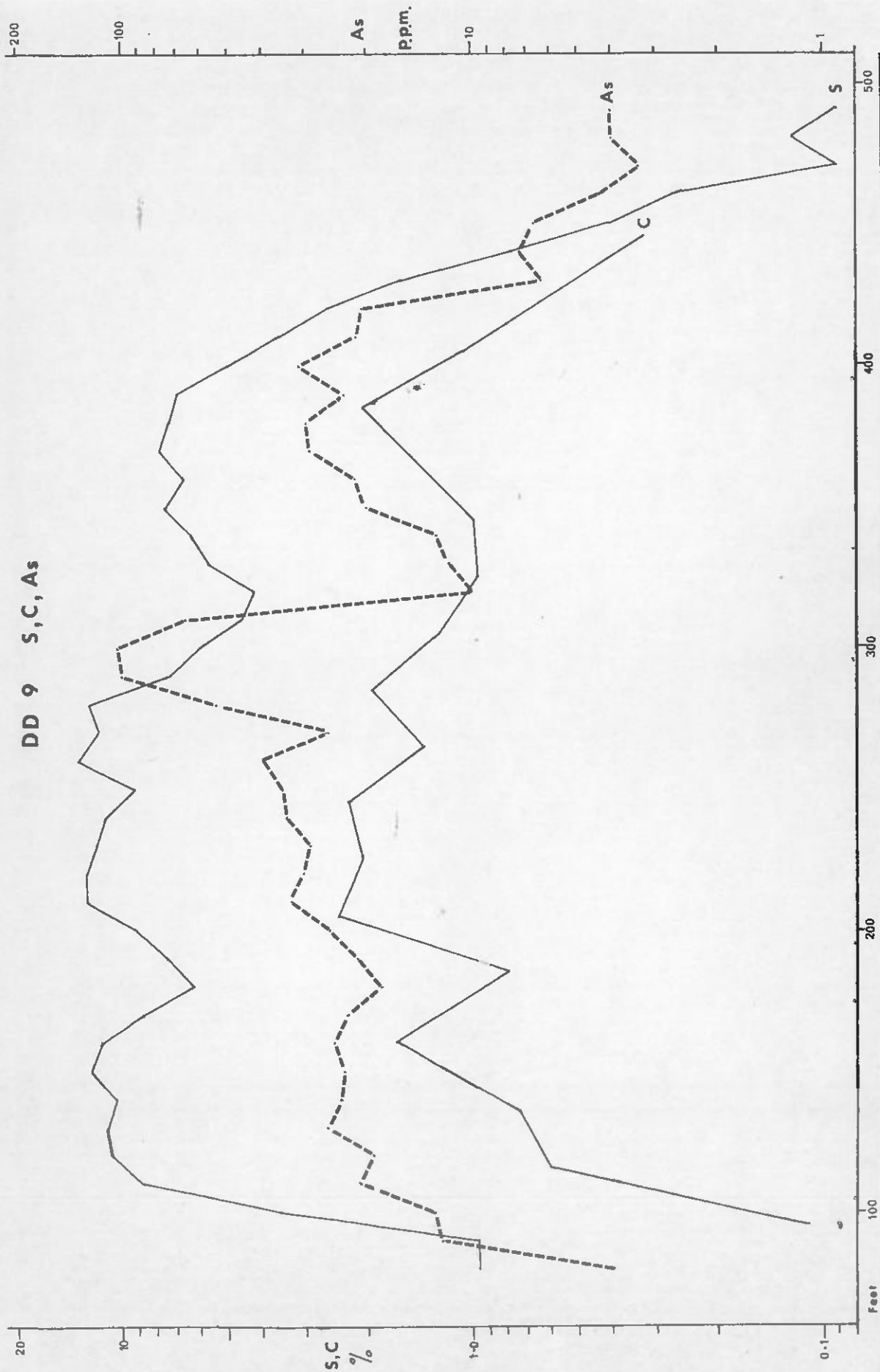


Fig. 2

DD 9 Ni, Co

T - Total Leach  
S - Sulphide Leach

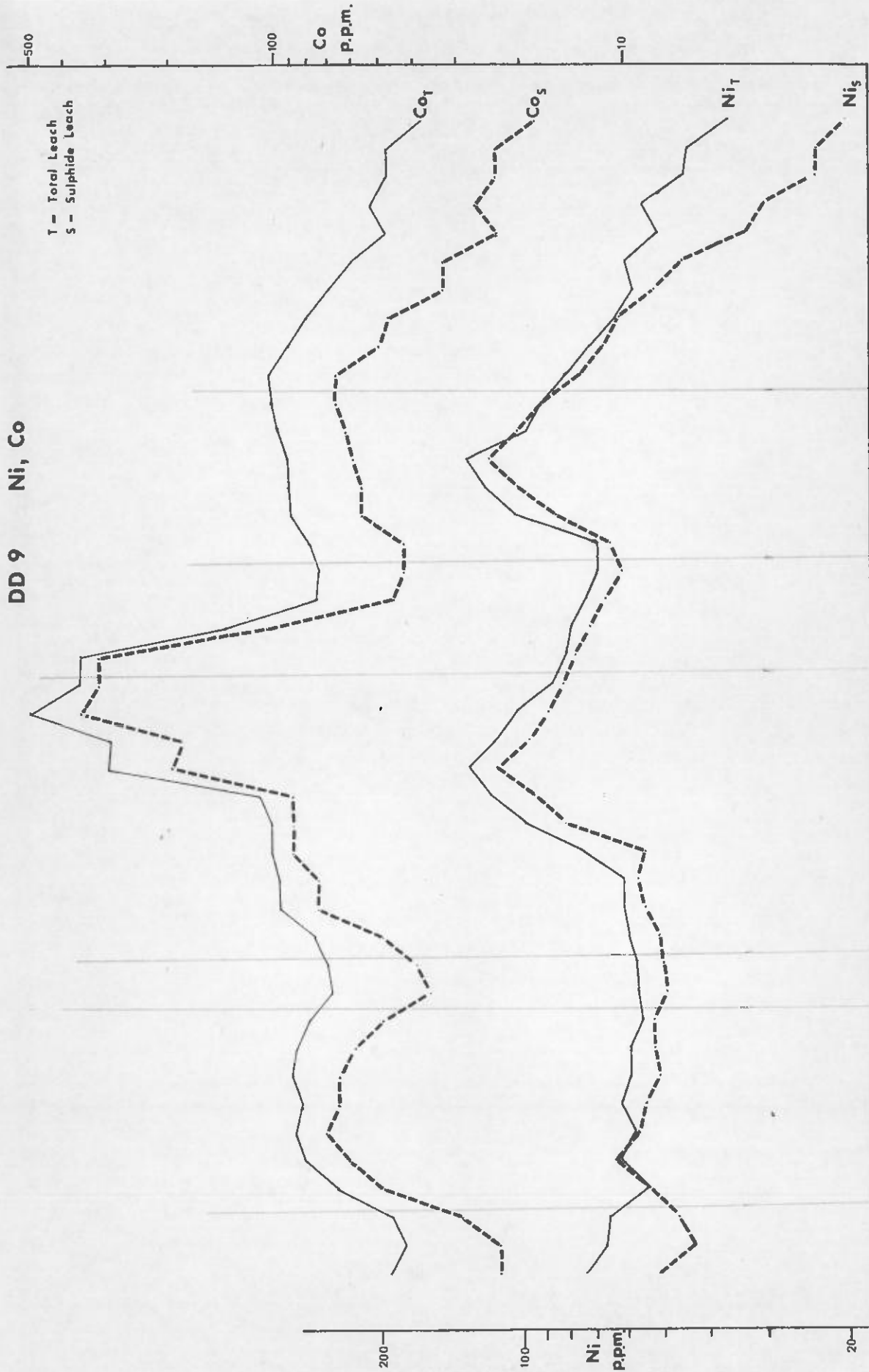


Fig. 3

DD 9 Pb, Zn

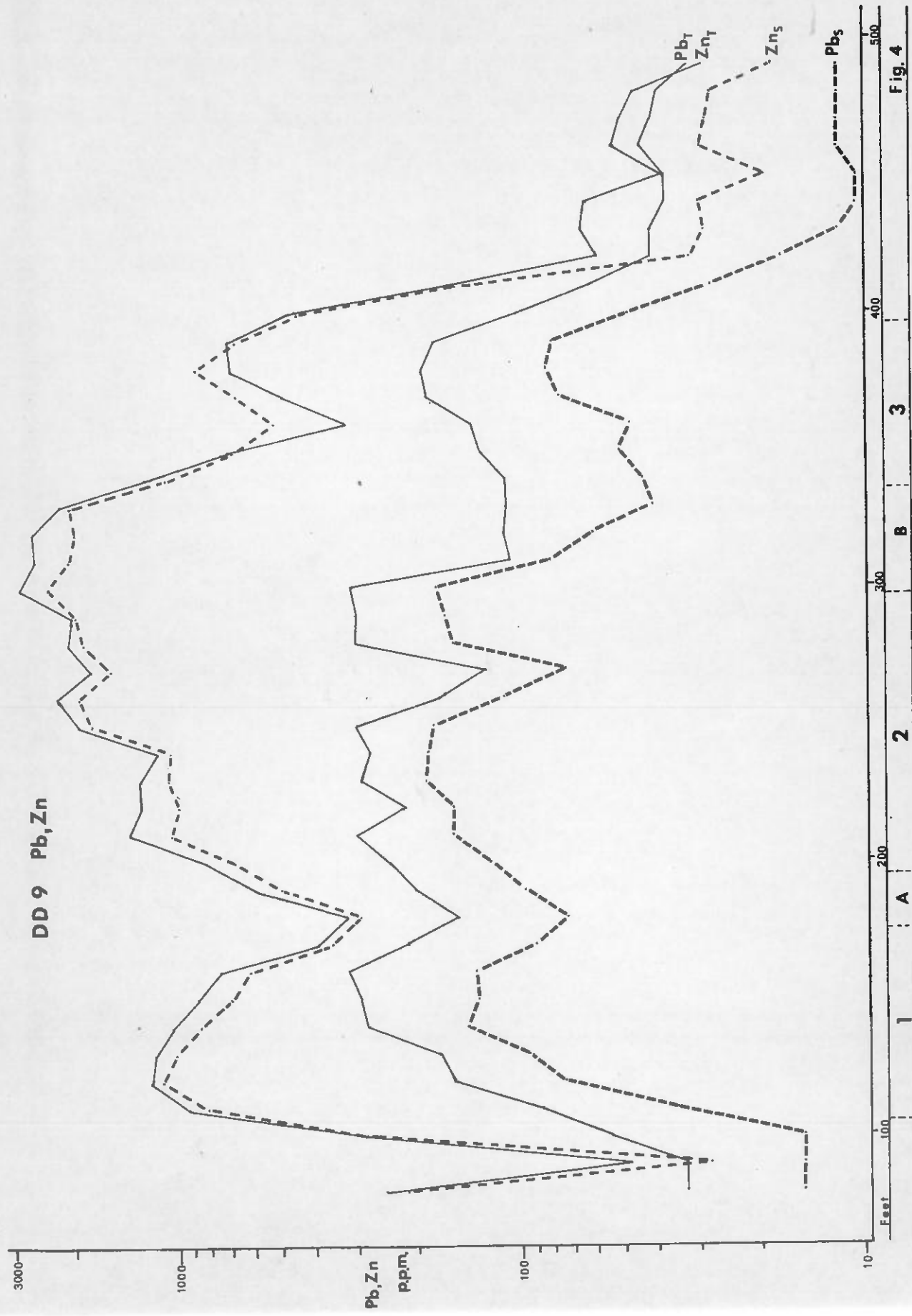


Fig. 4

DD 9 Fe, Mn

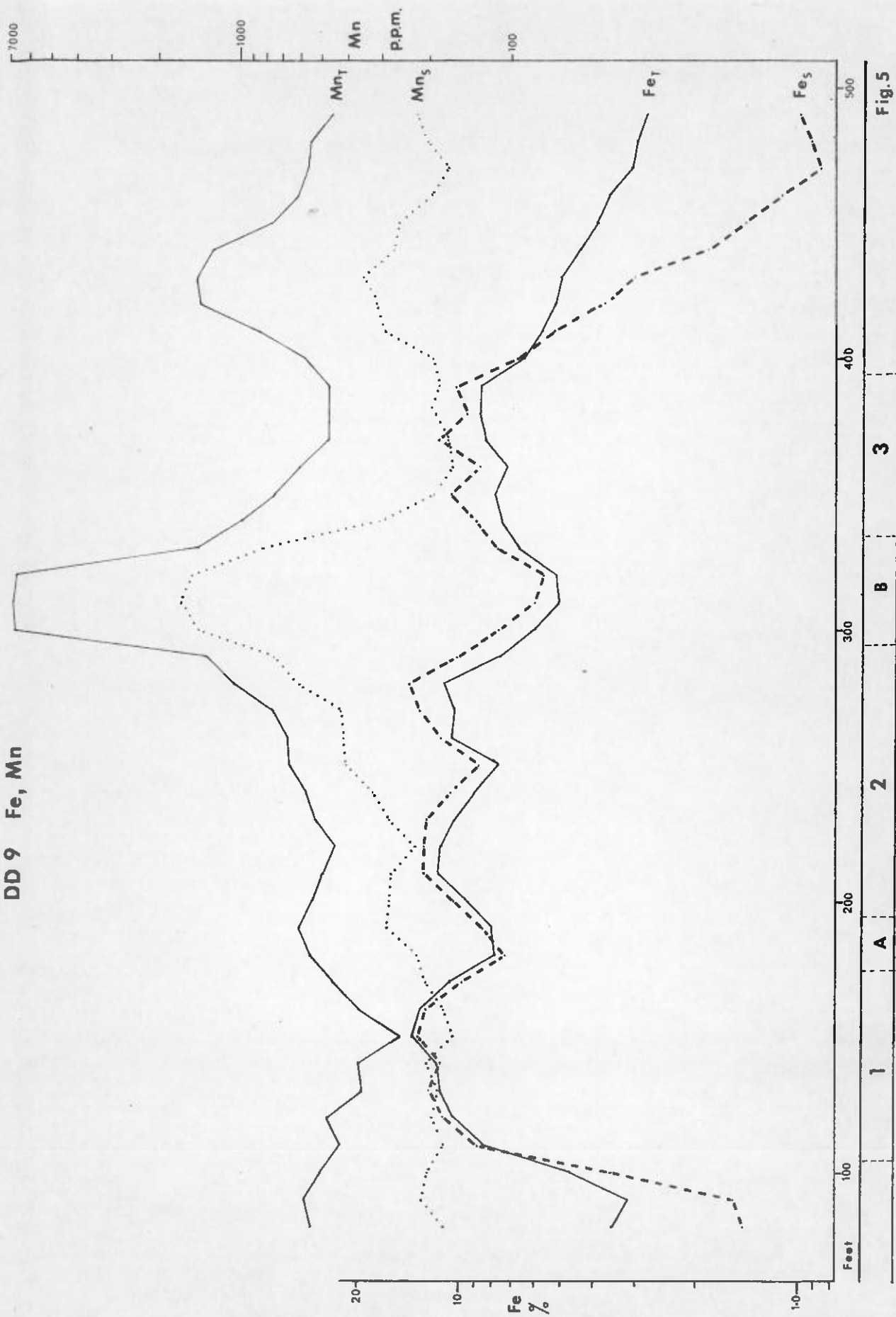


Fig. 5

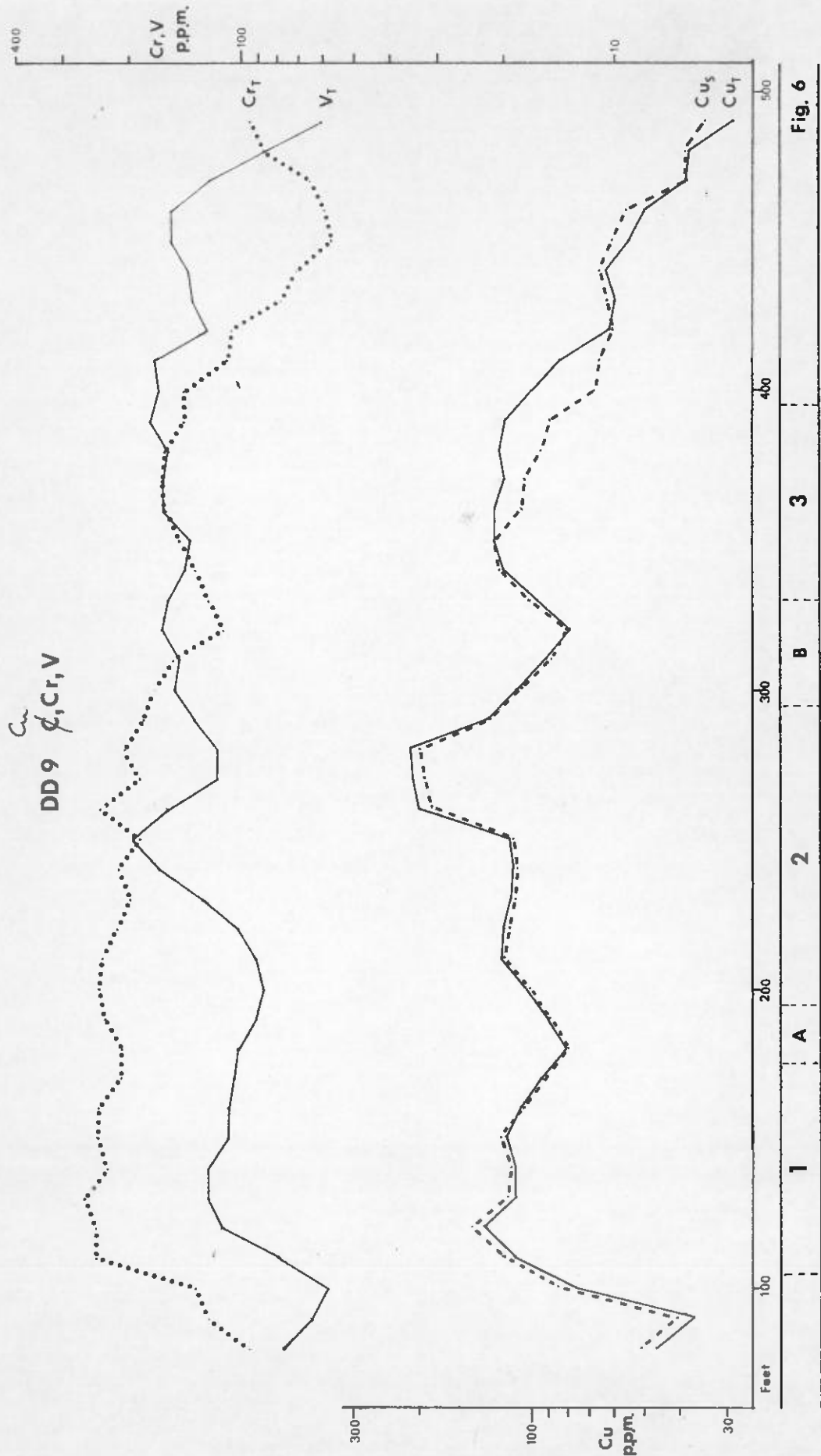


Fig. 6

DD10 S, As

