METALLOGENY OF THE "EAST SOUTH C" ORE ZONE IN THE DICKENSON MINE, RED LAKE, ONTARIO; EVIDENCE FOR SYNGENETIC GOLD DEPOSITION

By

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Title: Metallogeny of the "East South C" ore zone in the Dickenson Mine, Red Lake, Ontario; evidence for syngenetic gold deposition

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Living without pressure——without putting it on myself or others——without allowing others to put it on me. Living without strings, or selling, or charming, or kidding into compliance, or manipulating through niceness or threatened anger. Standing in the face of silence, and threats, and expectations, and misunderstandings——standing and gently saying, "No thank you, I'll be myself".

——————— Hugh Prather, 1972

ABSTRACT

The Dickenson Mine, a gold producer in the Uchi volcanic-plutonic subprovince of the Canadian Shield, lies along the eastern flank of a volcanic complex consisting mainly of massive to pillowed basaltic komatiites and magnesium tholeiites with some ultrabasic and felsic flows, chemical and clastic sediments and proximal volcaniclastites. Studies of the 17, 22, 24, 25 and 30 Levels in the "East South C" and "East South C Footwall" ore zones show that the gold-bearing horizons lie within stratigraphically conformable fragmental rocks, which have been derived from a source dominated by basaltic komatiites and felsic volcanics with minor cherts and Fe-rich tholeiites.

At least two different types of mineralization are recognized. In the "East South C Footwall" zone (25 Level), the mineralization occurs in the metamorphosed argillaceous sediments. Increasing gold content correlates with a strong enrichment in total Fe, MnO, S, As, Zn and Ce, and with moderate increases in MgO, CO_2, Ni, Co, Cu, Cr and V. There is also a strong depletion in SiO_2, CaO and Ba in the auriferous rocks. The dominant opaques are pyrrhotite

and magnetite with accessory pyrite, arsenopyrite and ilmenite. The "East South C" ore zone on the 30 Level is a felsic volcaniclastic horizon enclosed by pillowed mafic volcanics. With increasing gold content samples from this ore zone show a strong enrichment in total Fe, As, S, Zn and Ce and moderate increases in Cr, Ni, V and Ba. There is also a strong depletion in MgO and Zr. Profiles of Au, As and S about this ore zone indicate a strong asymmetry, in that background gold content is greater by a factor of 5 to 20 in the footwall rocks. The dominant opaques are pyrite, pyrrhotite and arsenopyrite with accessory magnetite.

These ore zones are pre-tectonic and post dated by at least two periods of lower amphibolite grade metamorphism. The dominant structural element is a northwesterly foliation. In areas of high strain, stratigraphy and mineralization parallel this trend. In areas of low strain, stratigraphy and mineralization trend in a northeasterly fashion and exhibit numerous northwest trending axial planes. The dominant metamorphic minerals are almandine, andalusite, cordierite and amphibole.

The metal-rich mineralized zone on the 25 Level is an auriferous sediment in which both chemical (exhalative) and clastic components are recognizable. Low temperature solutions carried and precipitated Au, As, S, Fe, Ti, Mn, Cu, Co, Zn and perhaps Si. MgO, Ni and Cr may have been enriched through leaching or erosion of nearby komatiites. The aluminum and silica content of these rocks indicates a significant detrital component. In the mineralized felsic volcaniclastites on the 30 Level, the precipitation of metals (Au, As, S, Fe, Zn) was synchronous with felsic volcanism or erosion of a felsic source.

In conclusion, the "East South C" and "East South C Footwall" ore zones are syngenetic deposits.

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Thanks kid!

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CHAPTER 1

INTRODUCTION

1.1 LOCATION AND ACCESSIBILITY

Dickenson Mine is one of two currently producing mines in the Red Lake gold camp. The camp lies within a metavolcanic-metasedimentary belt and forms part of the Uchi volcanic-plutonic subprovince of the Archean Superior Province (Fig. 1-1).

The Mine itself is located in the community of Balmertown (Balmer Township), which is approximately 10 km northeast of Red Lake and 150 km northeast of Kenora (Fig. 1-2). It can be reached by driving the Trans Canada Highway to Vermilion Bay and then taking Highway 105 North for approximately 130 km where it intersects with Highway 125 East, which passes through Balmertown.

1.2 PREVIOUS WORK

The first mention of the geology of the Red Lake area was by Bell (1873). While conducting a survey down the English River in 1872, he obtained samples of uncrystalline slatey rocks from Red Paint Lake (Red Lake) and suggested

