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# **MINERALOGY AND GEOCHEMISTRY OF MINERALIZED AND BARREN WEATHERED PROFILES, PARKINSON PIT, MT MAGNET WESTERN AUSTRALIA**

*K.M. Scott*

**CRC LEME OPEN FILE REPORT 12**

September 1998

(CSIRO Division of Exploration Geoscience Report 33R, 1989.  
Second impression 1998)

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## RESEARCH ARISING FROM CSIRO/AMIRA REGOLITH GEOCHEMISTRY PROJECTS 1987-1993

In 1987, CSIRO commenced a series of multi-client research projects in regolith geology and geochemistry which were sponsored by companies in the Australian mining industry, through the Australian Mineral Industries Research Association Limited (AMIRA). The initial research program, "Exploration for concealed gold deposits, Yilgarn Block, Western Australia" (1987-1993) had the aim of developing improved geological, geochemical and geophysical methods for mineral exploration that would facilitate the location of blind, buried or deeply weathered gold deposits. The program included the following projects:

**P240: Laterite geochemistry for detecting concealed mineral deposits (1987-1991).** Leader: Dr R.E. Smith.  
Its scope was development of methods for sampling and interpretation of multi-element laterite geochemistry data and application of multi-element techniques to gold and polymetallic mineral exploration in weathered terrain. The project emphasised viewing laterite geochemical dispersion patterns in their regolith-landform context at local and district scales. It was supported by 30 companies.

**P241: Gold and associated elements in the regolith - dispersion processes and implications for exploration (1987-1991).** Leader: Dr C.R.M. Butt.

The project investigated the distribution of ore and indicator elements in the regolith. It included studies of the mineralogical and geochemical characteristics of weathered ore deposits and wall rocks, and the chemical controls on element dispersion and concentration during regolith evolution. This was to increase the effectiveness of geochemical exploration in weathered terrain through improved understanding of weathering processes. It was supported by 26 companies.

These projects represented "an opportunity for the mineral industry to participate in a multi-disciplinary program of geoscience research aimed at developing new geological, geochemical and geophysical methods for exploration in deeply weathered Archaean terrains". This initiative recognised the unique opportunities, created by exploration and open-cut mining, to conduct detailed studies of the weathered zone, with particular emphasis on the near-surface expression of gold mineralisation. The skills of existing and specially recruited research staff from the Floreat Park and North Ryde laboratories (of the then Divisions of Minerals and Geochemistry, and Mineral Physics and Mineralogy, subsequently Exploration Geoscience and later Exploration and Mining) were integrated to form a task force with expertise in geology, mineralogy, geochemistry and geophysics. Several staff participated in more than one project. Following completion of the original projects, two continuation projects were developed.

**P240A: Geochemical exploration in complex lateritic environments of the Yilgarn Craton, Western Australia (1991-1993).** Leaders: Drs R.E. Smith and R.R. Anand.

The approach of viewing geochemical dispersion within a well-controlled and well-understood regolith-landform and bedrock framework at detailed and district scales continued. In this extension, focus was particularly on areas of transported cover and on more complex lateritic environments typified by the Kalgoorlie regional study. This was supported by 17 companies.

**P241A: Gold and associated elements in the regolith - dispersion processes and implications for exploration.** Leader: Dr C.R.M. Butt.

The significance of gold mobilisation under present-day conditions, particularly the important relationship with pedogenic carbonate, was investigated further. In addition, attention was focussed on the recognition of primary lithologies from their weathered equivalents. This project was supported by 14 companies.

Although the confidentiality periods of the research reports have expired, the last in December 1994, they have not been made public until now. Publishing the reports through the CRC LEME Report Series is seen as an appropriate means of doing this. By making available the results of the research and the authors' interpretations, it is hoped that the reports will provide source data for future research and be useful for teaching. CRC LEME acknowledges the Australian Mineral Industries Research Association and CSIRO Division of Exploration and Mining for authorisation to publish these reports. It is intended that publication of the reports will be a substantial additional factor in transferring technology to aid the Australian Mineral Industry.

This report (CRC LEME Open File Report 12) is a first revision of CSIRO, Division of Exploration Geoscience Restricted Report 033R, first issued in 1989, which formed part of the CSIRO/AMIRA Project P241.

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## PREFACE

The CSIRO-AMIRA project "Exploration for Concealed Gold Deposits, Yilgarn Block, Western Australia" has as its overall aim the development of improved geological, geochemical and geophysical methods for mineral exploration that will facilitate the location of blind, concealed or deeply weathered gold deposits.

This report presents results of research conducted as part of Module 2 of this project (AMIRA Project 241): "Gold and Associated Elements in the Regolith - Dispersion Processes and Implications for Exploration".

The objectives of this module are:

- i. To obtain a better understanding of the nature and genesis of lateritic and supergene gold deposits.
- ii. To determine characteristics useful for exploration, especially in areas of transported overburden, for: a) further lateritic and supergene deposits, and b) primary mineralization - including that with no expression as appreciable secondary mineralization.
- iii. To increase knowledge of the properties and genesis of the regolith.
- iv. To provide data applicable for exploration for other commodities in and beneath the regolith.

In particular this report on the Parkinson Pit at Mt Magnet in the Murchison Goldfields (a) documents geochemical and mineralogical associations of gold present in weathered basalts by comparing mineralized and barren profiles, b) suggests appropriate pathfinders for gold in that environment.

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### SUMMARY

In both mineralized and barren profiles in the northern portion of the Parkinson Pit at Mt Magnet progressive zonation occurs from a calcite (calcrete) zone through mica-rich and ferruginous assemblages into chlorite/dolomite assemblages before passing into unweathered pyrite/dolomite/siderite-bearing rocks. However, the barren profile shows the development of Na- and Ca-rich micas rather than muscovite. Ferruginization is more consistently present in the mineralized profile.

The elements Co, Cu, Ni, Sc, Ti, W and Zn are associated with Fe in highly ferruginous samples. The effect of discrete vertical zonation is reflected by surface enrichment of Ca, Mg, Ba, Sr, Ga and Zr and depletion in Co. However the most significant feature is the association of Ag, As, Mo and Sb with Au in the weathered profile. Readily mobilized elements like Co, Cu and Ni which occur within the pyrite are associated with Fe and are not good pathfinders for Au.

Weathering in the southern portion of the Parkinson Pit gives rise to essentially similar mineralogical zonation to that in the north except that a thick kaolinite blanket is developed in the top 20 m. Thus weathering conditions may have been more acidic in this portion of the pit.

## 1. INTRODUCTION

The rocks of the Parkinson Pit at Mt Magnet (500 km NNE of Perth) are foliated mafic volcanics, felsic volcanics and minor cherts. The North Morning Star mineralization within the pit has two styles - quartz + tourmaline + pyrite lodes and pyrite lodes (S. Hunt, pers. comm. 1987). Mineralization tends to be steeply dipping and poddy i.e. discontinuous with depth, but one diamond drill hole did essentially remain in ore through the weathered zones. Comparison of this hole (NMS D4) with a barren hole (NMS D5; Fig. 1) thus makes a good reference study for AMIRA Project 241 (Gold and associated elements in the regolith-dispersion processes and implications for explanation) within the Murchison Gold Field.

A comparison between mineralized sections in the north (NMS D4) and the south (NMS D9, Fig. 1) has also been made because the rocks of the pit are more intensely weathered in the southern portion of the pit (S. Hunt, pers. comm. 1987).

This report details the initial results from an integrated mineralogical and geochemical study of mineralized and barren drill hole material (foliated mafic volcanics). Subsequent reports will present detailed electron microprobe studies of minerals within the weathered profile for North Morning Star mineralization.

## 2. SAMPLES

A total of 78 samples of weathered and altered basalt were collected from diamond drill holes NMS D4, D5 and D9. Thirty-six samples from the mineralized hole NMS D4 were taken at approximately 2 m intervals. Sampling in the other holes was generally every 3 to 4 m. Samples were chosen to include material from each visually distinct zone within the weathered profile.