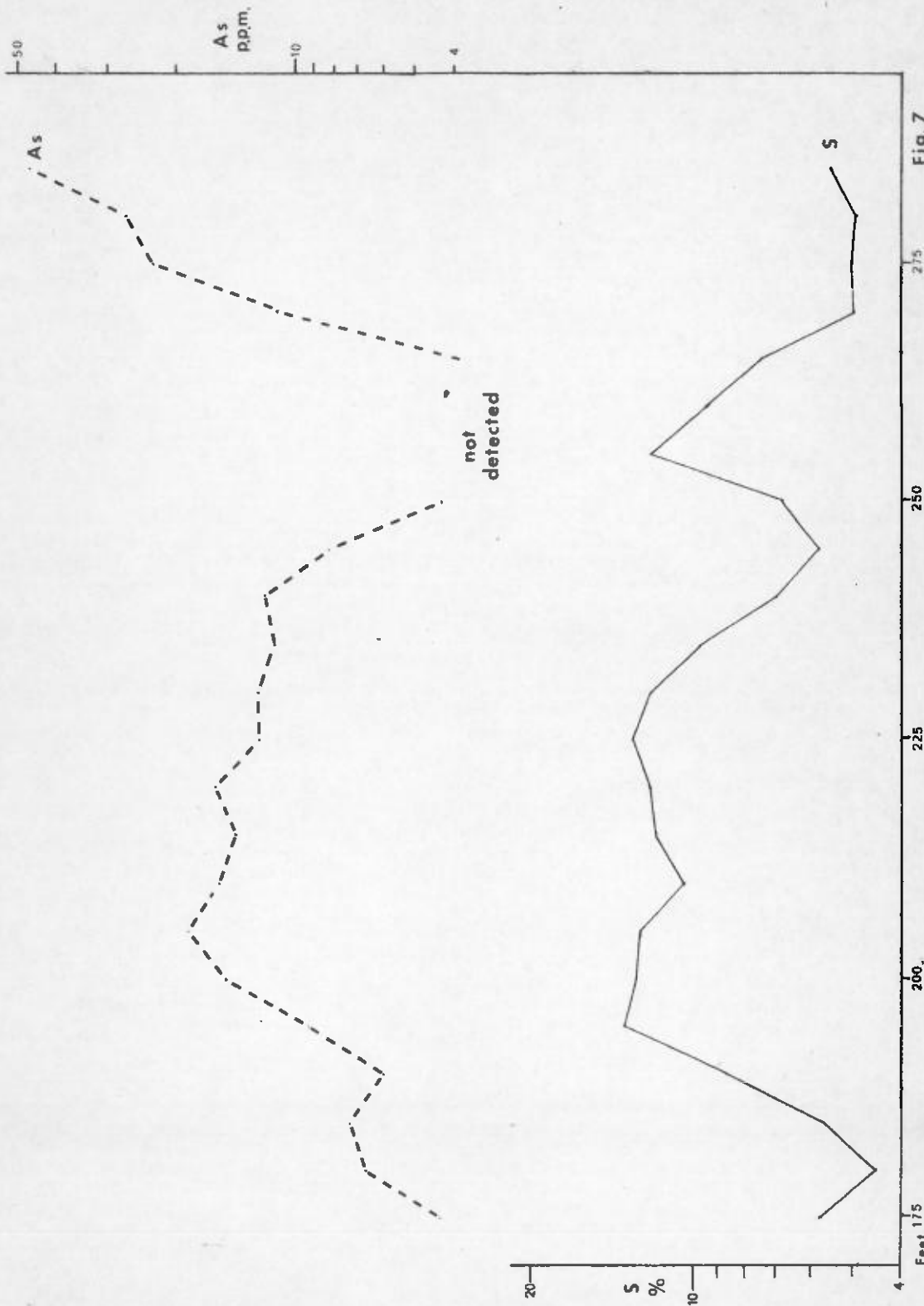


Fig. 7

Feet 175

200

225

250

275

A

2

B



DD 10 Ni, Co

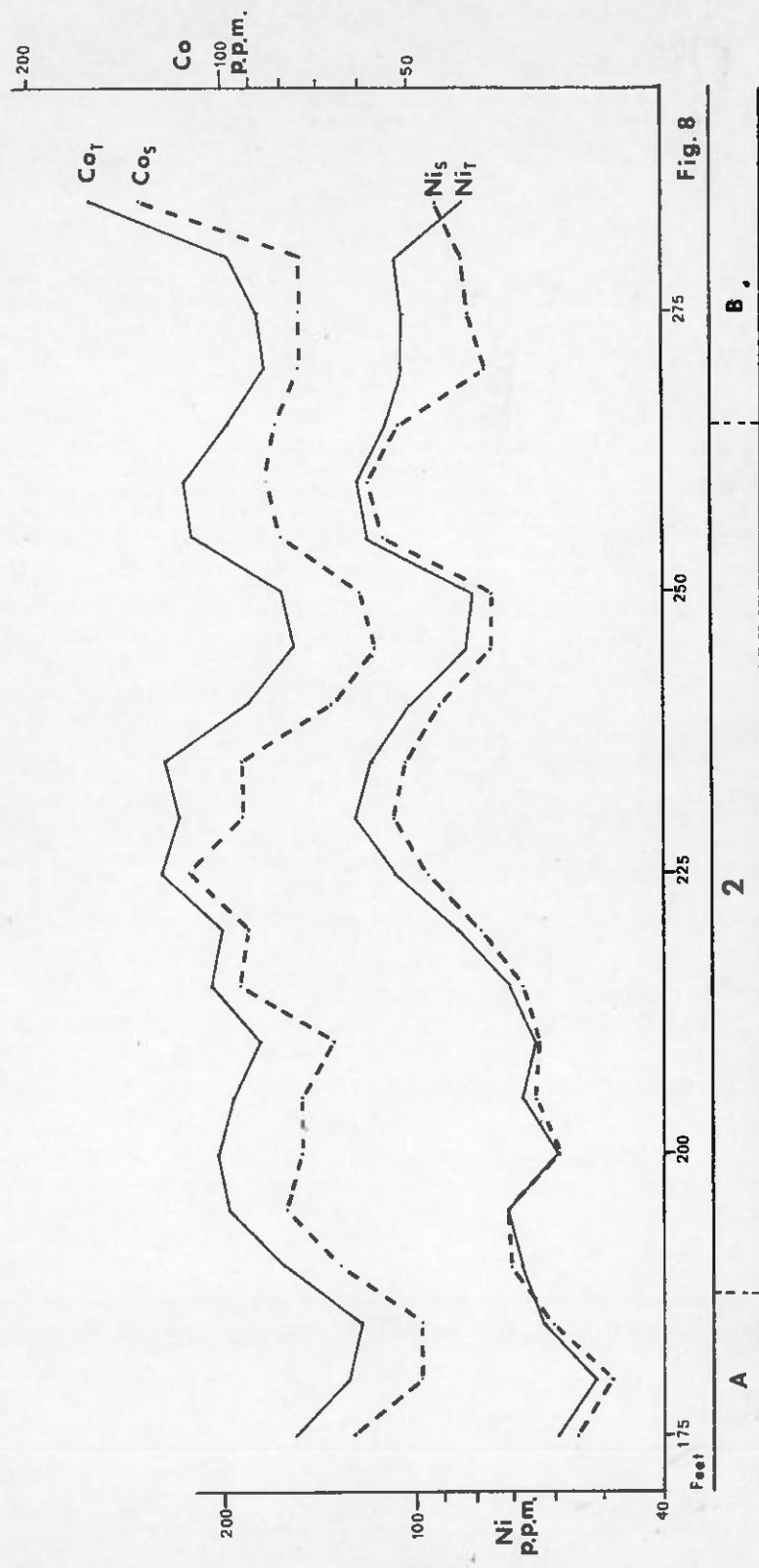


Fig. 8

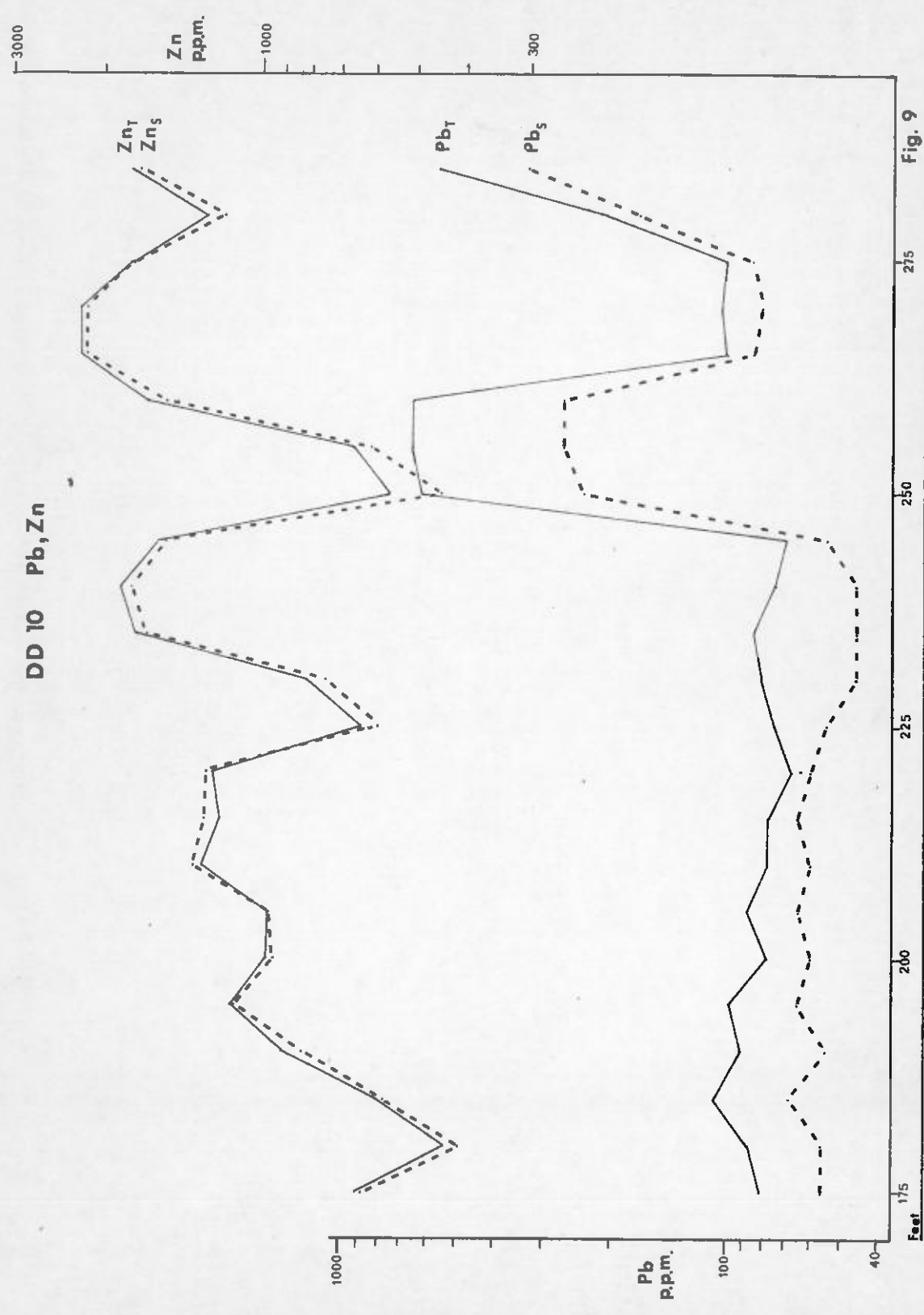


Fig. 9

A

2

B

DD 10 Fe, Mn

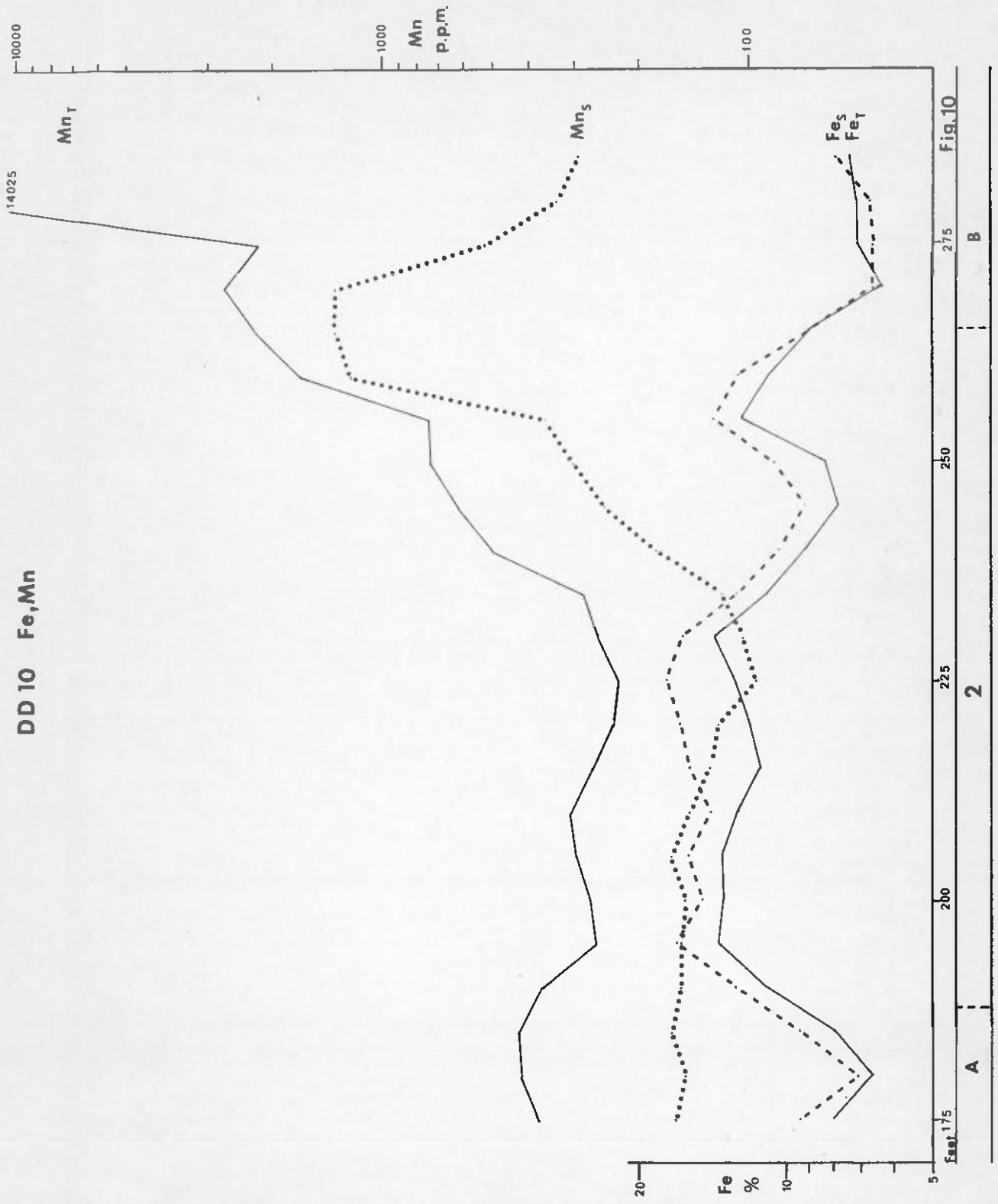


Fig. 10

B

2

A

DD 10 Cu,Cr,V

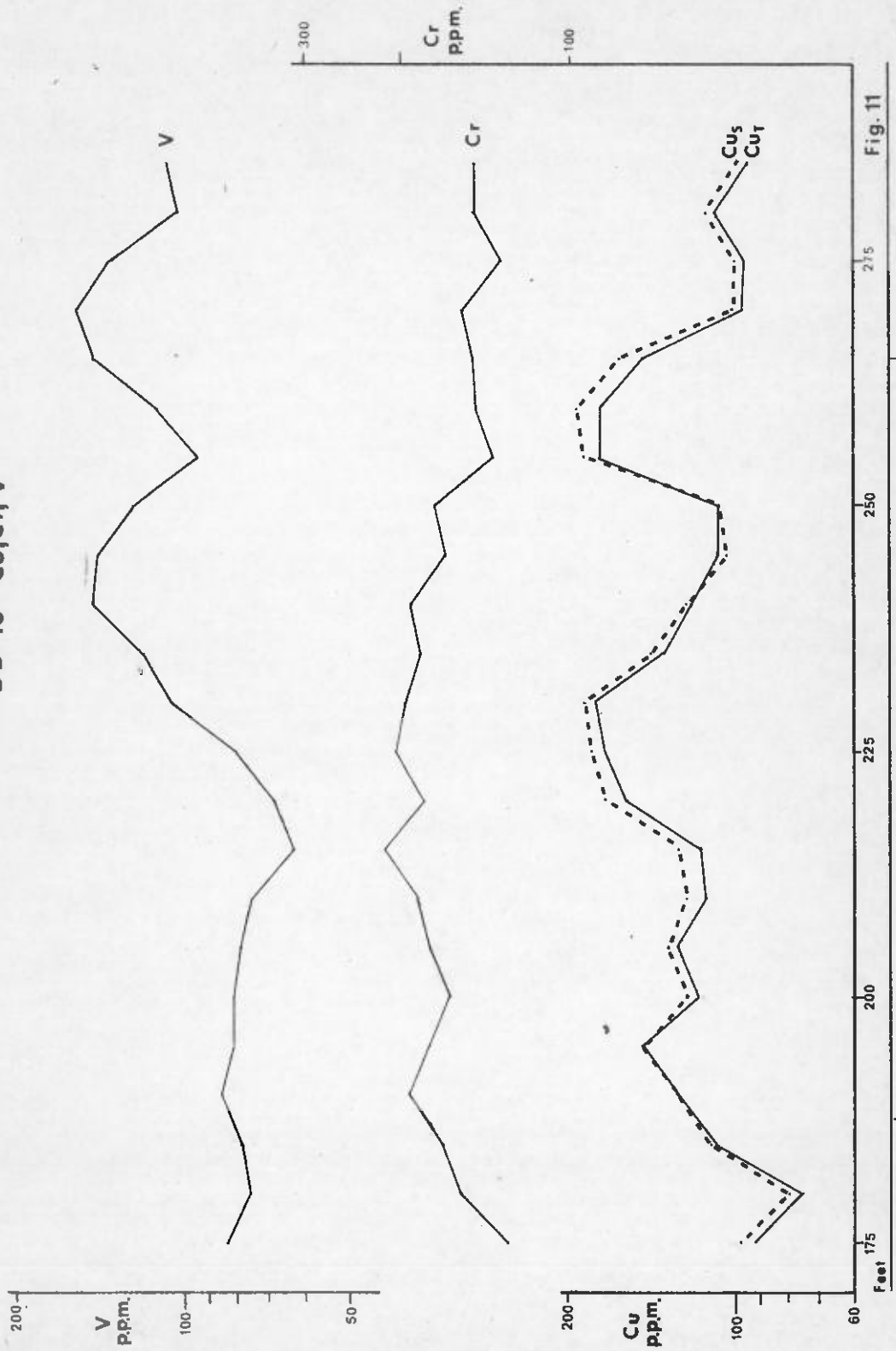


Fig. 11

sulphur content is due to sampling.

### TRACE ELEMENT ANALYSES

#### Arsenic

The arsenic analyses show a minor negative anomaly over waste bed A (fig. 2). A large positive anomaly exists over part of waste bed B. The cause of this anomaly was not observed in a polished block of the sample but 0.1% arsenopyrite would account for such an anomaly. The random variation of the profiles (figs. 2, 7) can be explained by the movement and concentration of As in veins during metamorphism. The As is found in arsenopyrite and in the rare sulphosalts of tension gash veins. The As content rises sharply from the unmineralized beds to the ore and waste beds.