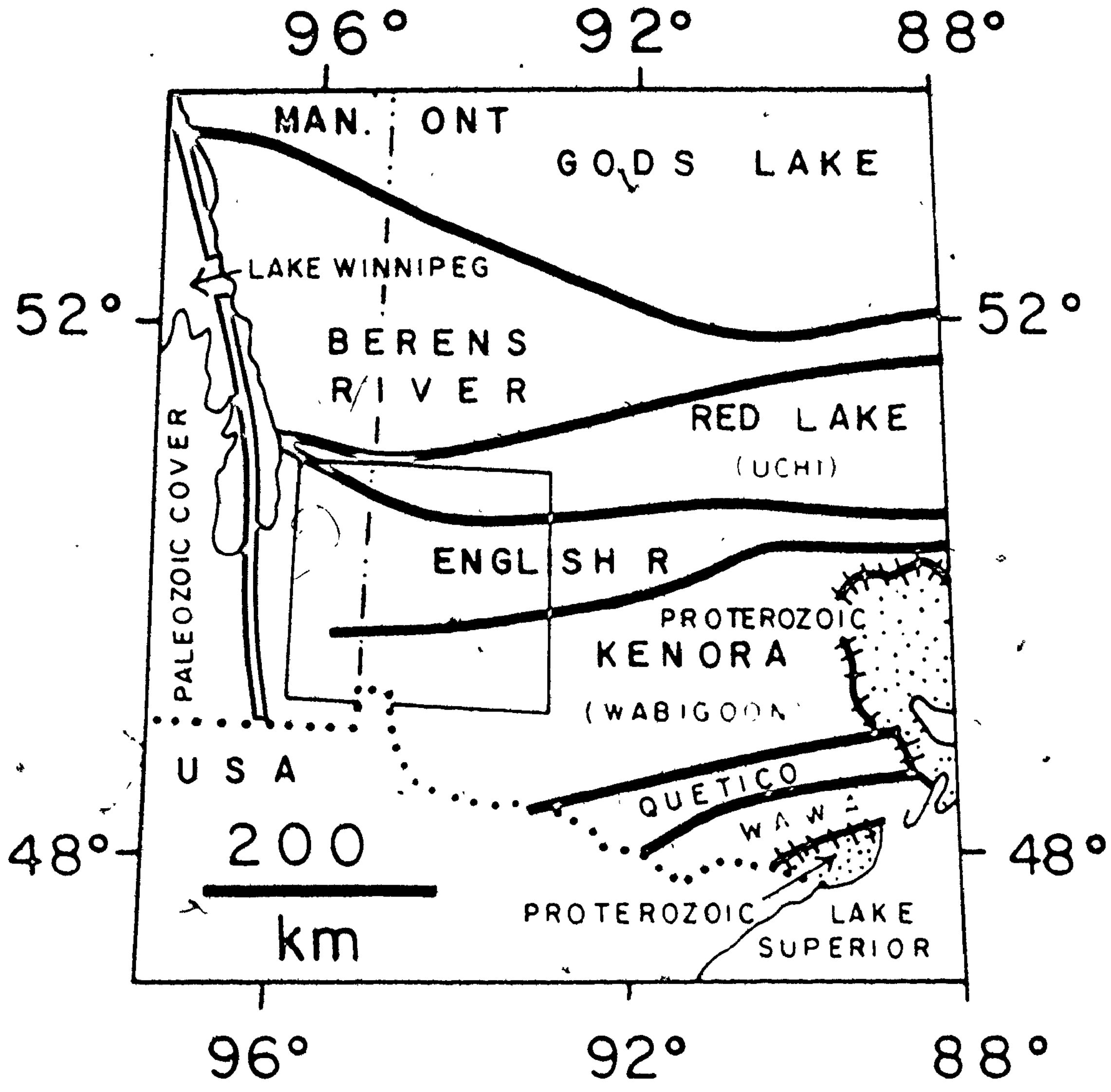
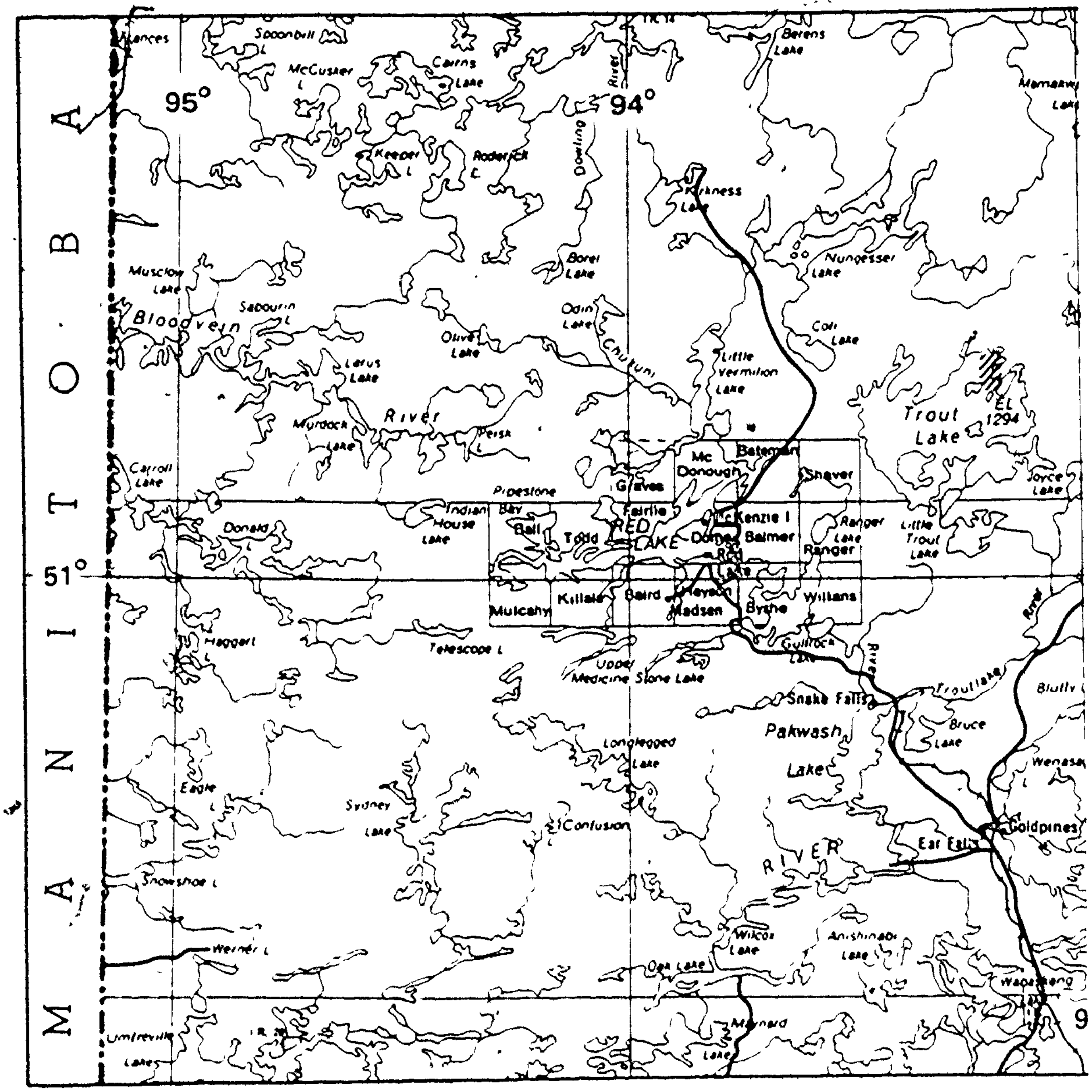


Figure 1-1. Map illustrating the location of the Uchi volcanic-plutonic subprovince (Red Lake) of the Western Superior Province of the Canadian Precambrian Shield.

from Beakhouse, 1977 .



Scale: 1 cm to 11.1 km

FIGURE 1-2: Location of Balmer Township and Red Lake, Northwestern Ontario.

that they were Huronian in age. A track survey in 1883 confirmed the presence of a wide belt of Huronian rocks, containing "some interesting minerals" (Bell, 1885).

The first actual geological work was a map and report published by D.B. Dowling (1896), who was particularly interested in the presence of dolomitic limestones and quartz porphyries. This was the only source of geological information regarding Red Lake until E.L. Bruce published his report in 1924. He recognized gold-bearing veins in Timiskaming type greenstones and sediments and suggested further prospecting. Also, he suggested that Dowlings' limestones were carbonate replacement zones in greenstones. A more detailed report was published in 1928 by Bruce and Hawley.

M.E. Hurst (1936) examined mineral occurrences in the area and the first extensive report was published in 1940 by H.C. Horwood.

Since then the area has been mapped by Chisholm (1951), Ferguson (1962-1968) and Riley (1972). The most recent maps are by Pirie et al. (1977-1979), with brief descriptions by Pirie (1977-1979).

1.3 HISTORICAL BACKGROUND

The first record of the actual search for and discovery of minerals of economic importance goes back to 1897 when the Northwestern Ontario Exploration Company, an English syndicate, sunk a small shaft at the northeastern end of Red Lake. The results however were not satisfactory and the project was abandoned. In 1922, rumours of silver occurrences in the area lead to approximately 100 claims being staked. The first gold showing was observed on the northern end of McKenzie Island on property that in subsequent years was developed into McKenzie Red Lake Gold Mines.

The birth of the Red Lake camp as a gold producer was on July 25th, 1925 with the establishment of the Howey and Hasaga Mines on property which featured large amounts of visible gold in quartz stringers. However, it was not until January of 1926 with the staking of several claims by prominent companies that the "gold rush" began. By the end of the year over 10,000 claims were filed. The price of gold at the time was $20.00 per ounce.

The ground upon which Dickenson Mine stands was first staked in the early days of the gold rush. It was restaked in 1944 after the original owners allowed the claims to lapse. In that year J.G. Dickenson bought a half interest in the property and the present company was formed. The first gold was produced in 1948.