A representative portion of 53 of the samples from NMS D4, D5 and D9 were crushed to  $-75\text{ }\mu\text{m}$  in Mn-steel jaw crushers and a ring mill. In five cases there was sufficient vein material present within the original sample to allow matrix and vein sub-samples to be taken and crushed separately.



Pyrite concentrates were prepared from unweathered material from NMS D4 and D9 using a combination of flotation, magnetic and gravity separation techniques. Purities of between 90 and 95% were generally obtained with the impurity being quartz in the form of composite quartz/pyrite grains.

### 3. ANALYSIS

The 63 crushed powders were initially analysed mineralogically using an X-ray powder diffractometer with a scanning speed of  $1/2^\circ$   $2\theta$ /min, copper radiation and a graphite-crystal monochromator. By choosing a chart speed such that each centimetre on the diffractogram is equivalent to  $1^\circ 2\theta$ , the characteristic peaks of the major and minor mineral components were identified and the abundances of the mineral phases present were estimated from the peak heights. This procedure is semiquantitative at best owing to the matrix effects on changing from ferruginous to carbonate assemblages, but major changes in mineral abundances can be clearly seen, especially in the weathered samples.

The 45 samples from NMS D4 and D5 were also chemically analysed. Major elements (except Na) and As, Ba, Rb, Sr, W and Zr were analysed by X-ray fluorescence spectrometry. Sodium, Co, Cr, Cu, Ni, Pb, Sc, Y and Zn were determined by inductively coupled plasma emission spectrometry (ICP). Semiquantitative optical emission spectroscopy was used for Ag, Au, B, Bi, Ga, Ge, Mo, Sb, Sn and Tl determinations. Gold values from the assaying of 1 m composites by Metana Minerals N.L. have also been used to provide better estimates of the gold grades in each zone than can be obtained from the spot samples used in this study.

The sulfide concentrates were analysed by ICP for Co, Cr, Cu, Fe, Mn, Ni, Pb, S and Zn and by optical emission spectroscopy for Ag, As, Au, Bi, Cd, Ga, Ge, Mo, Sb, Sn, Tl and W. To allow direct comparison of these results they were normalized to 100% sulfide.

#### 4. RESULTS

##### 4.1 Mineralogy of DDHs NMS D4, D5 and D9

Five distinctive mineralogical zones can be recognized below the pisolitic soil in DDH NMS D4. The distributions of the major phases used for discrimination are shown diagrammatically in Fig. 2. (Ubiquitous phases such as quartz and rutile are not shown). More detailed descriptions of each zone are given below.

(i) From 1.1 to 4.1 m calcite is the diagnostic mineral and the rocks change from brown to yellow in colour. Muscovite, kaolinite and goethite are well developed with minor chlorite ± tourmaline and, in one sample, gypsum.

(ii) Between 4.8 and 27.9 m the rocks are white with red or yellow Fe oxides developed in voids. More abundant muscovite and lower Fe oxide contents than elsewhere characterize this zone. Kaolinite is also much lower in this zone than in the calcite zone. Chlorite is present intermittently.

(iii) The ferruginous zone between 31.3 and 41 m is red/brown to yellow/brown in colour with green-grey colours dominant in the interval 41 to 52 m. Goethite, hematite, muscovite, intermittent chlorite and kaolinite occur throughout this zone from 31.3 to 52 m but the kaolinite abundance drops markedly below 41 m as the rocks become more fresh. Tourmaline is present in several samples.

(iv) The chlorite/dolomite zone (54.4 to 68.4 m) is green-grey with white dolomite veins and yellow/brown Fe staining. Goethite and muscovite are also developed here with minor calcite at the top of this zone.

(v) Pyrite, dolomite and siderite characterize the fresh rocks below 70 m. This assemblage is grey and does not contain any Fe oxides, otherwise it is relatively similar to the chlorite/dolomite zone above.

Five zones are also recognized below the soil cover in DDH NMS D5. Distributions of the more significant minerals are shown in Fig. 3 and are described below.

(i) The upper zone from 0.9 to 2.6 m is characterized by calcite. These rocks are white to pale brown in colour and they also contain abundant kaolinite, muscovite and paragonite (Na-mica) with only minor development of Fe oxides. Tourmaline may also be present.

(ii) The long interval between 4.4 and 44.6 m is characterized by presence of abundant paragonite especially below 24.9 m where the rocks change from white to yellow-red. Hematite is more abundant and kaolinite less abundant than in the calcite zone.

(iii) Between 49.8 and 53.2 m the rocks are green and brown with black goethite veins sometimes with dull black Mn oxides (?pyrolusite). Although goethite is better developed in this zone than in any other, the most diagnostic mineral is margarite (Ca-mica). Paragonite is still present, kaolinite is less abundant than above and chlorite is consistently present.

(iv) The muscovite/goethite zone from 56.4 to 64.7 m consists of green-grey rocks with ferruginous veins. Muscovite rather than other mica types is dominant here whilst chlorite abundance appears inversely related to goethite abundance.

(v) Below 68 m the rocks are green-grey with yellow to red goethite staining present to at least 78 m. Abundant chlorite, dolomite substantial muscovite and minor goethite characterize this partially weathered zone.

The profile beneath the soil cover provided by DDH NMS D9 can be divided into four zones. The more significant mineralogical distributions are shown in Fig. 4.

(i) The upper zone from 2.1 to 20 m consists of white kaolinite-rich assemblages with muscovite and minor goethite and chlorite  $\pm$  rutile  $\pm$  tourmaline.

(ii) Between 24 and 31 m the rocks are white and more muscovite-rich than above. Kaolinite is however less well developed. Fe oxides are very poorly developed. Rutile is relatively abundant.

(iii) Yellow to brown ferruginous rocks occur between 39 and 65 m. Goethite is a major constituent giving the rocks their colour, and kaolinite dominates over muscovite in this zone. Chlorite and talc are also present intermittently. Black Mn oxide veins (? pyrolusite) are present and albite occurs in the basal portion of this zone (Fig. 4).

(iv) Below 71 m the rocks are green-grey unweathered volcanics and characterized by the strong development of dolomite, muscovite and chlorite. Pyrite is also present. Kaolinite and Fe oxides are not present in these samples.

#### 4.2 Geochemistry of DDHs D4 and D5

Detailed chemical analyses are presented in Tables 1 and 2 with average compositions for the zones delineated above in Tables 3 and 4.

##### 4.2.1 DDH NMs D4

The calcite zone is characterized by high Ca, Ti, S, As, Au, B, Ba, Cr, Cu, Ga, Mo, Sb and Sr contents. Underlying muscovite-rich assemblages are particularly rich in Si, Al, K and Ba but depleted in Fe, Mg, Ca, Co, Cr, Cu, Ni, Sc and Zn relative to other zones. Ferruginous samples have elevated Ti, Ag, As, B, Co, Cr, Cu, Ni, Sb, Sc, W and Zn and low Ca and Sr contents. The chlorite/dolomite zone has high Mg, Ca, Co, Ni and Zn contents and relatively low Si, Al, K, Ba and Zr contents. At the base of the profile the pyrite/dolomite/siderite sample has higher Na, Mn and S contents than elsewhere as well as high Mg, Ca, Co and Sr and low Si, Al, K, Au and Ba contents (Table 3).

##### 4.2.2 DDH NMS D5

In this essentially unmineralized hole there is much less variation down the profile than in the mineralized hole (NMS D4). The calcite zone has high Mg, Ca, Ti, Ag, B, Ba and Zr and low Fe, As and Co



relative to lower zones. Paragonite-rich assemblages are characterized by their high Si, Na, Sb and Sr contents. Margarite-rich assemblages have elevated Fe, Ca, Mn, B, Co, Cu, Ni, Sc and Zn whereas the muscovite/goethite zone has high Si, K, As, Ba, Mo, Rb and W as well as a low Ca content. Gold is also present in some of the samples of this zone (Table 2). The chlorite/dolomite zone is particularly enriched in Fe, Mg, Cr, Cu, Ni, Zn and Sc and depleted in Si relative to overlying zones.