#### Carbon

The carbon content of the sequence shows the same trends as sulphur (fig. 2). The broader anomaly over waste bed B may be due to the small number of samples analysed. The carbon content of the ore beds varied from 1 - 2.4% which dropped to .7 to .9% in the waste beds. The carbon is in the form of graphite (LaGanza 1959, George (1967)).

*Explain C content as CO<sub>2</sub>*

#### Nickel

Most of the Ni is in the sulphide phase. This was confirmed by correlation coefficients (r) of .88 between total Ni and sulphide Ni, and .42 between total Ni and S. (Correlation coefficients greater than .30 are significant at the 99% level for 69 samples (Fisher 1948)). High total and sulphide Ni values (100-200 p.p.m.) indicate the position of ore beds 2 and 3. The No. 1 ore bed is not indicated by Ni values (Fig. 3). For DD10 the Ni values generally increase towards the base of ore bed 2 (Fig. 8). The low Ni values at 245-250 ft. in DD10 can be correlated with a decrease in S.

The range of Ni values (33-180 p.p.m.) obtained lies within the range for black shales (20-300 p.p.m.), reported by Hawkes and Webb (1962). This indicates that sedimentary processes can account for the Ni content of the sulphides.

### Cobalt

The cobalt values rise sharply when ore bed 1 is approached (Fig. 3). Ore beds 1 and 3 are characterized by broad plateaus of Co values (80-160 p.p.m.). The position of waste beds A and B is shown by a drop in the total and sulphide Co values. No. 2 ore bed is characterized by a large increase in Co content (100-700 p.p.m.). Below the pyritic beds the Co content tails off to 40 p.p.m. For DD10 (Fig. 8) the Co values are not as high as for DD9. Cobalt is also depleted at 245-250 ft. in DD10. The cobalt is present in the sulphide phase. The sulphide Co profiles show the same trends as does total Co ( $r = .97$ ).

### Lead

Lead is found in galena and in the rare sulphosalts particularly boulangerite. ( $r = .85$  for sulphide and total Pb). These minerals are found in tension gash veins which George (1967) has shown to be formed by the mobilization of elements during metamorphism. This concentration of Pb in veins accounts for the variability of the data (Fig. 4, 7). The Pb content rises from 30 p.p.m. in the hanging wall and footwall rocks to 100-725 p.p.m. in the ore beds. Generally, the Pb assays of the ore beds are lower than the Pb contents reported by Mirams (1965). Precipitation of  $PbCl_2$  out of the solutions used for A.A.S. analyses may be the cause of the lower Pb values. The high silicate Pb content (total Pb - sulphide Pb) of sample 62 (DD10, 255 ft.) may be the result of a sampling error. The .1 gm sample used for sulphide metal analyses has a greater sampling error than the larger sample analysed for total Pb content. The Pb profile for DD9 (Fig. 4) shows the position of the ore and waste beds but this is masked by variations within the ore beds. The top of ore bed 2 in DD10 is not distinguished

from waste bed A by the Pb assays.

### Zinc

Correlation coefficients imply that Zn is present as a sulphide ( $r = .98$  between total and sulphide Zn). Sphalerite has been observed in polished sections of the Nairne Pyrite. In section DD9 (Fig. 4) the position of waste bed A is shown by low Zn values compared with the Zn content of the ore beds. The average Zn content of waste bed B was higher than the Zn content of the ore beds. Mirams (1965) indicates a high Zn value for waste bed B (2,600 p.p.m.) but this is lower than the amount of Zn he found in the ore beds. In section DD10 (Fig. 9) the Zn content of waste bed B is also high (2,000 p.p.m.). These assays suggest that sphalerite has been concentrated in waste bed B. The profiles generally show a trend of increasing Zn content from waste bed A to waste bed B. The high Zn content of sample 1 (620 p.p.m.) is not anomalous for a black shale. No sphalerite was observed in a polished block of the sample but a small amount of sphalerite (.1%) in the crushed sample would account for this high Zn value.

### Iron

Correlation coefficients of .93 between the total and sulphide Fe and .92 between total Fe and S indicate that the majority of the Fe is in the sulphide phase as pyrite and pyrrhotite. The sulphide Fe contents obtained for the ore and waste beds were generally 2% higher than the total Fe values. This was thought to be a suppression effect in the total leach method. Several samples were analysed in solutions made up with  $\text{KMnO}_3$  instead of water. This method improved the solubility of Fe by amounts up to .5% but these values were still below those obtained from the sulphide leach. This difference is too large to be accounted for by experimental error (Appendix II). Another possible explanation of this effect is an enhancement of Fe values by the  $\text{H}_2\text{O}_2$  - ascorbic acid mixture. The results indicate that for high Fe contents the method is not completely satisfactory.

The iron profiles for DD9 and DD10 show the same trends as S. For Fe the contrast between ore and waste beds is less. George (1967) has shown that all the Fe occurs as pyrite and pyrrhotite in the ore beds but in the waste beds some Fe was found in the silicates. This was based on petrology which revealed the presence of an Fe rich biotite in the waste beds which was replaced by phlogopite in the ore beds. Outside the sulphur rich beds the sulphide Fe falls off sharply compared with the decrease in total Fe content. This indicates that the Fe is contained in the silicates. Whole rock analyses have shown the silicates beneath the No. 3 ore bed to contain 3% FeO (George, 1967).

*Discuss reliability of sulphide leach —  
does it extract any silicate Fe? Difference  
between Fe total and sulphide content  
"ore zone" is evidence that the  
similarity of these in the waste beds  
is meaningful.*



In section DD10 a barren lens towards the base of the No. 2 ore bed (240-250 ft.) is shown by the total and sulphide Fe contents.

### Manganese

Both total and sulphide Mn values are high in waste beds A and B (Fig. 5). High Mn contents were also found below the No. 3 ore bed (430-450 ft.). Small Mn depleted zones are found in ore beds 1 and 3. The Mn content of the unmineralized units above and below the ore beds is higher than the Mn content of the ore beds. The highest Mn value (1750 p.p.m.) was located in waste bed B. The high Mn values of waste bed B can be correlated with high Zn values. The high Mn values of samples from DD10 are also found in waste bed B (fig. 10). The sample at 265 feet can be correlated with high Zn values. The sulphide Mn profile shows the same trends as the total Mn. The correlation coefficient between total and sulphide Mn (.26) indicates that sulphide minerals do not contain all the Mn present. The sulphide Mn may be contained in sphalerite. Skinner (1961) has reported that two samples of sphalerite from the Nairne Pyrite Deposit contained 2.3 and 2.5 weight percent Mn. To account for the highest Mn values obtained in sphalerite, 100% sphalerite would be required. This implies that large amounts of Mn are present in other sulphide and silicate minerals. Only a minor amount of the 3.75% Mn in sample 68 (DD10, 285 ft.) is present in sulphide minerals (180 p.p.m.). No pyrophanite or other Mn minerals were observed in a polished block of sample 68. The high total Mn value is due to sampling and/or experimental errors.

### Copper

Copper shows a broad anomaly over the mineralized sequence (Fig. 6). Depletions of approximately 30 p.p.m. Cu indicates the position of the waste beds. The highest Cu value obtained (380 p.p.m.) was an analysis of a sample (21) containing a large cross-cutting vein. The Cu was concentrated in veins during metamorphism.

In figure 11 the sulphide Cu profile is above the total Cu profile but the variation of these values is within experimental error, thus indicating that all of the Cu is present as sulphide minerals. Chalcopyrite and cubanite have been observed in polished sections.

? Secondary bornite was observed in sample 20 (DD9, 270 ft.). Section DD10 shows an increase in Cu towards the base of the No. 2 ore bed except for a depleted zone at 240-250 ft. Waste bed B is defined by a depletion of Cu.

#### Chromium

Chromium content does not distinguish clearly between the ore and waste beds of the deposit. The Cr values show a broad plateau over the pyritic sequence with the Cr content decreasing towards the base (Fig. 6.). A small depleted zone signifies waste bed B. The more detailed study of DD10 (Fig. 11) shows an increase in Cr content for ore bed 2. The Cr values (Appendix III) are not total Cr because the perchloric acid does not completely extract Cr. Contamination from the chrome-steel crushing vessel is assumed uniform for all samples. Chromium was not detected using a sulphide leach. No chromite has been observed at the Nairne Pyrite Deposit and so the Cr is probably present in chlorite and clay minerals.

#### Vanadium

The vanadium assays showed a general increase from approximately 60 p.p.m. in the unmineralized beds to 100-200 p.p.m. in the ore and waste beds. The V content of ore bed 1 and waste bed A is lower than the other units. Anderson (1969) has suggested that the V is contained in the sulphides (pyrite) of sedimentary deposits. Vanadium was not detected in the sulphide phase because of the low concentration in solution and poor sensitivity of the method.

*What was detection limit?*

#### Selenium

The Se analyses showed no trends distinguishing ore beds from the waste beds. The samples that contained Se greater than

the detection limit of 3 p.p.m. were taken from ore beds 2, 3 and waste bed B. The highest Se value obtained was 9.5 p.p.m. in sample no. 23 (DD9, 290 ft.). These Se values are not reliable because of the variation in background slopes.

*Need to explain this.*

#### DISCUSSION

Loftus-Hills and Solomon (1967) have proposed that sedimentary pyrite can be indicated by Co/Ni ratios less than unity. The total metal analyses of the ore and waste beds of the Nairne Pyrite Deposit generally gave Co/Ni ratios greater than 1.