Robin Red Lake Mines, which is east-southeast of the Dickenson property is largely controlled by Dickenson Mines and was incorporated in 1945. It is presently mined through the Dickenson shaft and the ore is treated in the Dickenson mill.

In all, the Red Lake camp has had 15 producing mines (Fig. 1-3) of which only three are still in production; Campbell Red Lake, Dickenson and Robin Red Lake. However, recent high gold prices have fueled speculation as to re-opening of several. Table 1-1 indicates the amount and total years of production for these mines to the end of 1979.

1.4 STATEMENT OF PROBLEM

During the summer of 1977 Dr. J.M. Franklin D.E.M.R., visited and sampled specific levels in the Dickenson Mine and subsequently introduced the author to the area. In May and June of 1978 samples were obtained from three levels; 17, 25 and 30. The area was revisited in the spring of 1980 at which time further samples were obtained, including some from Level 24.

The principal objectives of the project were to:

(a) determine whether there is any systematic variation in gold or other elements about the mineralized zone,

(b) obtain a better understanding of the lithologies near the ore,

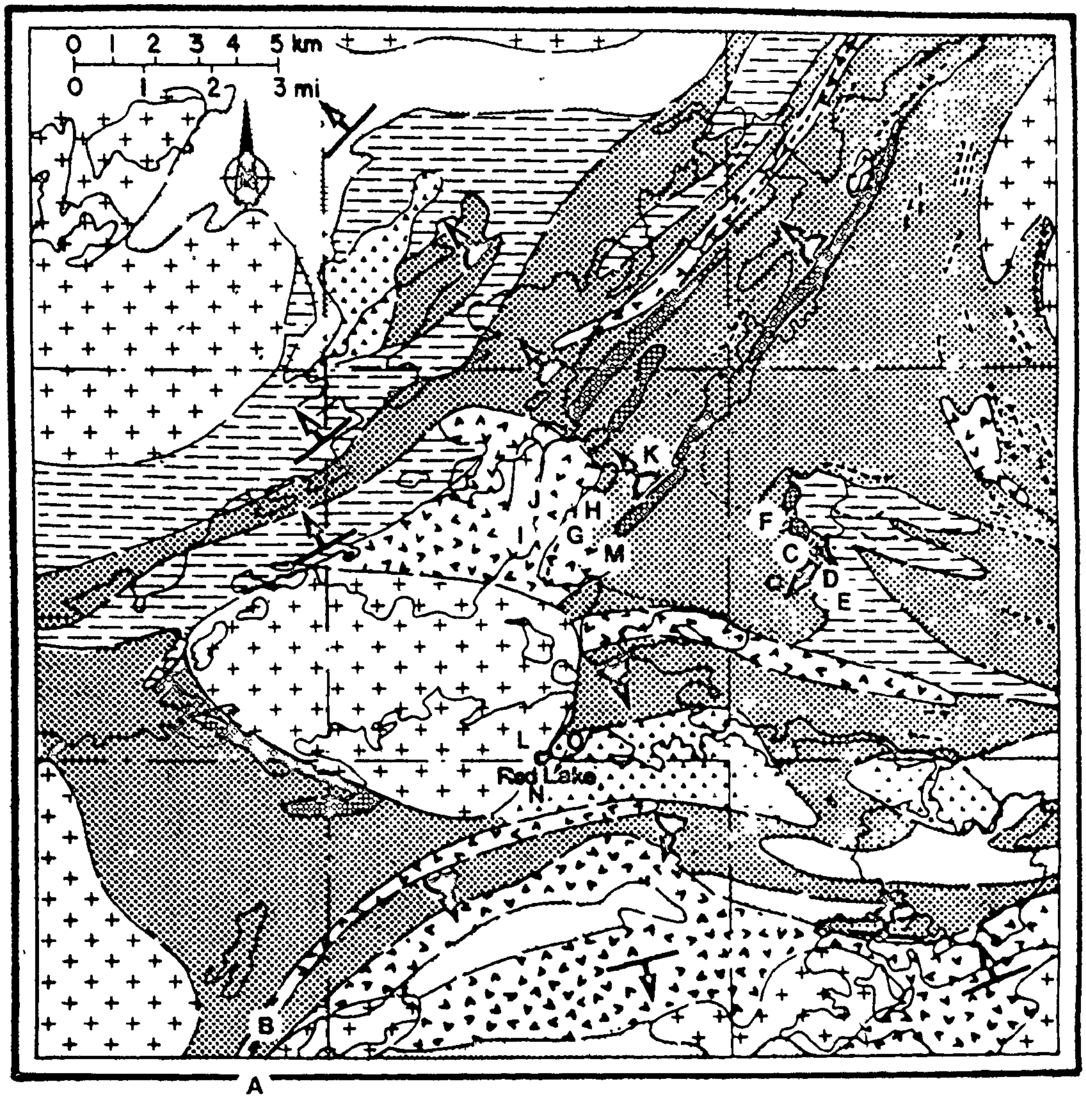
(c) deduce the nature of and mechanisms for formation of the gold ores.

Figure 1-3. The geological setting of past and present gold producers in the Red Lake camp.

(Modified after Pirie, 1980).

INDEX TO MINES

A- Madsen
B- Starratt-Olsen
C- Campbell Red Lake (current producer)
D- Dickenson (current producer)
E- Robin Red Lake (current producer)
F- H.G. Young
G- Annco
H- Cochenour-Willans
I- Gold Eagle
J- McKenzie Red Lake
K- McMarmac
L- Red Lake Shore
M- Wilmar
N- Hasaga
O- Howley



LEGEND

▩ Mafic to ultramafic metavolcanics

☐ Intermediate metavolcanics

▲ Felsic metavolcanics

▤ Clastic metasediments

▤ Chemical metasediments

▨ Mafic to ultramafic intrusives

∴ Felsic subvolcanic intrusives

+ Felsic to intermediate batholithic intrusives

TABLE 1-1 Gold production from all mines in Red Lake Camp to end of 1979 and average grade of ore produced during life of each mine.

	Ounces Gold Produced	Avg.Gold Grade (Oz/Ton)	Started Production	Ceased Operation
Annco	53,903	----	1965	1971
+Campbell Red Lake	4,914,097	0.61	1949	----
Cochenour-Willans	1,131,689	0.46	1939	1971
Dickenson	2,162,393	0.45	1948	----
Gold Eagle	40,204	0.22	1937	1942
Hasaga	218,213	0.14	1938	1952
Howey	421,593	0.09	1930	1957
McKenzie Red Lake	651,156	0.27	1935	1966
McMarmac	45,246	0.29	1940	1948
Madsen	2,416,609	0.29	1938	1976
Red Lake Gold Shore	21,100	0.24	1936	1938
*Robin Red Lake	-----	----	----	----
Starratt-Olsen	136,990	0.18	1948	1956
Wilmar	52,204	----	1967	1971
H.G. Young	55,244	0.19	1960	1963

*- Production included in Dickenson mines total.

+- Includes production to end 1978 only.