#### 4.3 Geochemistry of pyrites

The composition of pyrite concentrates from unweathered material in drill holes NMS D4 and D9 is presented in Table 5. All three samples show high Ag, As, Co, Cu and Ni contents with variable Au, Sb, Mn, Mo and Pb contents. Sample 105103 from the northern mineralized hole (NMS D4) has the highest Au content and also has higher Mn, Mo, Ni and lower Co and Pb than pyrites from the southern mineralized hole (NMS D9). Further investigation of these samples using an electron microprobe is being undertaken to determine whether Au occurs as inclusions in the pyrite or simply reports to the pyrite fraction during preparation of the concentrates.

#### 4.4 Comparison of weathered vein and matrix material

Comparison of the five samples where abundant vein material could be separated from surrounding matrix (Table 6) shows that the veins are richer in Fe oxides but poorer in phyllosilicates (mica and chlorite) than the corresponding matrix. Thus chemically the matrix is richer in Al, Na, K, Ti (Ba), Cr, Ga, Rb, Sc and Zr with the veins having more abundant Fe, Mn, (As), Co, Mo, Sb, (W) and (Zn) (Table 7). Gold values are generally below the limit of detection, although Au is certainly elevated in the vein from the calcite zone in NMS D4 (105073, Table 6). Mobilization of Au into the matrix may be indicated by sample 105121 (Table 6). Silver contents are low in both veins and their matrices. The relatively low B contents in veins (Table 7) implies that the veins are derived from essentially pyritic lodes rather than tourmaline-rich lodes.

## 5. DISCUSSION

### 5.1 Northern Portion of Parkinson Pit

Comparison of the mineralized and unmineralized profiles in DDHs NMS D4 and D5 (Fig. 5) shows that zonation in the northern part of the Parkinson Pit proceeds from a calcite zone (calcrete) through more mica-rich assemblages to more ferruginous assemblages and then into chlorite/dolomite assemblages which are only slightly weathered. (Siderite and pyrite occur when the rock is completely unweathered in the mineralized hole).

In the unmineralized hole the mica-rich assemblages are characterized by the presence of paragonite rather than simply muscovite. The ferruginous samples immediately underlying the paragonite zone in the barren hole also bear margarite. The significance of these Na- and Ca-micas in the barren hole is not understood although the presence of paragonite in black shale sequences at Panglo, near Paddington (Scott, 1989) and margarite at Gibraltar (Simpson, 1952) suggests that these micas may be widely associated within the wall rocks of Yilgarn gold deposits.

Chemically the calcite zone is richer in Fe and the chalcophile elements S, Ag, As, Cu, Mo, Sb and Zn when mineralized (Tables 3 and 4). These elements now occur in goethite (Scott, 1990), i.e. they are actually siderophile although the high S in 105072 is mainly due to the presence of gypsum in that sample. Chromium is also higher in the mineralized calcite zone. Tungsten, Ba and Sr occur in substantial amounts in the calcite zone generally, with the latter element varying directly with Ca abundance (Tables 1 and 2).

In the mineralized hole, the muscovite zone is low in Fe and the trace elements, As, Cr, Cu, Mo, Ni, Sc and W. Although some Au occurs in this zone it is of lower grade than in the more ferruginous zones above and below (Table 3). The paragonite zone in the barren sequence also has low abundances of Fe and most of the above trace elements relative to its neighbouring zones. Strontium abundances are

consistently high in the paragonite zone, suggesting incorporation into the paragonite structure. Certainly the retention of Cr in this zone reflects its incorporation within paragonite (Scott, 1990) .

Both the ferruginous zone in the mineralized hole and the laterally equivalent margarite zone in the barren hole have high Fe, Ti, Co, Cu, Ni, Sc, W and Zn contents. When this zone is mineralized Ag, As, Au, Mo and Sb are also elevated, as in NMS D4 (Table 3). The muscovite/goethite zone below the margarite zone is not as rich in Fe and its associated trace elements as the margarite or mineralized ferruginous zone although isolated high values do occur, e.g. in sample 105120 (Table 2). This zone contains the highest Au grades observed in the barren hole (Table 4).

The chlorite/dolomite zone may be more dolomitic in the mineralized hole giving rise to lower silicate contents but other features are basically similar. Gold is still present in this zone within the mineralized hole but it is not present where sulfides are developed with siderite at the base of the hole (Table 3).

Although the pyrite concentrates may show significant Ag, As, Au, Co, Cu, Ni, Sb, Mo and Pb contents (Table 5) only Ag, As, Mo and Sb are consistently associated with Au in the weathered profile. (Lead may also be associated with Au, as in the calcite zone in NMS D4, but its low abundance does not make it a good pathfinder element). The distributions of the elements Co, Cu and Ni are essentially controlled by Fe (as are Ti, Sc, W and Zn) in the weathered profile. However, the Fe association and the Au association may frequently be superimposed, as in the calcite and ferruginous zones of NMS D4. Therefore the recognition of these two distinct associations is important for cases where ferruginization is not well developed e.g. the muscovite/goethite zone in MNS D5, where a significant Au resource occurs just above the chlorite/dolomite zone (Table 4).

Although Ag, As, Mo and Sb are associated with Au in the weathered zone, the change in the composition of gold grains from Au<sub>88</sub>Ag<sub>12</sub> (at %) in the partially weathered chlorite/dolomite zone to Ag-free gold in the

calcite zone (Scott, 1990) indicates that Ag has been more mobile than Au during weathering at North Morning Star. This feature may reflect saline weathering conditions (Mann, 1984). The preferential retention of Sb relative to As in the near surface calcite zone in NMS D4 also reflects the different mobilities of pathfinders during development of the weathering profile.

The elements Ba, Sr, Co, Ga and Zr form a third association which is related to height in the weathered profile. Barium and Sr may show enrichment in the near-surface calcite zone and Ba is present in the muscovite zone, but not in the laterally equivalent paragonite zone where Sr is retained (Tables 3 and 4). Although the mode of occurrence of Ba in the calcite zone is unknown, the good association between Sr and Ca (Tables 1 and 2) implies that Sr is retained in calcite near the surface. Cobalt distribution is largely determined by the Fe distribution (as seen above), but its low abundance in the upper two zones in both mineralized and unmineralized profiles (Tables 3 and 4) suggests an upward dispersion of Co during profile development. Gallium and Zr are enriched in the calcite and muscovite zones (Tables 3 and 4) with the deeper extent of residual concentration in the mineralized hole possibly suggesting more intense leaching associated with mineralization. Thus Co is leached from and Ba, Sr, Ga and Zr concentrated in the upper portion of the profiles.

Because the Cr mica, fuchsite, is widely found in Au deposits of the Yilgarn Block, the presence of Cr in paragonite in NMS D5 and its apparent absence in the laterally equivalent muscovite in NMS D4 suggests that the composition of micas is well worth further investigation, particularly as the distributions of Ba and Sr may be partly controlled by micas too.

## 5.2 Southern Portion of Parkinson Pit

The mineralogical profile provided by NMS D9 is similar to that from the northern portion of the Parkinson Pit except for the top 20 m (Fig. 5). In the south, no calcite (calcrete) zone is developed -



instead, 20 m of extremely kaolinitic material is encountered before a relatively thin muscovite zone is developed. Ferruginized and chlorite/dolomite zones are then developed. The latter zone has associated pyrite and albite and is much fresher than in the north where the chlorite/dolomite zone is transitional between fresh and weathered rocks.

The development of a thick kaolinite zone, instead of a thin calcrete zone over a thicker mica zone, may reflect more acid weathering conditions in the southern portion of the Parkinson Pit. Additional sampling of profiles in this portion of the pit (e.g. DDH's NMS D6 - D8) may be useful for developing an understanding of the differences in weathering within the Parkinson Pit at Mt Magnet.