The average Co/Ni ratio based on the sulphide metal content, was 1.13 with a range from .36 to 9.33. The sulphide Co/Ni ratios for samples in ore beds 1 and 2 are generally greater than 1, while the ratios of samples from ore bed No. 3, waste beds A and B and the samples above and below these units are less than 1. A number of samples with pyrite as the major sulphide present had sulphide Co/Ni ratios less than unity.

This was shown by samples 12, 30 and 31 with sulphide Co/Ni ratios of .55, .54 and .48 respectively. Samples 30 and 31 also had total Co/Ni ratios in this range. Other pyrite rich samples had ratios greater than 1, e.g. sample 10 had a sulphide Co/Ni ratio of 1.20. These results show that without mineral separations, no clear indication of a sedimentary origin is shown by Co/Ni ratios. The variation in the Co/Ni ratios may be due to the selective mobilization of the trace elements as a "dispersed phase" during metamorphism (George 1967).

For both the total and sulphide metal contents of each sample Cu/Zn ratios were calculated. The sulphide Cu/Zn ratios vary from 1.0 to 5.0 for the samples outside of the ore and waste bed sequence (except for sample 1). The mineralized beds generally have

ratios of .03 to .7 (sample 21 has a ratio of 1.25). The sulphide Cu/Zn ratios for waste bed A were slightly higher than the ratios for ore beds 1 and 2. The sulphide Cu/Zn ratios for waste bed B did not vary significantly from the ore bed ratios. Similar trends are shown by the total Cu/Zn ratios. These trends are opposite to those used by Hallberg (1972), as environmental indicators. Hallberg has reported that Cu/Zn ratios are higher in zones that have been chemically reduced.

The above discussion revealed that the Cu/Zn ratios are the lowest in the ore beds which were <sup>presumably</sup> formed under strong reducing conditions.

*ie > ? Se*

For the samples containing 3 or more p.p.m. Se, S/Se ratios were calculated. The ratios ranged from 4118 to 35,771. The validity of the higher ratios is doubted because the Se values were close to the detection limit of the analytical method used. For the samples containing the highest Se contents the S/Se ratios are less than 20,000. Ratios in this range for pyrite were considered by Edwards and Carlos (1954) to indicate a hydrothermal origin of the deposit. LaGanza (1959a) states that Se is concentrated in the carbonaceous material. A high Se content of the graphite would account for the low S/Se ratios.

*Why?*

Correlation coefficients between the total elements and between the sulphide metals analysed were calculated. The coefficients, significant at the 99% confidence limit are underlined in Table I. The significant correlations indicate a corresponding increase in metal content in ore beds and a decrease in waste and unmineralized beds. The correlation coefficients cannot be used to say clearly in what mineral phases all of the true elements are found. Nickel correlates with Cu and Fe. This may suggest that Ni is present in chalcopyrite, pyrite and/or pyrrhotite. The only conclusions reflected in these coefficients is that Ni, Cu and Fe contents all

*How do correlations indicate this*

TABLE 3.

CORRELATION COEFFICIENTS

Number of samples = 69.

Correlations significant at the 99 percent level are underlined.

A. Total elements.

Ni	<u>.64</u>									
Co	<u>.51</u>	<u>.32</u>								
Pb	.14	.19	<u>.32</u>							
Zn	.27	.24	<u>.46</u>	.26						
Fe	<u>.77</u>	<u>.43</u>	.30	.21	.19					
Mn	-.07	0	.01	.09	.16	-.20				
V	-.04	.23	.11	.05	<u>.34</u>	-.19	-.01			
Cr	<u>.38</u>	.12	<u>.31</u>	.14	.20	<u>.55</u>	-.03	-.11		
S	<u>.76</u>	<u>.42</u>	<u>.41</u>	.24	.28	<u>.92</u>	-.16	-.17	<u>.67</u>	
As	.11	.14	<u>.58</u>	.27	<u>.35</u>	.09	.01	.14	<u>.35</u>	.21
	Cu	Ni	Co	Pb	Zn	Fe	Mn	V	Cr	S

B. Sulphide Metals (H<sub>2</sub>O<sub>2</sub> digestion)

Ni	<u>.68</u>					
Co	<u>.39</u>	<u>.31</u>				
Pb	.11	.24	<u>.40</u>			
Zn	.27	<u>.36</u>	<u>.54</u>	<u>.45</u>		
Fe	<u>.77</u>	<u>.53</u>	<u>.35</u>	.26	.26	
Mn	-.04	.08	.17	.22	<u>.46</u>	-.19
	Cu	Ni	Co	Pb	Zn	Fe

show similar geochemical trends across the sulphide beds. Similar conclusions can be obtained for Co. The significant correlation between sulphide Mn and Zn proves that the Mn of the sulphide phase is found in sphalerite. The poor correlation between total Mn and Zn implies that a large portion of the Mn is in silicate or oxide phases. The negative correlation between Mn and S (significant at the 85% level) also indicates that the majority of the Mn is not present in the sulphides but is tied up in the silicates or oxides which were not deposited when the S fugacity was high.

The significant correlation between carbon and sulphur ( $r = .75$ ) supports the qualitative estimates of graphite content made by George (1967). George suggests that the relationship between the graphite and sulphide content of the beds reflects a correspondence between sulphide generation and organic decay. The sulphur has been derived from the biogenic reduction of sulphate ions (Jensen and Whittles (1969). Anaerobic conditions are required by the sulphate reducing bacteria. Love (1969) suggests that large quantities of organic matter is required for the growth of the organisms and the production of S. Therefore the correlation of high carbon content with high sulphur content agrees with the theory of a sedimentary origin for the Nairne Pyrite Deposit.

*Introduce method, what variables used*

The dendrogram obtained from a cluster analysis of the geochemical data collected from DD9 is shown in figure 12. The cluster analysis places all but two of the foot wall and hanging wall samples into a major group. The other major group contains samples from the ore and waste beds. Waste bed B is distinguished from waste bed A. Both waste beds are separated from the ore beds but no grouping is made of the individual ore beds.

A-B ?

*Indicate this group*

The major separation of unmineralized from mineralized beds is significant when discussing the origin of the deposit. The geochemical profiles show a marked increase of Fe along with Cu,

CLUSTER ANALYSIS

ISOTOPE DATA FROM DD 9

Fig. 12

Sample Positions

- H Hanging Wall
- 1 No. 1 Ore Bed
- A Waste Bed A
- 2 No. 2 Ore Bed
- B Waste Bed B
- 3 No. 3 Ore Bed
- F Footwall



Sample pos:  
Sample No.

Co, Ni, Pb and Zn contents in the ore and waste beds compared with the unmineralized beds. A smaller increase is shown in the Cr and V values. This indicates an external source for the metal content of the sulphides. A large influx of Fe with the associated trace elements into a closed basin took place before sulphide deposition. The Mn content of the sediments was high before the sulphides were deposited. The waste beds are more closely related to the ore beds than to the barren footwall and hanging wall rocks.

During the deposition of the Nairne Pyrite Member periods in which the conditions were less reducing, accounts for the lower sulphide content of the waste beds and barren lenses in ore beds (DD10). This change of conditions is reflected by the carbon content of ore and waste beds. The metal content in the overlying water probably was the same during the formation of the ore and waste beds, with the amount of sulphide precipitated controlled by the amount of sulphur produced by the bacteriogenic reduction of sulphate. This is dependent on the reducing conditions and the amount of organic matter present in the basin of deposition.



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## APPENDIX I

### MINERAGRAPHIC TECHNIQUES

All the reflectance measurements were made using monochromatic light (wavelength = 546 n.m.) on a Vickers-Eel Microphotometer. The microphotometer was standardized with a tungsten carbide standard (reflectance = 43.9%).

A Vickers Microhardness tester was used to measure the hardness of the minerals, which was reported as a Vickers Hardness Number. The size of the load was selected depending on the hardness of the mineral so that an indentation with a diagonal length between 15 and 25 microns was obtained.

The magnetic colloid used to identify monoclinic pyrrhotite was prepared by Dr. J. Graham <sup>(CSIRO Division of Mineralogy, Perth)</sup> using the general method of B. Gustard (1967) in which acetone was replaced by water and detergent as a suspension medium. The brown magnetic particles collected on the monoclinic pyrrhotite while the surface of the hexagonal pyrrhotite remained clear.

Microscopically unidentifiable mineral grains (greater than 1.5 mm in diameter) were drilled out of the polished section. This sample was then collected on a glass spindle coated with vaseline and mounted in an X-ray powder camera. The sample was then irradiated for a specific time (20 min to 6 hours) depending on the mineral. Minerals suspected of containing iron were irradiated with Fe K-alpha radiation (Mn filter). Other minerals were irradiated with Cu K-alpha radiation (Ni filter). The diffraction film was measured and d spacings calculated. The mineral was then identified by looking up the d spacing of the most intense lines in the

Inorganic Index to the Powder Diffraction File (1971) with final confirmation from the A.S.T.M. powder diffraction index.

The electron microprobe analyses (carried out at C.S.I.R.O. Division of Soils, Adelaide) of minerals containing Pb and As were not corrected for mass absorption. Pb had to be measured on a M-alpha peak because of mutual interference of Pb and As L-alpha peaks. No correction factors were available for M radiation.

## APPENDIX II

### ANALYTICAL TECHNIQUES

#### SAMPLE PREPARATION

Approximately 70 gms. of the drill core sample (Kleeman 1967) was crushed with a small jaw crusher (ceramic jaw). This was then pulverized in a Siebtechnik Mill using a chrome steel vessel. Each sample was crushed for 3 minutes to achieve the required grain size of - 120 mesh for X-ray Fluorescence and atomic absorption analysis.

#### ATOMIC ABSORPTION SPECTROPHOTOMETRY (A.A.S.)

Two different digestions were used for iron and trace element analyses.