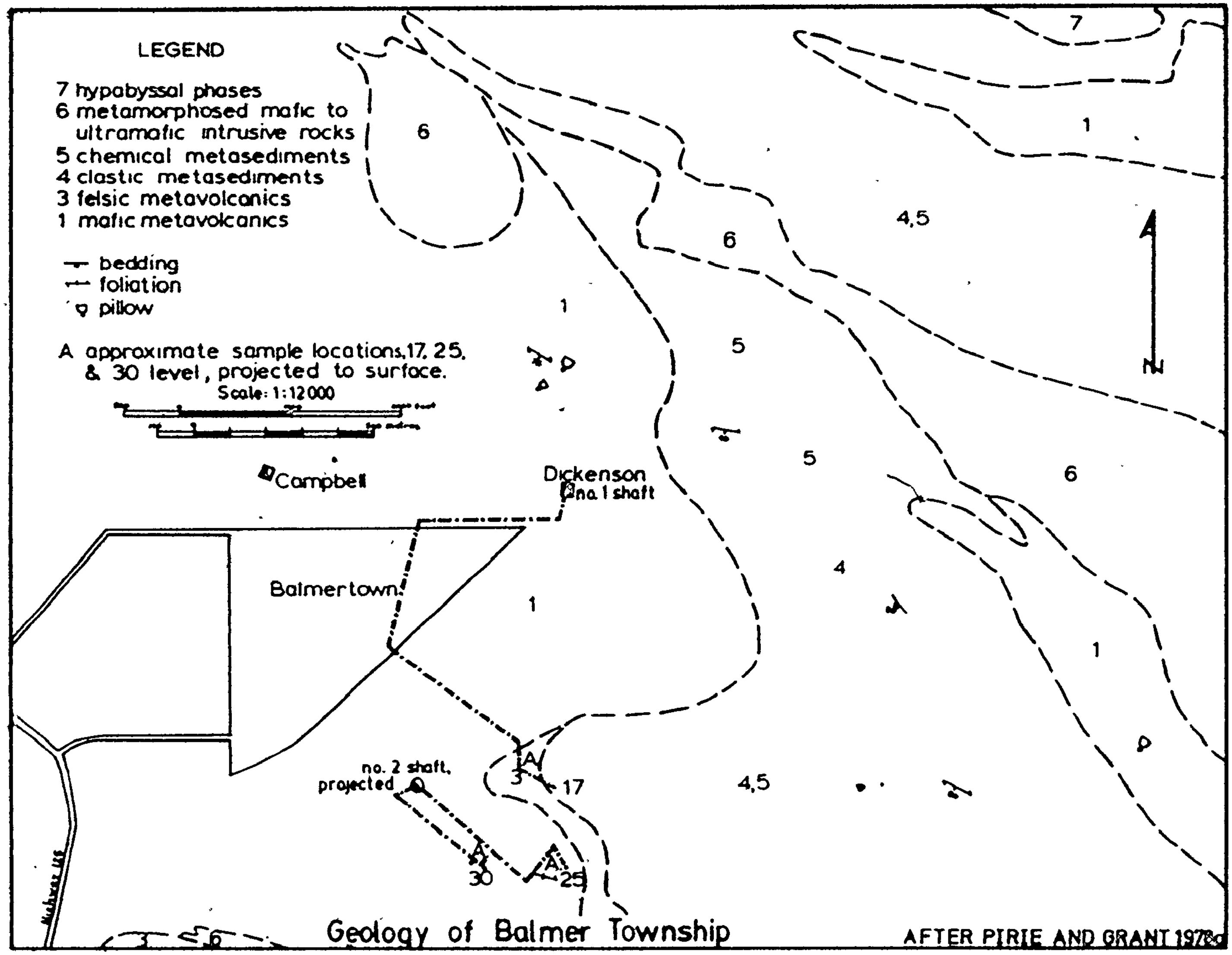
1.5 METHODS OF MAPPING AND SAMPLING

The surface projections of the sampled localities are illustrated in Fig. 1-4. Two crosscuts were sampled on the 30 Level. They occur 400 m east to southeast of the number 2 shaft, which itself is located approximately 950 m south-southwest of the number 1 shaft. The south crosscut was mapped and sampled for the entire 125 m of its length, as was the 75 m of the north crosscut. Sampling was done at one to two foot intervals near the ore zone and progressively increased to 15 feet away from the ore zone. Samples of the ore zone from the drift between these two crosscuts were obtained (30-S580 E.Dr.) as were samples from the ore zone at the end of the south crosscut (30-S-1492 E.Dr.). Further sampling was done in two drilling stations 40 feet west of the south crosscut. Drill core from the vicinity of the sampled areas was also examined. Map 1 is a sample location map of the 30 Level.

Mapping on the 25 Level was carried out at the eastern end of the workings along north crosscut 25-598 and in an ore body some 125 m northeast of the main drift (25-274 E.Dr.). Samples were obtained over a distance of 150 m and include the two parallel, 70 m long southeast trending drifts. This local is approximately 500 m east-southeast of the No.2 shaft (Map 2).

Samples on the 24 Level were obtained at the end of the "East South C" ore zone, some 700 m southeast of the No.2 shaft.

FIGURE 1-4. Surficial geology around Dickenson Mine with projections of the sampled localities.



Geology of Balmer Township

AFTER PIRIE AND GRANT 1978a

The 17 Level samples were obtained approximately 900 m south of the No. 1 shaft. The area mapped and sampled was essentially 10 m on either side of the east drift in crosscut 17-1582 (Map 3).

CHAPTER 2

GENERAL GEOLOGY

2.1 REGIONAL GEOLOGY

The Red Lake volcanic-sedimentary[1] belt is Archean in age and isolated from other greenstone belts in that it is bounded on all sides by younger diapiric granitoid batholiths (Figs. 2-1 and 2-2).

The dominant rock types are a sequence of mafic to ultramafic volcanics whose composition varies from komatiitic to high iron and magnesium tholeiitic. The pyroxenitic komatiites commonly exhibit well preserved spinifex texture. In the basaltic komatiites and magnesium tholeiites tremolite is the dominant mafic mineral, whereas in the iron tholeiites it is actinolite. Variolitic and pillowed flows capped with flow-top breccia are common. The pillows exhibit an ellipsoidal form. These volcanics are commonly carbonatized and saussauritized.

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[1] Greenschist facies regional metamorphism has overprinted rock types in the area. In the interests of brevity, the prefix meta is omitted.