## 6. CONCLUSIONS

Mineralogical zonation through the mineralized and unmineralized profiles in the northern portion of the Parkinson Pit at Mt Magnet comprises a progression from calcite to mica to ferruginous assemblages then into chlorite/dolomite bearing rocks and finally unweathered pyrite/dolomite/siderite assemblages. In the mineralized profile the mica is muscovite whereas in the barren profile the mica is paragonite which becomes more Ca-rich (margarite) in the upper part of the ferruginous sequence.

These mineralogical features affect the geochemistry, e.g. Sr occurs in calcite close to the surface, and in paragonite but not muscovite in the underlying mica zones. Even more important is the close association of Co, Cu, Ni, Sc, Ti, W and Zn with Fe in the weathered profiles, especially since ferruginization is more consistently developed in the mineralized hole. A vertical trend toward surface enrichment in Ba, Sr, Ga and Zr and depletion in Co is also evident in the profiles. The elements Ag, As, Mo and Sb are consistently associated with Au in the weathered profile.

The more intense weathering in the southern portion of the Parkinson Pit is reflected by the development of a thick kaolinitic blanket in the upper part of the profile there.

## 7. ONGOING/FUTURE WORK

As elements like Ba, Sr and Cr appear to vary in some zones according to the mica-type, further study of micas will be made.

The compositions of Fe oxides at different depths in the profiles will be determined to try to understand better the factors affecting the distribution of Sb and As.

Gold grains found within the profiles will be investigated. Careful examination of pyrite grains will be undertaken to determine exactly how Au is associated with pyrite. Similarly, the mode of occurrence of As in pyrite will be investigated.

Additional sampling of profiles in the southern portion of the Parkinson Pit appears to be warranted to verify the significance of the trends found in NMS D9.

## 8. ACKNOWLEDGEMENTS

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Table 1 Chemical composition of samples, DDH NMS D4 (major components, wt%; minors, ppm)

Sample No.	105070	105072	105073M	105074	105076	105077	105079	105081	105083	105085	105087	105088	105089	105091	105094M	105096	105097	105098	105099	105100M	105101	105102	105103
Depth (m)	1.05	2.35	4.10	4.75	9.30	11.1	13.3	18.4	22.9	27.9	31.3	33.0	35.4	40.0	46.7	50.7	52.0	54.4	58.3	60.2	65.0	68.4	70.8
SiO <sub>2</sub>	55.0	53.3	46.5	60.1	74.7	75.7	75.4	69.6	75.6	73.0	68.8	61.3	57.0	59.4	72.1	70.1	69.7	55.5	14.2	46.9	51.4	28.8	36.4
Al <sub>2</sub> O <sub>3</sub>	18.0	15.7	16.8	27.4	16.1	15.5	15.6	18.6	15.3	17.6	13.8	14.4	20.2	19.6	10.7	12.4	12.0	15.5	7.99	12.0	12.1	11.2	9.82
Fe <sub>2</sub> O <sub>3</sub>	8.53	1.88	17.5	0.40	1.42	1.99	1.67	3.80	1.41	2.41	9.16	12.5	10.8	10.8	10.1	9.32	9.00	14.3	12.2	9.44	8.59	10.4	18.3
MgO	2.14	1.44	0.67	0.20	0.14	0.13	0.15	0.21	0.16	0.14	0.37	3.28	0.84	0.23	0.56	0.60	0.86	4.46	14.0	6.96	5.12	8.62	4.06
CaO	1.63	3.69	3.11	<0.04												0.06	0.08	0.08	18.2	7.02	6.44	14.2	7.55
Na <sub>2</sub> O	0.49	0.45	0.44	0.32	0.46	0.46	0.48	0.48	0.45	0.54	0.30	0.12	0.21	0.42	0.32	0.35	0.31	0.26	0.11	0.18	0.46	0.50	0.66
K <sub>2</sub> O	1.37	2.46	3.10	2.67	3.79	3.76	3.83	4.29	3.96	4.37	1.96	0.69	2.05	3.06	2.29	2.91	2.69	2.45	1.04	1.49	1.39	1.41	1.63
TiO <sub>2</sub>	0.56	0.70	0.89	0.82	0.34	0.34	0.35	0.54	0.35	0.41	0.59	0.32	0.94	0.99	0.51	0.61	0.60	0.71	0.38	0.56	0.57	0.53	0.45
P <sub>2</sub> O <sub>5</sub>	<0.1																						
MnO	0.04	<0.04														0.33	0.09	0.08	0.30	0.27	0.14	0.11	1.01
SO <sub>3</sub>	0.21	2.21	0.14	<0.1									0.11	<0.1									4.39
Ag	0.1	0.3	1	1	0.6	0.6	0.2	0.8	0.2	0.4	0.5	0.6	0.7	0.6	1	1	7	0.8	0.6	0.2	0.1	0.1	0.6
As	130	34	650	10	19	66	63	70	49	27	250	210	160	30	130	180	180	100	100	58	27	24	64
Au	2	2	2	<2																			
B	600	500	200	150	100	60	40	70	100	100	2000	50	150	100	500	100	500	80	30	60	150	80	60
Ba	300	380	320	310	390	410	400	440	400	450	190	91	240	230	150	190	190	130	110	130	61	120	120
Co	15	5	11	<5							77	140	24	16	65	34	33	66	50	42	40	37	41
Cr	330	290	590	450	63	56	41	180	33	40	340	900	510	400	190	260	260	290	150	230	230	220	150
Cu	140	65	570	6	38	54	16	16	19	30	230	390	160	74	79	41	54	86	200	88	72	140	58
Ga	40	25	30	30	25	25	25	20	25	25	20	20	25	25	15	20	20	20	15	20	20	15	15
Ge	2	3	2	4	2	3	2	2	2	4	2	2	3	3	3	2	3	3	1	2	3	2	2
Mo	60	10	70	0.4	3	6	7	3	2	2	15	10	10	6	4	6	20	4	3	2	1	0.5	3
Ni	100	40	92	20	<20						160	1170	470	120	150	81	90	190	130	140	130	130	93
Pb	<50	<50	58	<50																			
Rb	60	77	95	84	110	110	120	130	120	130	60	22	66	92	70	86	82	54	36	48	44	37	40
Sb	600	200	2000	40	50	70	40	25	50	20	250	150	150	40	70	50	80	150	80	50	25	25	30
Sc	29	28	42	36	6	8	7	21	<5	8	45	52	72	50	25	29	32	39	23	27	27	28	22
Sn	3	2	2	2	1	4	<1	1	<1	<1	2	2	2	2	2	2	2	2	1	1	1	1	1
Sr	93	380	140	52	85	84	92	98	91	120	54	19	77	67	52	60	48	39	48	46	81	130	100
W	18	24	47	25	<10	11	13	11	12	<10	170	240	70	17	22	11	21	19	15	<10	19	19	25
Y	9	6	8	7	3	3	5	6	5	6	9	6	15	11	8	5	4	10	12	9	7	8	8
Zn	52	15	23	<5	5	<5	9	8	8	8	67	640	330	89	120	36	39	140	90	90	56	98	34
Zr	120	61	75	66	86	86	96	94	100	120	54	30	81	78	50	54	47	61	28	47	47	43	36

NOTE: B1 <3; T1 <3 ppm



Table 2. Chemical composition of samples, DDH NMS D5 (major components, wt%; minors, ppm)