(a) Perchloric acid digestion ("total" leach). 4 mls. of 70%  $\text{HClO}_4$  was added to .4 gms. of sample in a volumetrically calibrated glass test tube and heated on a sand bath at 180-200°C for 16 hours. The temperature was then raised to 240°C for 2 hours to boil off excess  $\text{HClO}_4$ . The solutions were then made up to 20 mls. with distilled  $\text{H}_2\text{O}$ , shaken and allowed to stand 8 hours before being analysed.

(b) Hydrogen Peroxide - Ascorbic Acid digestion ("sulphide" leach). The method described by Lynch (1971) was used.

AA-1000  
The solutions were analysed for Fe, Cu, Co, Ni, Pb, Zn, Cr and Mn with an A.A.-1 instrument, using an air acetylene flame. Vanadium was analysed with an A.A.-3 instrument, using a nitrous oxide - acetylene flame. The precision of the analyses was checked by running standards with each batch. The standards used were those prepared by G. Stolz and D. Milton.

Estimates of precision obtained from the analytical data, were -

Element	HClO <sub>4</sub>	H <sub>2</sub> O <sub>2</sub> Leach
Ni	± 2.5 p.p.m.	± 5 p.p.m.
Co	± 5 p.p.m.	± 10 p.p.m.
Cu	± 2.5 p.p.m.	± 5 p.p.m.
Pb	± 5 p.p.m.	± 10 p.p.m.
Zn	± 8 p.p.m.	± 10 p.p.m.
Fe	± .05%	± .075%
Mn	± 10 p.p.m.	± 5 p.p.m.
V	± 5 p.p.m.	-

The precision varies with the assay value.

For high metal values the reproducibility of the results was poor because of the flattening out of the calibration curve.

Loftus-Hills and Solomon (1967) in analysing Co and Ni contents of pyrite by A.A.S. have reported a suppression of Co and Ni by high iron concentrations. Preliminary work was undertaken to check whether this suppression would be of importance in this study. Solutions with varying Fe concentrations containing 4 p.p.m. Co and Ni in solution were made and then analysed. Co and Ni contamination of the Fe solution was taken into account. The results (Fig. A1) showed that the suppression of Co and Ni values was less than 0.5 p.p.m. for the range of Fe concentrations studied. Therefore it was not necessary to correct the Co and Ni assays of the Nairne Pyrite samples because the suppression effect was less than the precision of the assays.

#### X-RAY FLUORESCENCE (X.R.F.)

Sulphur, arsenic and selenium were analysed by X.R.F. methods

# SUPPRESSION of Co and Ni by Fe

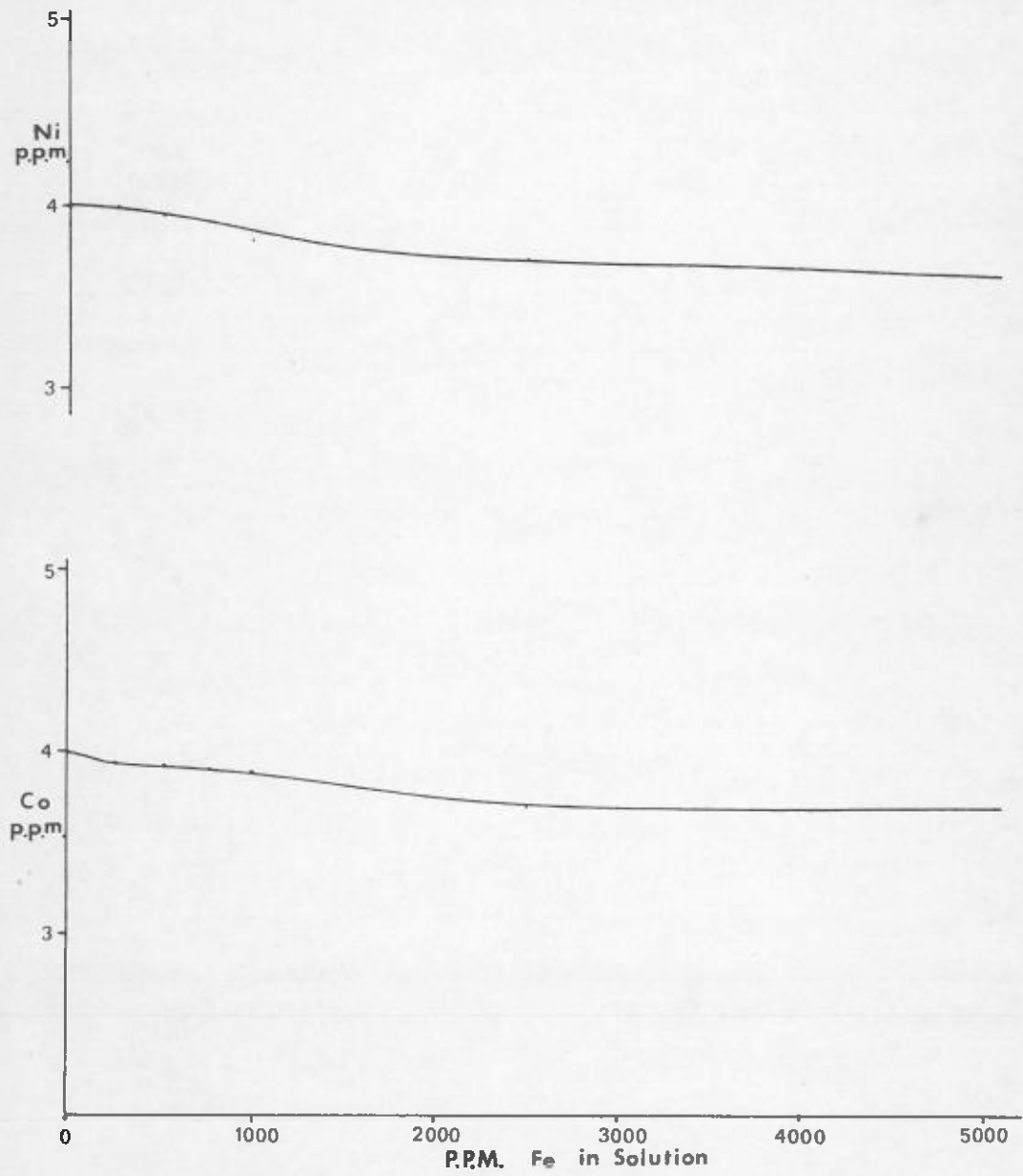


Fig. A1



using pressed mounts.

#### SULPHUR ANALYSES

The method developed by Stolz (1971) was used. Stolz's calibration factor was unsuitable for this study. Calibration standards were made using accurately weighed amounts of pyrite (assumed to be stoichiometric  $\text{FeS}_2$ ) in a rock matrix obtained from the base of the Nairne Pyrite Member (sample no. 44). Standards using hexagonal and pyrrhotite from the Nairne Pyrite quarry, were also made. The composition of the hexagonal pyrrhotite was taken as  $\text{Fe}_{0.96}\text{S}$  (Arnold 1968). The pyrite standards indicated that one count per second equals 7.5 p.p.m. sulphur. A calibration factor of 7.2 was obtained from the pyrrhotite standards. The presence of some monoclinic pyrrhotite may be the cause of the lower factor than that obtained from the pyrite standards. In calculating the sulphur assays one count per second was taken as 7.5 p.p.m. S. This gives a correct sample to sample variation but the absolute value of sulphur obtained for a sample may have a small error.

#### ARSENIC ANALYSES

Arsenic was analysed by X.R.F. using method developed by J. Sumartojo (pers. comm.). The position of the As K-alpha<sub>1</sub> peak is the same as the Pb L-alpha<sub>1</sub> peak. Correction for Pb was made by measuring the Pb L-beta peak. The ratio between the Pb K-alpha<sub>1</sub> and Pb L-beta peaks was measured on a pure  $\text{PbNO}_3$  plus quartz standard. A 1000 p.p.m. As standard was prepared with  $\text{As}_2\text{O}_3$  and quartz powder.

Operating conditions and method used

- (1) Molybdenum tube (60 K volts, 40 m. amps.)
- (2)  $\text{LiF}_{220}$  crystal.
- (3) fine collimator.
- (4) Scintillation counter.
- (5) As K-alpha peak angle:  $48.70^\circ$   
background angle:  $46.80^\circ$

(5) (continued)

Pb K-beta peak angle:  $40.27^\circ$   
background angle:  $39.50^\circ$

- (6) 40 second counts were made on the four angles listed above.
- (7) the 10008 As standard was counted in each run.
- (8) Ultrasil was used to give the background slope.
- (9) The mass absorption coefficient of each sample was obtained by measuring the time to accumulate 400,000 counts on the Compton scattering peak angle ( $30.426^\circ$ ).
- (10) The counts on the As peak, corrected for background and Pb were converted to p.p.m. As by comparison with the counts on the standard. The p.p.m. As values were corrected for mass absorption by the equation:

$$\text{corrected p.p.m.As} = \frac{H_{\text{sample}}}{H_{\text{standard}}} \times \text{p.p.m.}$$

(H = mass absorption)

#### SELENIUM ANALYSES

The method of G. Stolz (1971) was attempted. Problems arose because of the variability in the background slope factors measured and the low Se content of the samples. The majority of the samples had a Se content below the detection limit of 3 p.p.m.

#### CARBON ANALYSES

Carbon was analysed using an induction furnace at Simpson Pope's Finsbury plant. The induction furnace was linked to a small  $\text{MnO}_2$  trap to collect the  $\text{SO}_2$  produced, but because of the sulphur rich nature of the samples, the sulphides had to be removed before the analyses were done. The sulphides and any carbonates present were dissolved in concentrated hydrochloric acid.

APPENDIX III

TABLES OF ANALYTICAL RESULTS.

(1) Analyses of samples taken from Diamond Drill Hole No. 9.  
 Fe and S contents are expressed as percentages.  
 All other elements are expressed as parts per million (P.P.M.).