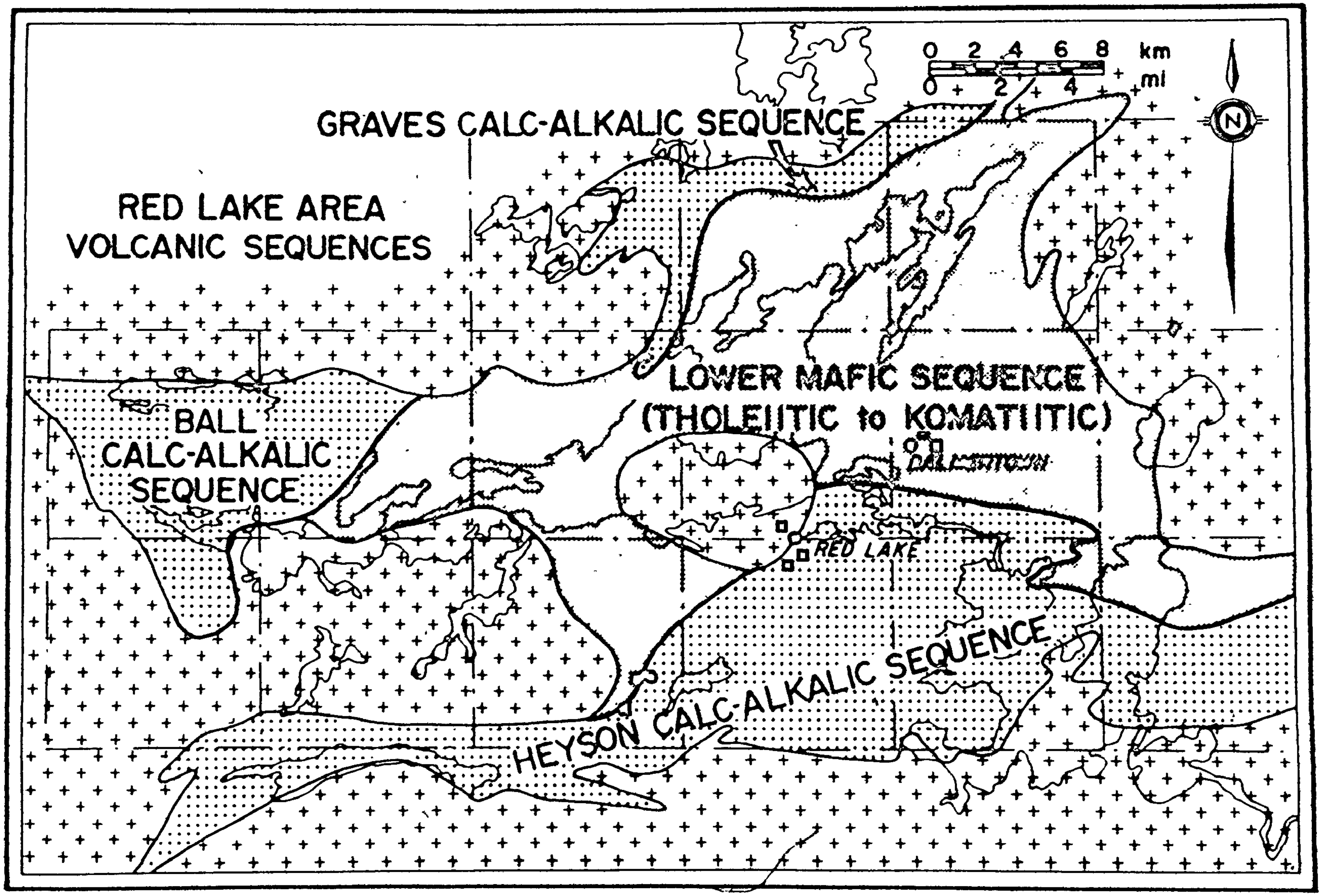


Figure 2-1. Major volcanic sequences in the Red Lake area.

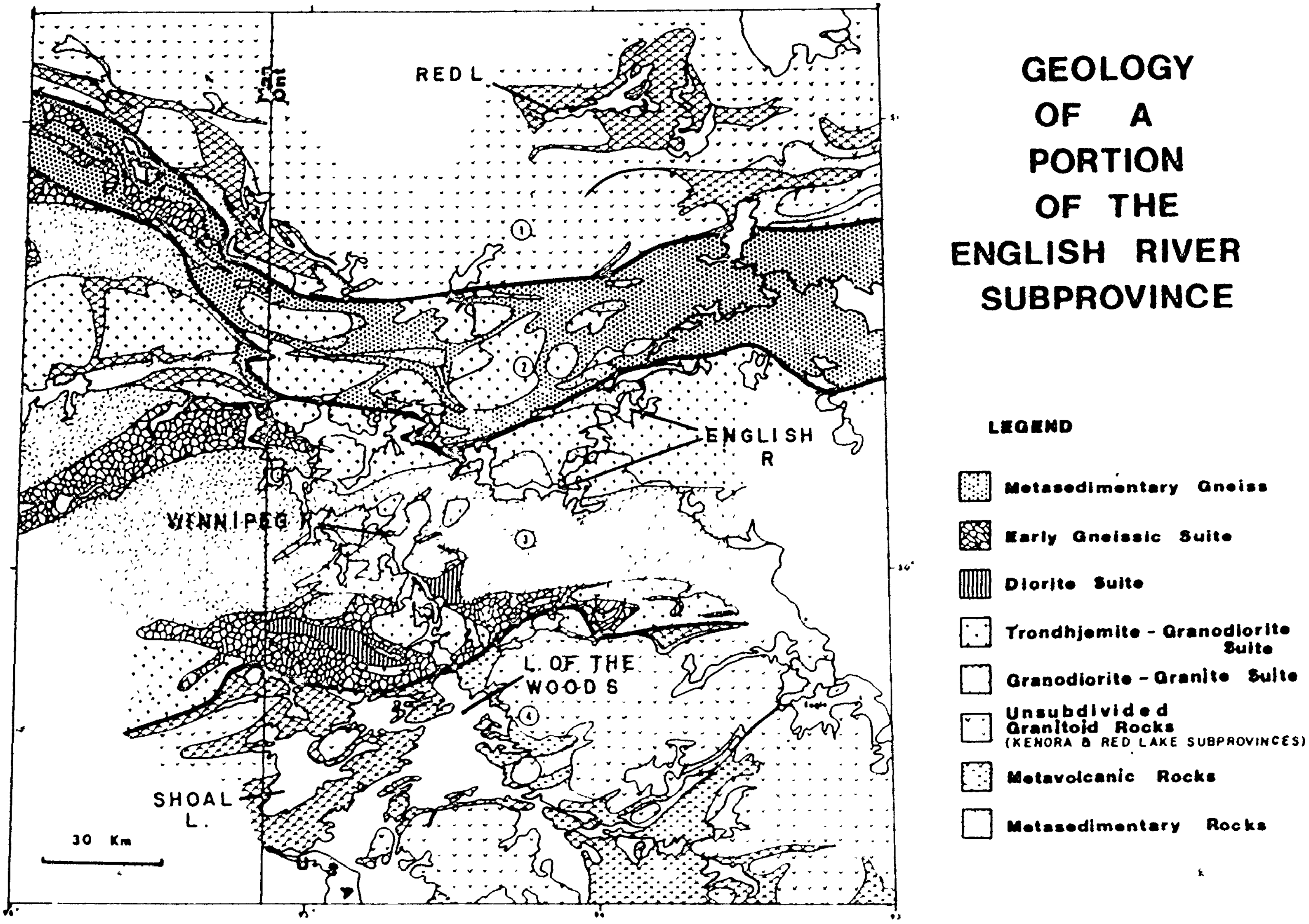
from Pirie, 1980.

Figure 2-2. Geologic setting of Red Lake with respect to adjacent subprovinces.
The geologic terrains are designated by numbers.

1. Red Lake subprovince
2. Ear Falls - Manigotagan gneiss belt
3. Winnipeg River batholithic belt
4. Kenoran suprovince

(from Beakhouse, 1977).