Sample No. No. Depth (m)	105105	105106	105107	105108	105110	105111	105113	105114	105116	105117M	105118	105119	105120	105121M	105122	105123	105124
	0.90	2.6	4.4	11.8	24.9	31.9	34.5	39.1	44.6	49.8	53.2	56.4	61.2	64.7	68.0	71.0	78.0
SiO <sub>2</sub>	56.2	66.6	83.4	68.3	69.8	65.2	67.7	67.8	64.0	58.8	54.8	67.3	74.3	64.7	52.8	58.2	50.6
Al <sub>2</sub> O <sub>3</sub>	18.7	19.7	11.1	22.0	21.1	22.4	21.5	18.4	19.8	19.3	19.8	17.8	12.3	21.0	23.0	16.6	15.0
Fe <sub>2</sub> O <sub>3</sub>	0.74	1.24	0.72	0.33	0.42	2.75	2.01	4.84	6.14	11.1	12.9	5.26	4.45	3.69	9.85	10.0	10.7
MgO	1.52	0.50	<0.1						0.84	0.78	0.56	0.57	<0.1	0.21	2.37	2.11	4.82
CaO	6.67	0.82	0.13	0.40	0.44	0.40	0.42	0.39	1.06	2.10	2.57	0.62	0.06	0.18	0.26	1.80	4.95
Na <sub>2</sub> O	0.97	0.34	0.46	1.29	2.00	2.32	2.08	1.47	1.36	1.08	0.93	0.84	0.43	0.75	0.64	0.74	0.70
K <sub>2</sub> O	1.86	0.59	0.64	2.11	1.49	1.05	1.13	0.96	1.33	0.77	0.73	2.54	2.93	4.71	2.90	2.62	1.35
TiO <sub>2</sub>	0.70	1.80	0.29	0.71	0.75	0.84	0.76	0.68	0.75	0.77	0.83	0.74	0.42	0.79	0.85	0.69	0.68
P <sub>2</sub> O <sub>5</sub>	<0.1																
MnO	<0.04									0.06	0.87	<0.04	1.46	<0.04	<0.04	0.30	0.19
SO <sub>3</sub>	<0.1																
Ag	0.6	2	0.4	0.5	0.2	0.3	0.5	0.2	2	0.6	0.2	0.2	1	0.2	0.2	0.2	0.2
As	6	<5	10	11	<5	40	30	43	87	60	39	110	76	100	65	40	36
Au	<2													3	<2		
B	600	5000	800	60	60	60	200	50	150	300	250	300	50	70	250	80	80
Ba	810	71	50	190	210	160	160	170	220	92	160	190	320	250	170	170	98
Co	9	5	<5					8	59	70	98	38	49	16	41	52	53
Cr	290	260	160	290	280	350	340	280	290	370	230	300	130	310	420	330	340
Cu	19	6	7	<5	<5	160	100	230	150	160	73	81	27	95	110	120	130
Ga	20	40	10	20	25	30	30	25	30	30	40	30	25	25	25	20	20
Ge	4	5	4	2	1	2	2	2	3	2	2	2	2	3	3	3	2
Mo	0.4	2	2	0.5	0.3	5	3	3	2	4	3	2	60	8	2	4	2
Ni	68	73	31	<20	<20	60	43	76	230	160	170	130	70	54	290	95	170
Pb	<50																
Rb	63	17	21	73	52	36	39	36	43	25	24	82	83	130	87	79	43
Sb	50	60	<25	50	40	150	80	80	100	50	70	60	40	60	60	<25	80
Sc	33	23	11	39	35	57	49	40	41	49	52	41	24	41	47	44	42
Sn	2	2	1	1	2	2	2	2	2	2	2	2	<1	2	2	2	2
Sr	210	59	47	150	220	230	190	140	150	110	120	88	95	78	70	87	77
W	16	72	<10					10	30	29	51	18	170	35	49	33	20
Y	13	16	2	6	5	7	6	6	6	11	8	9	6	7	15	12	12
Zn	10	13	6	<5	<5	15	9	34	130	160	110	52	38	36	180	84	140
Zr	60	140	24	58	58	67	60	50	60	57	60	53	33	55	68	52	49

NOTE: B1 &lt;3; T1 &lt;3 ppm

Table 3 Average composition of zones, DDH NMS D4 (major components, wt%; minors, ppm)

Zone	Calcite	Muscovite	Ferruginous	Chlorite/dol	Py/dol/siderite
Depth (m)	1.1-4.1	4.8-27.9	31.3-52.0	54.4-68.4	70.8
SiO <sub>2</sub>	51.6	72.0	65.5	39.4	36.4
Al <sub>2</sub> O <sub>3</sub>	16.8	18.0	14.7	11.8	9.82
Fe <sub>2</sub> O <sub>3</sub>	9.30	1.87	10.2	11.0	18.3
MgO	1.42	0.16	0.96	7.83	4.06
CaO	4.48	<0.04	<0.04	9.19	7.55
Na <sub>2</sub> O	0.46	0.46	0.29	0.30	0.66
K <sub>2</sub> O	2.31	3.81	2.24	1.56	1.63
TiO <sub>2</sub>	0.72	0.45	0.65	0.55	0.45
MnO	<0.04	<0.04	0.08	0.20	1.01
SO <sub>3</sub>	0.85	<0.1	<0.1	<0.1	4.39
Ag	0.5	0.5	2	0.4	0.6
As	270	43	160	62	64
Au	2(9.1)	<2(2.6)	15(3.1)	2(4.2)	<2(0.01)
B	430	90	490	80	60
Ba	330	400	180	140	120
Co	10	<5	56	47	41
Cr	400	120	410	220	150
Cu	260	26	150	120	58
Ga	32	25	21	18	15
Ge	2	3	3	2	2
Mo	47	3	10	2	3
Ni	77	<20	320	140	93
Rb	77	110	68	44	40
Sb	930	42	110	66	30
Sc	33	13	44	29	22
Sn	2	1	2	1	1
Sr	200	89	54	69	100
W	30	12	79	15	25
Y	8	5	8	9	8
Zn	30	6	190	95	34
Zr	85	93	56	45	36

NOTE: P<sub>2</sub>O<sub>5</sub> <0.1%; Bi <3; Pb <50, Tl <3 ppm

Au value in parenthesis - determined by Metana Minerals N.L. for this interval

Table 4 Average composition of zones, DDH NMS D5 (major components, wt%; minors, ppm)

Zone Depth (m)	Calcite 0.9-2.6	Paragonite 4.4-44.6	Margarite 49.8-53.2	Musc/goethite 56.4-64.7	Chl/dol 68.0-78.0
SiO <sub>2</sub>	61.4	69.5	56.8	68.8	53.9
Al <sub>2</sub> O <sub>3</sub>	19.2	19.5	19.5	17.0	18.2
Fe <sub>2</sub> O <sub>3</sub>	0.99	2.46	12.0	4.47	10.2
MgO	1.01	0.16	0.67	0.28	3.10
CaO	3.75	0.46	2.34	0.29	2.34
Na <sub>2</sub> O	0.66	1.57	1.01	0.67	0.69
K <sub>2</sub> O	1.23	1.24	0.75	3.39	2.29
TiO <sub>2</sub>	1.25	0.68	0.80	0.65	0.74
MnO	<0.04	<0.04	0.47	0.50	0.17
Ag	1	0.6	0.4	0.5	0.2
As	<5	32	50	95	47
Au	<2(0.07)	<2(0.06)	<2(0.04)	<2(1.2)	<2(0.05)
B	600*	200	280	140	140
Ba	440	170	130	250	150
Co	7	11	84	34	49
Cr	270	280	300	250	360
Cu	13	93	120	68	120
Ga	30	24	35	27	22
Ge	5	2	2	2	3
Mo	1	2	4	23	3
Ni	71	66	170	85	190
Rb	40	43	25	98	70
Sb	55	73	60	53	51
Sc	28	39	50	35	44
Sn	2	2	2	1	2
Sr	130	160	120	87	78
W	44	<10	40	74	34
Y	15	5	10	7	13
Zn	12	28	140	42	130
Zr	100	54	58	47	56

NOTE: P<sub>2</sub>O<sub>5</sub> <0.1, SO<sub>3</sub> <0.1%; Bi <3, Pb <50, Tl <3 ppm

Au value in parenthesis - determined by Metana Minerals N.L. for this interval

\*One value only, highly anomalous value disregarded.

Table 5 Normalized composition of pyrite concentrates, North Morning Star (ppm, unless otherwise indicated)

No.	105103	105144	105145
DDH	NMS D4	NMS D9	NMS D9
Depth (m)	70.8	73.6	85.0
Ag	11	15	27
As	2900	3100	3300
Au	40	26	<3
Bi	<3	3	<3
Co	570	1900	1000
Cr	38	15	40
Cu	840	1400	910
Fe %	50.2	48.0	49.4
Ga	7	1	1
Mn	410	40	36
Mo	2	0.8	<0.3
Ni	1100	920	620
Pb	<60	90	100
S %	49.2	51.2	50.0
Sb	90	420	54
Zn	24	14	7

NOTE: Cd <5, Sn <1, Tl <3, W <10.