		TOTAL METAL CONTENT (HClO <sub>4</sub> digestion).								
Samp. No.	Posn. ft.	Ni	Co	Cu	Pb	Zn	Fe	Mn	Cr	V
1	70	55	40	40	25	620	2.25	400	125	75
2	80	75	63	73	45	80	4.75	660	118	100
3	90	93	40	25	30	50	3.58	575	40	55
4	100	35	25	15	25	13	1.20	500	205	38
5	110	70	75	190	110	800	9.38	425	150	83
6	120	58	100	130	125	1900	15.0	350	375	113
7	130	58	75	90	240	920	6.63	650	205	138
8	140	58	90	115	155	760	12.5	75	205	113
9	150	65	90	130	450	1450	16.4	375	270	113
10	160	55	90	113	280	425	13.0	325	250	100
11	170	58	85	85	225	375	9.75	400	200	113
12	180	55	70	88	130	370	7.50	650	175	100
13	190	58	55	73	100	220	6.63	600	250	90
14	200	60	90	115	375	1175	10.3	575	270	83
15	210	60	90	135	250	1075	11.9	450	200	90
16	220	65	115	123	275	1900	13.3	450	235	100
17	230	60	90	105	125	895	9.75	438	208	113
18	240	100	105	123	475	1075	8.13	663	155	175
19	250	138	115	120	225	1438	9.50	625	270	210
20	260	110	115	113	200	3250	5.88	700	138	200
21	270	140	672	380	85	1975	16.5	688	313	63
22	280	90	100	148	90	160	8.88	900	110	90
23	290	80	735	125	725	4000	8.00	1550	190	200
24	300	90	255	130	75	1850	6.38	1500	245	113
25	310	73	90	80	125	2740	3.70	17500	75	138
26	320	73	70	75	115	3150	5.50	1950	138	188
27	330	75	70	90	90	1925	6.50	1225	122	158
28	340	60	85	135	120	1500	8.38	1050	110	130
29	350	73	85	145	115	215	8.00	650	168	138
30	360	180	100	110	150	360	7.50	563	160	150
31	370	105	90	135	140	380	6.38	600	155	200
32	380	105	85	120	260	710	11.5	563	175	138
33	390.5	85	120	125	168	950	8.50	550	155	138
34	400	85	100	123	90	410	6.25	600	140	250
35	410	70	90	63	40	25	5.00	900	130	113
36	420	58	85	75	50	40	6.38	1100	60	150
37	430	60	70	55	30	108	4.40	2200	130	113
38	440	55	55	58	40	45	4.55	1025	45	150
39	450	65	55	85	40	33	4.40	538	40	158
40	460	35	35	30	30	33	3.00	550	90	158
41	470	65	70	43	60	90	3.65	750	50	150
42	480	35	40	18	30	25	2.75	400	60	55
43	490	33	35	28	25	20	2.75	500	155	55
44	500	40	40	15	40	40	3.00	475	75	75

Analyses of Diamond Drill Hole No. 9 continued.

Samp. No.	TOTAL		SULPHIDE METAL (H <sub>2</sub> O <sub>2</sub> digestion)						
	As	S	Ni	Co	Cu	Pb	Zn	Fe	Mn
1	5	0.45	55	20	50	20	580	0.80	130
2	3	2.26	60	30	70	20	35	2.50	200
3	4	0.18	40	20	35	5	30	1.10	200
4	30	0.46	30	20	20	20	20	1.10	240
5	5	10.05	70	50	205	20	750	8.60	170
6	28	15.80	63	80	135	65	1700	17.0	125
7	25	6.50	60	60	100	140	900	8.06	290
8	25	10.93	50	80	120	80	605	12.0	140
9	22	13.92	55	60	125	208	1100	15.0	175
10	24	11.83	50	60	120	115	380	13.3	175
11	29	8.48	53	60	80	90	355	10.0	185
12	16	6.00	55	30	90	65	335	6.60	255
13	10	4.43	40	20	75	65	190	5.60	230
14	38	12.04	55	70	110	160	975	13.7	375
15	29	11.03	60	60	125	140	875	12.0	235
16	33	14.92	50	100	130	170	1300	16.0	220
17	30	11.92	60	70	100	160	800	13.7	230
18	25	8.90	55	100	110	235	1100	11.8	400
19	48	12.52	130	100	125	160	1225	7.13	350
20	32	6.32	100	100	115	140	3000	7.80	460
21	39	21.46	105	400	335	30	1525	19.5	440
22	7	7.76	85	60	150	50	120	11.8	375
23	116	8.33	75	700	130	390	4000	11.0	1005
24	177	6.10	85	210	120	50	1750	7.80	880
25	17	3.65	70	60	80	80	1425	4.76	2350
26	5	4.02	60	50	75	60	3000	5.50	1700
27	8	4.94	70	30	95	40	1525	6.80	470
28	22	8.00	55	50	145	60	1500	11.3	275
29	8	6.14	70	50	135	30	200	9.50	165
30	30	8.60	130	70	110	60	342	11.7	140
31	27	5.44	105	50	85	50	1000	5.30	190
32	30	9.42	115	60	130	115	657	13.5	185
33	32	7.40	85	80	80	80	925	10.0	195
34	8	4.08	70	60	70	40	410	6.80	175
35	53	3.52	70	60	60	20	30	3.72	215
36	3	3.09	60	30	75	20	15	5.40	490
37	6	1.12	55	50	55	10	50	2.20	235
38	10	0.55	40	20	65	10	20	1.60	330
39	6	0.60	40	30	85	10	18	1.80	250
40	4	0.06	20	20	40	10	18	0.90	200
41	3	0.13	30	30	50	20	50	0.70	145
42	3	0.08	20	20	30	10	15	1.00	165
43	6	0.15	20	20	45	10	15	1.10	305
44	3	0.05	20	15	35	20	20	0.90	200

- (2) Analyses of samples collected from Diamond Drill Hole No.10  
 Fe and S values are expressed as percentages.  
 All other elements are reported as P.P.M.

TOTAL METAL CONTENT (HClO<sub>4</sub> digestion).

Samp. Posn. No. ft.	Ni	Co	Cu	Pb	Zn	Fe	Mn	Cr	V	
45	170	73	90	118	65	1000	9.50	425	125	100
46	175	60	85	100	65	620	9.13	250	130	90
47	180	45	55	60	113	340	5.25	475	130	63
48	185	50	50	65	85	360	5.50	550	200	75
49	190	93	75	200	125	1088	12.6	275	175	100
50	195	60	115	113	65	1263	14.6	300	205	83
51	200	58	105	123	105	1025	13.8	225	155	63
52	205	58	85	110	65	640	11.0	300	123	100
53	210	85	100	145	95	1250	15.0	375	260	75
54	215	50	75	80	75	1988	11.0	263	175	55
55	220	75	135	115	65	360	7.13	180	210	63
56	225	130	90	278	65	1300	17.5	275	160	90
57	230	113	145	120	95	263	13.3	235	240	90
58	235	120	115	138	85	880	11.2	275	195	138
59	240	113	105	140	75	4000	8.13	350	123	130
60	245	70	55	80	65	650	7.80	900	255	170
61	250	65	70	95	70	80	7.60	650	125	130
62	255	105	115	140	1725	960	9.63	700	145	75
63	260	180	145	290	175	960	19.0	900	138	83
64	265	75	75	93	65	3000	3.70	3750	160	175
65	270	70	75	55	60	2750	4.20	2050	150	188
66	275	160	105	145	180	975	11.0	2400	155	113
67	280	75	85	90	60	1625	5.88	2175	90	113
68	285	75	105	90	385	1200	4.40	37500	200	83
69	290	100	290	105	1250	2550	11.8	1850	155	130

Analyses of Diamond Drill Hole No. 10 continued.

Samp. No.	TOTAL		SULPHIDE METAL (H <sub>2</sub> O <sub>2</sub> digestion)						
	As	S	Ni	Co	Cu	Pb	Zn	Fe	Mn
45	5	7.56	70	80	130	50	1025	12.3	210
46	5	6.50	60	65	100	20	550	11.0	100
47	10	3.26	35	40	65	90	340	5.00	180
48	7	3.85	50	40	75	50	340	5.50	180
49	nd	10.04	95	65	190	65	1050	17.8	140
50	20	12.45	65	90	120	50	1100	15.0	125
51	24	17.15	53	84	130	80	1180	18.0	180
52	12	8.30	60	50	120	50	540	11.7	125
53	11	12.03	80	90	150	65	1275	18.3	160
54	20	10.28	50	60	100	65	2225	12.5	160
55	17	12.30	70	133	130	65	355	16.3	70
56	nd	13.34	115	80	285	50	1200	20.5	140
57	20	13.01	100	120	130	50	220	15.6	80
58	13	9.27	107	80	150	38	830	12.3	100
59	3	6.61	100	80	145	50	4000	10.0	180
60	9	4.84	65	40	75	50	490	8.86	270
61	nd	5.87	60	50	90	65	80	8.90	300
62	3	9.44	100	90	150	590	775	14.3	350
63	nd	15.24	170	100	325	140	980	19.0	440
64	5	3.41	80	65	105	65	2750	3.90	2900
65	5	3.50	65	80	60	50	2750	4.60	775
66	24	7.79	85	80	145	130	950	11.5	440
67	40	3.57	95	65	100	80	1650	3.72	385
68	19	3.27	70	80	90	300	900	5.00	180
69	82	9.42	107	250	110	620	2600	15.0	310

Carbon Analyses.

Grouped Sample Numbers.

C content (percent)

3, 4	0.11
5, 6	0.60
7, 8	0.74
9, 10, 11	1.65
12, 13	0.79
14, 15	2.43
16, 17	2.07
18, 19	2.29
20, 21	1.38
22, 23	1.94
24, 25	1.23
26, 27	0.97
28, 29	0.98
32, 33	2.04
34, 35	1.04
38, 39	0.32