GEOLOGY OF A PORTION OF THE ENGLISH RIVER SUBPROVINCE



This mafic sequence is overlain by substantial thicknesses (2 to 10 km) of mixed felsic to intermediate volcanics with minor mafic units (Pirie, 1980). Compositionally the group ranges from andesite to rhyolite and exhibits both tholeiitic and calc-alkalic trends. The tholeiitic felsic volcanics are generally narrow pyroclastic units with lesser flows, whereas the calc-alkalic sequence contains thick units of pyroclastites.

Chemical and clastic sediments occur as thin units intercalated with these volcanics as well as thick regionally mappable units.

The clastic sediments include wacke-mudstones, argillites, graphitic argillites, and polymictic and oligomictic conglomerates, with a wide range of fragment size and texture. Primary structures such as graded bedding, bedding and ripple-marks are evident.

The chemical sediments consist of laminated cherts and iron formations which generally occur as thin discontinuous but concordant units, and are commonly associated with the mafic flows. The exception is east of Dickenson Mine and south of Balmer Lake where they occur as thick kilometer wide units.

This supracrustal sequence is intruded by a number of intermediate to basic stocks and dykes, ranging in composition from trondhjemite to diorite, the largest of which is the "Howey Diorite". Also present are younger sills and dykes ranging in composition from peridotite to diabase. The ultrabasic intrusives are commonly serpentinized.

2.2 METAMORPHISM

The regional metamorphic grade is greenschist although locally a lower amphibolite mineralogy has developed, particularly in the mine environment.

2.3 STRUCTURAL GEOLOGY

Grant et al. (1965) conducted a gravity traverse across the belt (N-S) and proposed a basin-like model with a maximum thickness of 7.5 km. They envisaged an asymmetrical synclinorium 40 km in length (east-west) and 20 km wide (N-S). The central core of this structure contains 2.2 km of lighter rocks including sediments and granites. They also suggest two periods of complex isoclinal folding.

In the east half of the belt sedimentary structures and pillow shapes indicate that the major structure appears to be an anticline with subsidiary anticlinal and synclinal folds (Pirie, 1980; Fig. 1-3, this thesis). The bedding and main foliation on and to the north of McKenzie Island trend northeast whereas in the eastern part of Dome and into Balmer Township the main foliation and lithologies trend west to northwest.

2.4 GEOLOGICAL SETTING OF DICKENSON MINE

The most recent geological map of Pirie and Grant (1978a) including the surficial geology around Dickenson Mine, is reproduced in part with deletion of the boundaries of individual outcrops in Figure 1-4. The geological setting of all past and present gold producers in the Red Lake camp is illustrated in Figure 1-3.

The Dickenson No. 1 shaft and mine buildings (Plate 2-1) sit on a unit of altered pillowed mafic volcanics. A second shaft sunk from the 22nd level is located approximately 900 m south to southwest of the No. 1 shaft. The contact between these pillowed flows and a thick sequence of clastic and chemical metasediments (units 4 and 5), is approximately 400 m east of both shafts and provides a convenient datum. Bedding within the sediments generally trends to the northwest with a steep southwesterly dip. Stratigraphic tops face to the southwest. Just south of the No. 2 shaft is a 500 m thick unit of felsic to intermediate, locally reworked quartz and feldspar porphyritic pyroclastites with minor felsic flows.

2.5 GOLD MINERALIZATION

A review of the literature (Ferguson, 1962, 1965, 1966, 1968; Pirie, 1977, 1978, 1979) indicates that gold deposits in the Red Lake area occur in essentially five

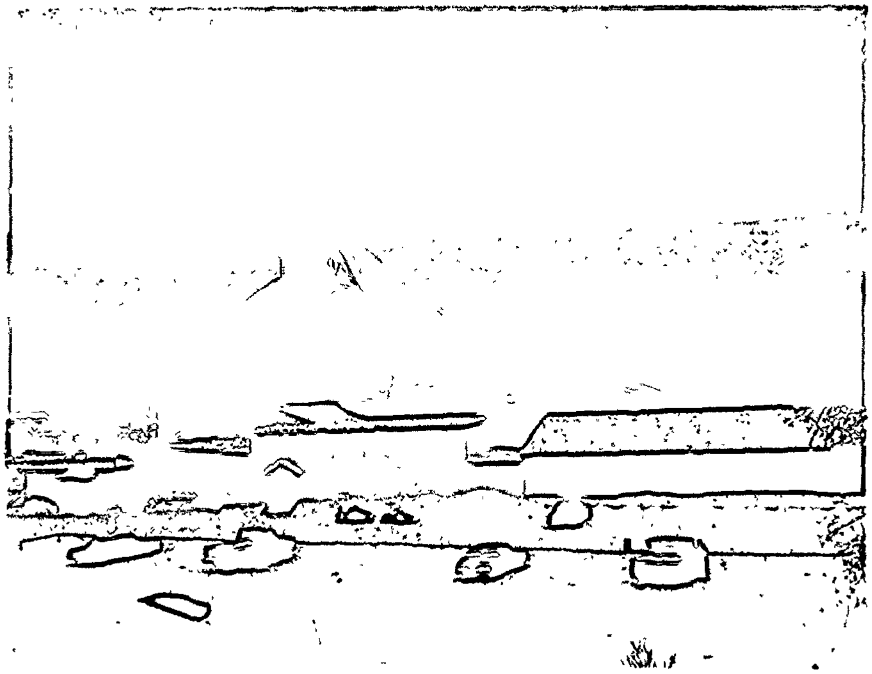


PLATE 2-1. Headframe above the Dickenson No. 1 shaft. Mill is in the background.

settings: a) generally discordant sets of quartz-carbonate veins with associated veinlets and stringers, in carbonatized mafic volcanics which locally are pillowed and in places variolitic (Campbell Red Lake, Cochenour-Willans); b) quartz and quartz-carbonate zones which are conformable with and enclosed by volcanic strata (Dickenson Mine); c) as narrow laminations within primary interflow sulphide sediments and accompanying cherty material (Dickenson Mine); d) quartz enfilled silicified shear zones and fractures related to basic to intermediate intrusions (McKenzie Red Lake, Howey, Gold Eagle, Hasaga, Red Lake Gold Shore); e) massive to weakly banded tuffs, which locally are garnetiferous (Madsen, Starratt Olsen).

2.6 BASE METALS

The first viable deposit of base metals in the Red Lake District was discovered in 1968 by Selco Exploration Limited, in the Uchi area 80 km east of Red Lake. Economic reserves of copper, zinc and silver lead to the opening of the South Bay Mine which began production in 1971 and was the forerunner of other discoveries, the largest of which too date is the Mattabi Mine at Sturgeon Lake (225 km southeast of Red Lake).

Another deposit of interest is Griffith Mine which is located at Bruce Lake approximately 50 km to the south of Red Lake. Owned and operated by the Steel Company of Canada it began producing iron pellets in 1968.

Recent airborne magnetic and electromagnetic maps of the Red Lake area (OGS 1978), indicate the presence of a large amount of small but continuous conductors. Although these largely pyrite-pyrrhotite zones may prove uneconomic as base metal deposits, they do have potential as gold-bearing zones. This point shall be clarified in the ensuing text.

CHAPTER 3

ANALYTICAL METHODS

3.1 GOLD ANALYSIS

Gold abundances were determined using both radiochemical (RNAA) and instrumental (INAA) neutron activation analysis.