Table 6 Mineralogy of matrix and veins within weathered profile,  
North Morning Star

		Quartz	Hematite	Goethite	Rutile	Calcite	Dolomite	Mica	Chlorite	Kaolinite	Mont/mixed layer	Tourmaline
105073	m	1		2	6	3		1	4	2	6	
	v	1		2	6	5		4	5	4		
105094	m	1		2	6			2	5	5		
	v	1	3	3				4	5	6	6	6
105100	m	1		4	6		1	3	1			
	v	1		3	6		1	4	4		6	
105117	m	1		2	6			2	3	4	5	
	v	1	2	2	6			4	5			
105121	m	1			6			1	3			
	v	1		3	6			2	5			

m = matrix, v = vein

Note: Abundances above are X-ray abundances ranked in decreasing order from 1 to 6.  
Such abundances may not necessarily reflect relative modal abundances within a sample.

Table 7 Compositions of matrix and veins, North Morning Star (major components, wt%; minors, ppm)

No.	105073		105094		105100		105117		105121	
Location	D4:4.10		D4:46.7		D4:60.2		D5:49.8		D5:64.7	
Zone	Calcite		Ferruginous		Ch/dol		Margarite		Muscovite/goe	
	Matrix	Vein	Matrix	Vein	Matrix	Vein	Matrix	Vein	Matrix	Vein
SiO <sub>2</sub>	46.5	62.1	72.1	47.3	46.9	28.9	58.8	48.5	64.7	83.6
Al <sub>2</sub> O <sub>3</sub>	16.8	6.62	10.7	2.88	12.0	4.53	19.3	10.4	21.0	6.95
Fe <sub>2</sub> O <sub>3</sub>	17.5	21.9	10.1	41.3	9.44	10.2	11.1	30.9	3.69	3.96
MgO	0.67	0.28	0.56	0.32	6.96	10.5	0.78	0.38	0.21	<0.1
CaO	3.11	0.74	<0.04	0.08	7.02	16.7	2.10	1.09	0.18	0.07
Na <sub>2</sub> O	0.44	0.18	0.32	0.13	0.18	0.10	1.08	0.59	0.75	0.25
K <sub>2</sub> O	3.10	1.09	2.29	0.63	1.49	0.68	0.77	0.48	4.71	1.65
TiO <sub>2</sub>	0.89	0.30	0.51	0.04	0.56	0.20	0.77	0.41	0.79	0.30
P <sub>2</sub> O <sub>5</sub>	<0.1					0.11	<0.1	0.10	<0.1	<0.1
MnO	<0.04	<0.04	0.33	2.34	0.14	0.23	0.06	0.54	<0.04	1.11
SO <sub>3</sub>	0.14	0.10	<0.1							
Ag	1	1	1	3	0.2	0.2	0.6	0.4	0.2	0.5
As	650	900	130	170	58	99	60	81	100	68
Au	2	250	<2						3	<2
B	200	100	500	70	60	60	300	250	70	100
Ba	320	130	150	110	130	140	92	90	250	110
Co	11	13	65	170	42	57	70	220	16	26
Cr	590	510	190	20	230	78	370	180	310	69
Cu	570	750	79	59	88	95	160	260	95	61
Ga	30	20	15	5	20	6	30	15	25	10
Ge	2	2	3	4	2	2	2	2	3	5
Mo	70	150	4	15	2	2	4	10	8	25
Ni	92	96	150	170	140	100	160	270	54	51
Pb	58	80	<50							
Rb	95	36	70	20	48	23	25	18	130	45
Sb	2000	2000	70	150	50	60	50	100	60	60
Sc	42	18	25	16	27	15	49	36	41	20
Sn	2	2	2	2	1	1	2	1	2	1
Sr	140	43	52	170	46	80	110	76	78	42
W	47	26	22	23	<10	13	29	140	35	49
Zn	23	33	120	210	90	66	160	230	36	36
Zr	75	43	50	10	47	20	57	35	55	25

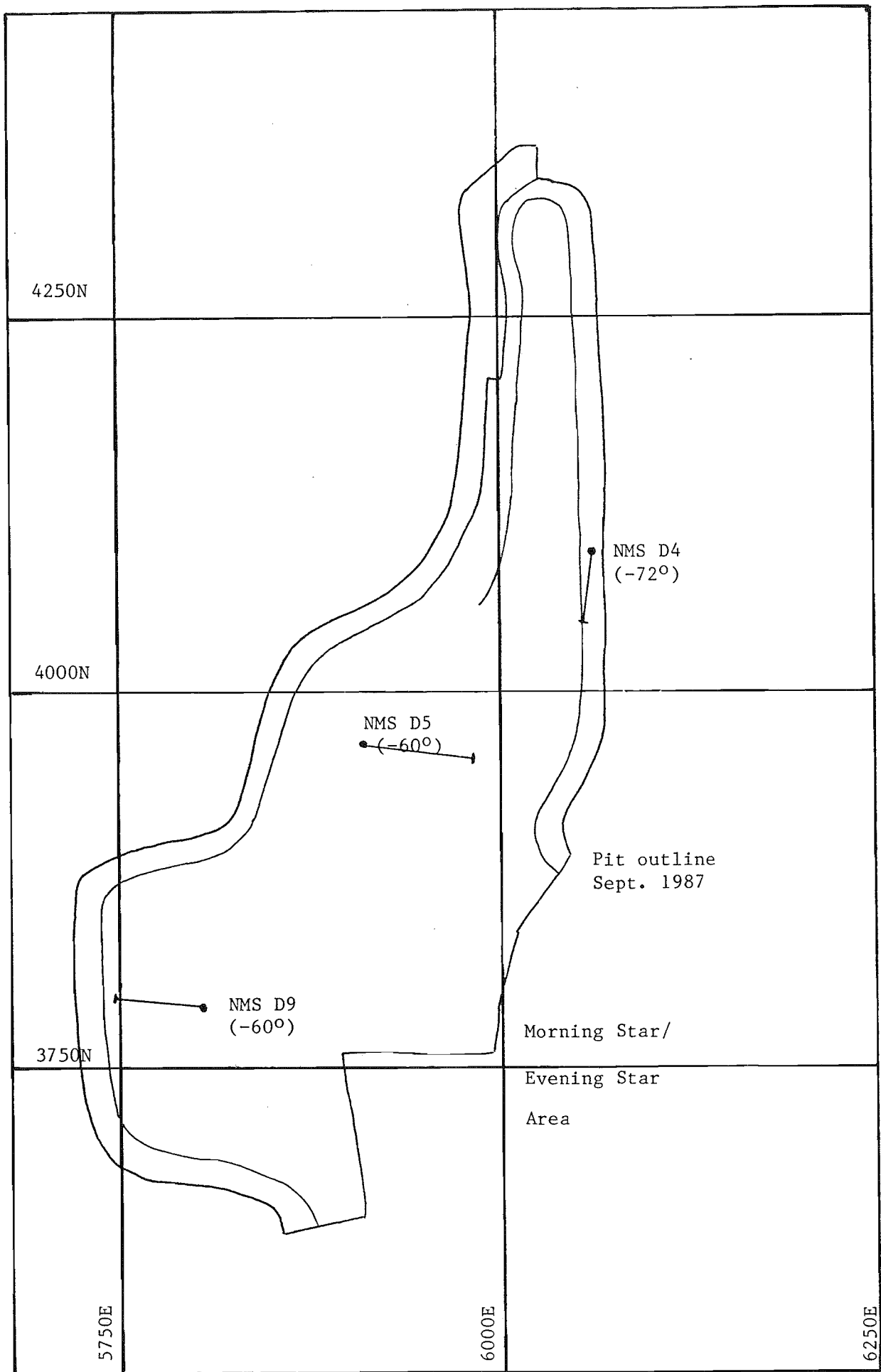


Fig. 1. Location of studied drill holes relative to Parkinson Pit, North Morning Star area