The only naturally occurring stable isotope of gold is the nuclide ^{197}Au. When subjected to neutron bombardment it undergoes a (n,γ) reaction producing the radionuclide ^{198}Au. The latter has a half-life of 2.696 days (64.704 hrs) and decays to stable ^{198}Hg by emission of a 412 KeV gamma ray.

Samples and standards were irradiated in the McMaster pool-type nuclear reactor in a neutron flux of about 1.5×10^{13} neutrons/cm^2/sec. Counting was carried out on an Ortec, Li drifted Ge detector with a resolution of 2.0 KeV at 662 KeV (^{137}Cs). Sample counts were normalized to a common time to correct for the decay of ^{198}Au, according to the equation

$$\left(e^{\frac{.6901}{64.704} t} \right) NT$$

where; t:time since first chemical standard began counting,

NT:net total counts

and then compared with the chemical standards. The resulting gold abundances were calculated in ppb.

3.1.1 Radiochemical Neutron Activation Analysis (RNAA)

A total of ten experiments were conducted using RNAA. The irradiation package consisted of ten to twelve, 300 mg rock samples, two chemical standards and one rock standard, (W-1). The chemical standards were prepared by loading crushed silica powder into ampoules, doping with a dilute gold-chloride solution and then drying at approximately 70°C. The wet chemical procedure used required two days for separation and purification of 10 to 12 samples and standards, and is similar to that described by Crocket et al. (1968), with some minor but significant variations. The procedure is briefly described below.

(1) Approximately 300 mg of 200 mesh rock powder is loaded into silica ampoules and sealed with an aluminum foil top.

(2) Samples and standards are loaded into aluminum capsules, irradiated for 24 mega watt (MW) hours, and then allowed to cool for 5 days.

(3) The radioactive rock powders (samples) are then transferred into zirconium crucibles containing approximately 20 mg of gold carrier (2.00 ml of carrier solution and 2 or 3 Na_2O_2 - NaOH pellets are evaporated to dryness under a heat lamp).

(4) About 3 g of Na_2O_2 - NaOH flux is then added.

(5) Fusion is accomplished by heating over low heat (Bunsen flame) for 2-3 minutes and then over an intense heat for 3-5 minutes. The molten mixture is swirled 2 or 3 times to enhance mixing.

(6) Following a 10 minute cooling the crucibles are transferred into 400 ml beakers and covered with watch glasses. Dissolution of the fusion cakes is accomplished by adding 10 ml of 2M HNO_3 and 15 ml of concentrated HNO_3 in 2-3 ml aliquots. Care should be exercised during the initial addition of HNO_3 due to the strong effervescence.

(7) The crucible and lid are then removed and cleaned with approximately 25 ml of 2M HNO_3.

(8) Samples containing more than 65 wt % SiO_2 and 10 wt % Al_2O_3 should be centrifuged for approximately 10 minutes to remove silica gel. The silica gel should then be washed with 15 to 20 ml 2M HNO_3, centrifuged, and then discarded into liquid wastes. Although this addition to the procedure

reduces the yield by 10%, it eliminates bursts during (9) and coagulation during (10), both of which are caused by excess silica.

(9) The beakers are placed on hot plates at a temperature of 450°C (setting 3). They are covered with a watch glass, and also heated by infra-red lamps. A light spray of air is passed over them. After evaporation to about 20 ml, 10 ml of aqua regia (3 parts concentrated HCl, 1 part concentrated HNO_3) is added and the solution evaporated to incipient dryness. Two additional 5 ml aliquots of concentrated HCl are then added and the salts are broken up with a stirring rod as they reach incipient dryness. All the gold present in the samples should be converted to gold chlorides.

(10) The salts are then taken up in 40 ml of 0.5M HCl and filtered onto ion exchange columns (Dowex 1 anion resin, 50-100 mesh, X8 cross linkage) through Whatman No. 541 (fast) filter papers. After washing the sides of the column 3 times with 5 ml of 0.5M HCl the resin is eluted twice with 60 ml of 0.5M HCl. The washings are discarded to liquid radioactive waste.

If the samples are highly radioactive, centrifuging as in (8) may not be wise as this requires additional handling. The alternative is to heat the beakers in (9) very slowly (setting 1) and then in (10) allow the salts to coagulate and settle, thereby separating them from the liquid portion which can easily be poured into the columns. Wash the salts and repeat. This alteration to the procedure will however be very time consuming.

(11) The gold is then eluted with 120 ml of thiourea solution (0.1M thiourea in 1M HCl) and collected in a 400 ml beaker.

(12) The Au-thiourea elutate is heated near boiling (450°C, setting 3). 30 ml of concentrated NH_4OH is added and results in the precipitation of Au sulphide.

(13) After evaporation to 90 ml the solution is transferred to two 50 ml tubes and centrifuged. The liquid portion is decanted and the sulphide precipitates are washed with hot water. Cold water washing must be avoided as this will cause the precipitate to disaggregate into too fine a state to centrifuge.

Purification

(14) The gold sulphide is dissolved in 4 ml of aqua regia and converted to choride complexes by successive evaporation with 2 ml of concentrated HCl.

(15) Add 20 ml of 2M HCl to take the gold into solution; add 1 g of hydroquinone to the warm solution to reduce the gold to the metallic state and then centrifuge.

(16) Purification is completed by two additions of alcohol and water slurried with alcohol (causes fine gold to sink). The solution is centrifuged after each addition.

(17) The gold is then pipetted into weighed 0.25 dram pyrex counting vials and dried under an infra-red lamp with the aid of a light spray of air.

Preparation of Standards

(A) The outside of the standard ampoule is cleaned with acetone.

(B) The ampoule is cracked open and, along with the quartz powder, placed into a 100 ml beaker. Ten ml of aqua regia are added, the beaker covered with a watch glass and warmed for 10 minutes at 250°C (setting 1).

(C) Pipette some of the liquid in the beaker into the ampoule, to ensure the removal of the noble metals. The ampoules are removed and the solution is evaporated to incipient dryness (setting 1).

(D) 5 ml of concentrated HCl are added twice and then evaporated to incipient dryness. The gold is next taken up in 15 ml of 1M HCl, filtered through Whatman No. 541 fast filter paper and transferred to 50 ml centrifuge tubes.

(E) Steps 15 to 17 described above are then carried out.

3.1.2 Instrumental Neutron Activation Analysis (INAA)

INAA has three significant advantages over RNAA. The most important factor is that since all of the wet chemistry is eliminated, the researcher is exposed to much less radiation. Also, the possibility of cross sample contamination is eliminated. Finally, the larger sample size (1-1.3 g) which may be irradiated, reduces the possibility of unrepresentative analysis due to sample heterogeneity, a significant factor when dealing with auriferous rocks. A major disadvantage of INAA is the much lower sensitivity due mainly to higher background during counting.

The usefullness of INAA in determining gold abundances is being currently investigated at McMaster and the author has benefited from discussions with A. Fyon regarding methodology. INAA was used in five experiments, the first three of which were conducted in the following manner.