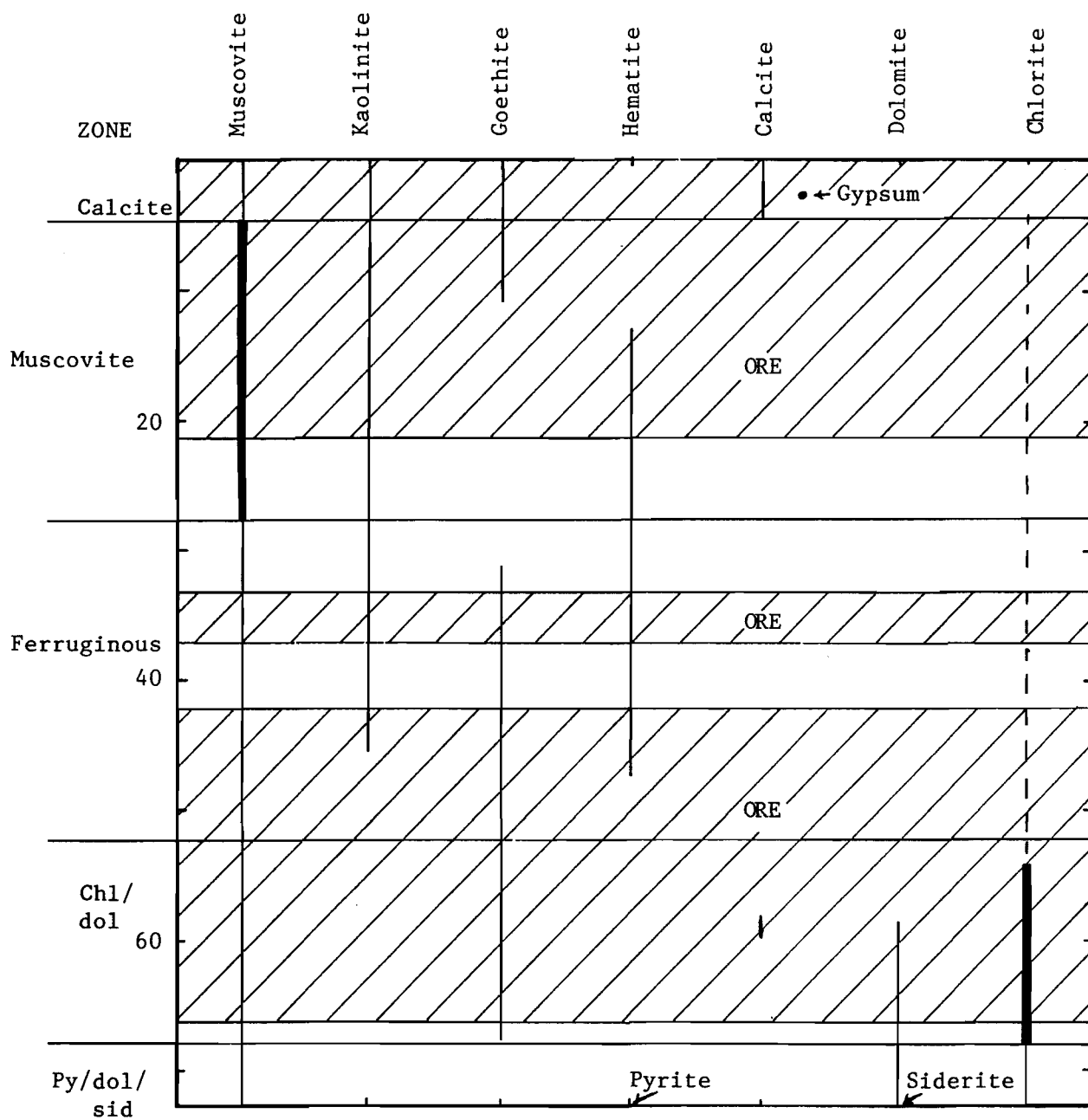


Fig. 2. Mineralogical profile through mineralization, DDH NMS D4

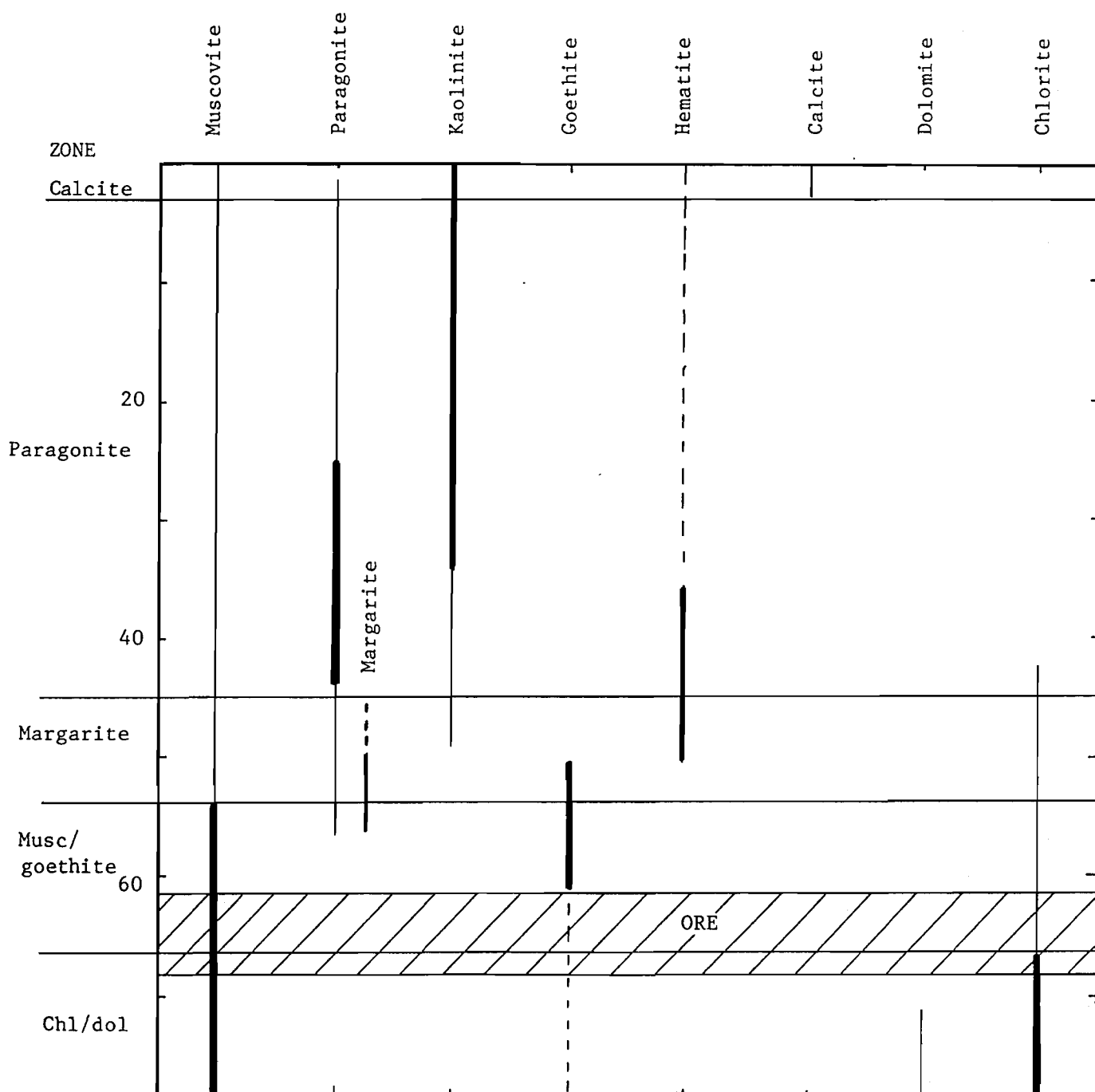


Fig. 3. Barren mineralogical profile, DDH NMS D5

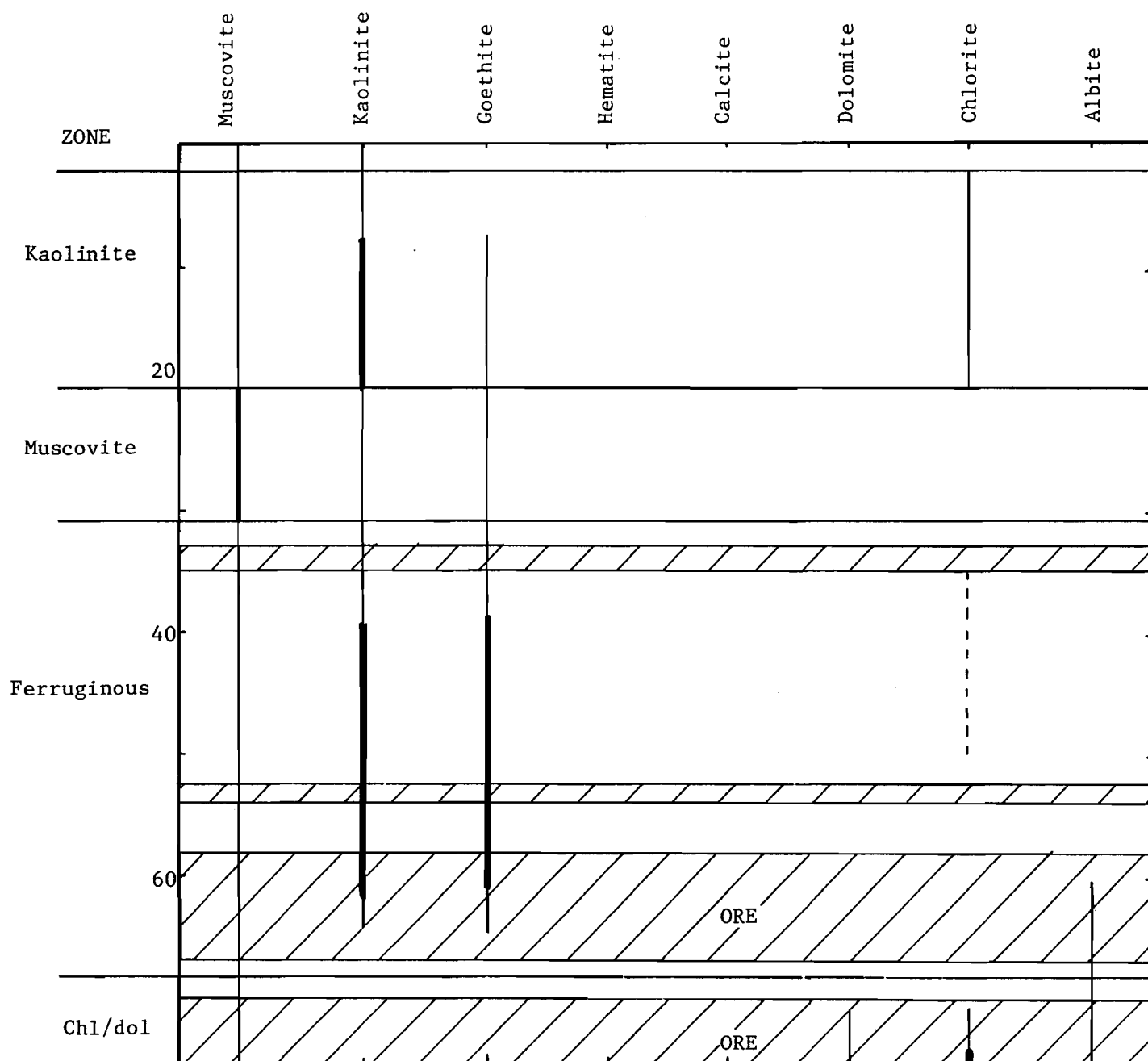


Fig. 4 Mineralogical profile through mineralization, DDH NMS D9  
(southern part of Parkinson Pit)

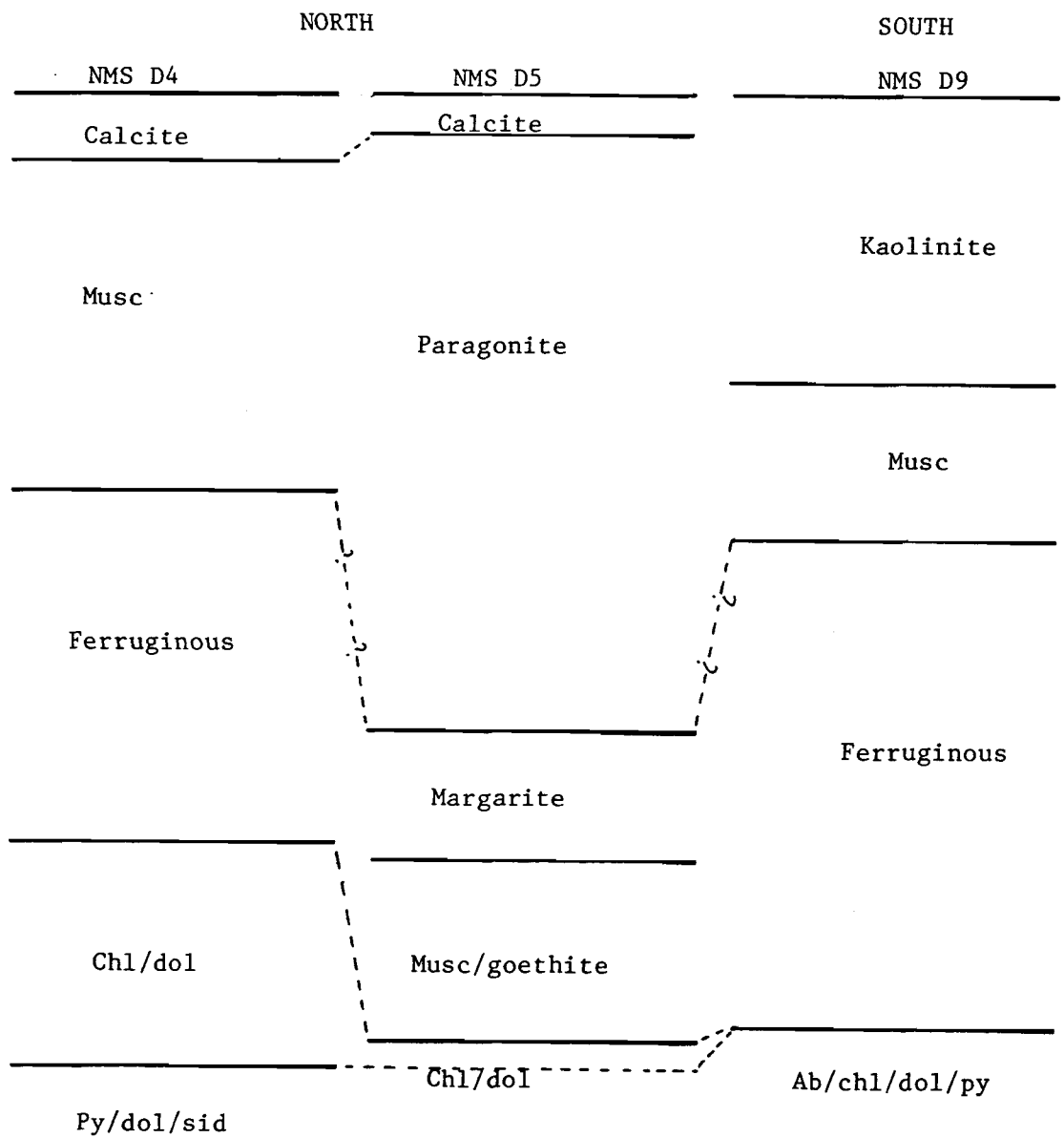


Fig. 5. Comparison of profiles, North Morning Star