The irradiation package consisted of 11 rock samples, 2 chemical standards and 1 rock standard. The rock samples and standard contained approximately 1 g of powder, whereas the chemical standards consisted of a basic rock powder doped with high concentrations of Au-chloride solution. All samples were loaded into fused silica vials and sealed with a polybond glue-polyethylane cap. The package was then irradiated for 12 MW hours in the cadmium shield (epithermal), rotating "RIFLS" (Reactor irradiation facility for large samples), high flux position. This not only ensures the homogeneous bombardment of the samples, but the cadmium shield suppresses the thermal neutrons (energy E<0.4 ev) thereby significantly reducing the total activity of elements such as Na, K, Fe and the rare earths in comparison to Au. After a minimum of 4 days of cooling the samples were transferred into 4 dram pyrex vials and then counted. A problem was encountered in those samples with >250 ppm arsenic and <200 ppb gold in that the 412 KeV gamma line of gold occurred on the shoulder of the Compton plateau of ^{76}As. This is best illustrated in Plates 3-1 and 3-2. These peaks can be contrasted with the symmetrical, low background peaks of chemical standards or highly auriferous samples (Plates 3-3 and 3-4). The lowest gold value attained using this method was 2.71 ppb. This was however, for a non arsenic bearing komatiitic flow.

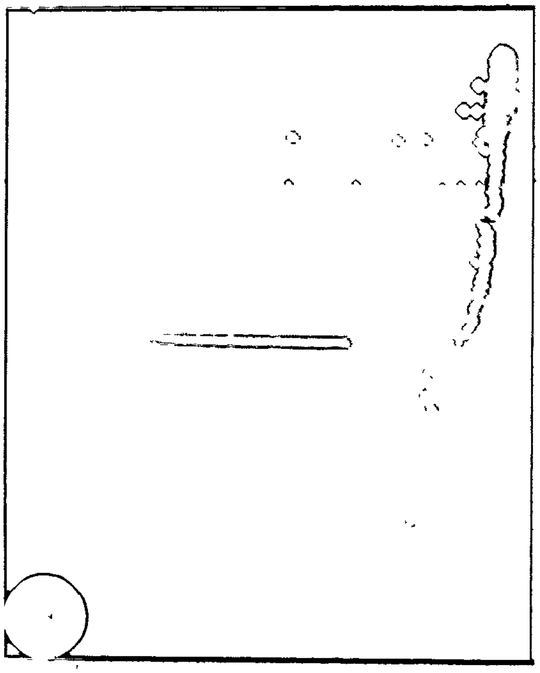
In an effort to reduce the background, the final two experiments were conducted in the following manner. Twelve samples containing approximately 1.25 g of rock powder and two chemical standards were heat sealed in polystyrene vials. This package was then irradiated for

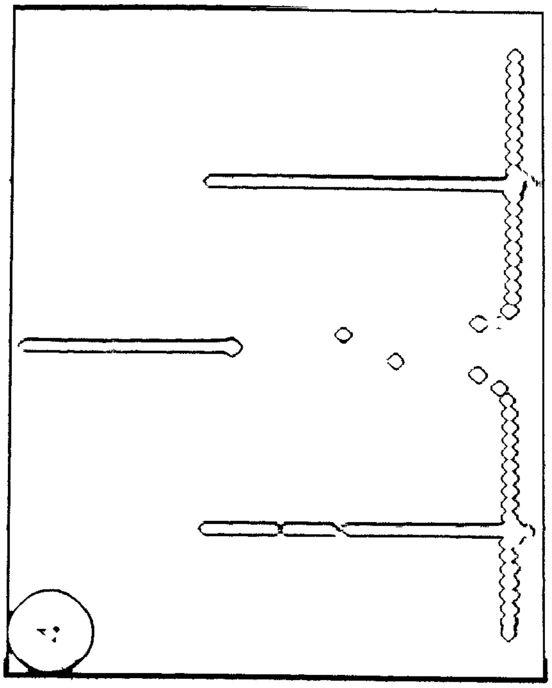
PLATE 3-1. INAA gamma ray spectrum of irradiated sediment sample (25-14), showing the 412 KeV photopeak of ^{198}Au in the four channels between the cursors (2 vertical lines). Photopeak to the right of Au is 480 KeV line of ^{56}Ba.

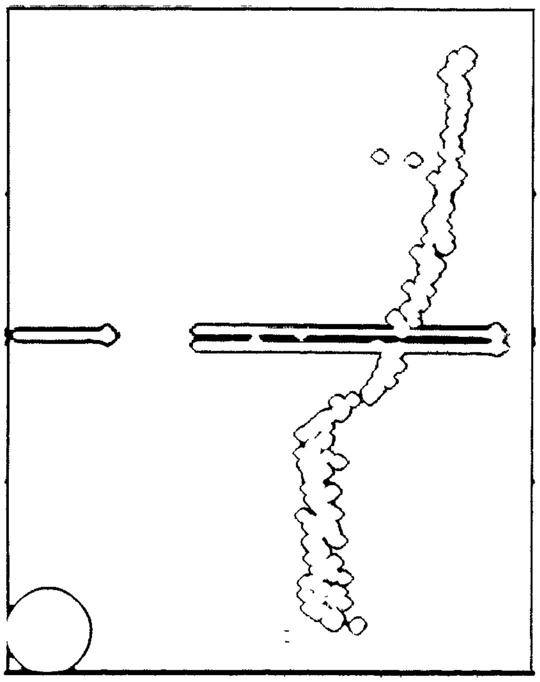
PLATE 3-2. INNA gamma ray spectrum of irradiated ore zone sample (240-B2), showing 412 KeV line of ^{198}Au (peak under white line). Photopeaks to the right of gold represent ^{76}As (559 and 657 KeV) and ^{74}As (596 KeV).

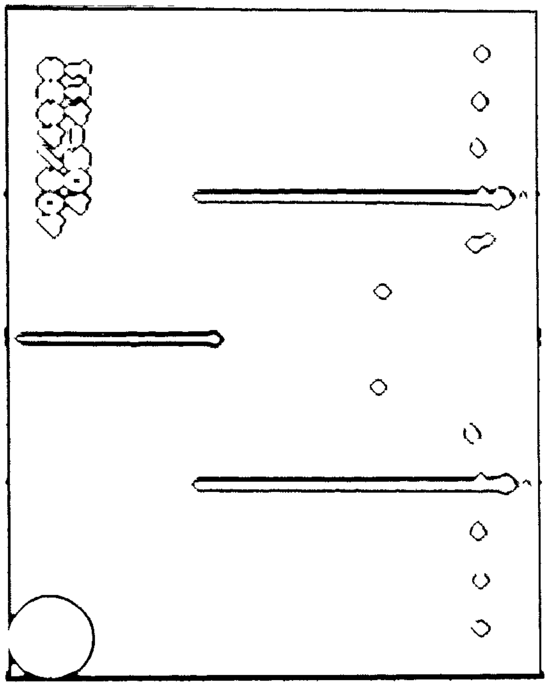
PLATE 3-3. Sample 80-12A. Symmetrical γ peak for auriferous sample from the main 30 Level ore zone. Similar peaks were obtained for chemical standards. Each white dot represents a channel.

PLATE 3-4. Sample 80-16. Well defined γ peak for an auriferous sediment. Note low background. Analysis by INA.









a minimum of two days. Initial counting was done 3 days after irradiation and the same samples were counted 4 to 6 days later to observe what effects different background decay rates would have on the gold values. The results are illustrated in Table 3-1 and indicate that for samples with >100 ppb Au, differential background decay has little effect. More experiments are necessary to see the effects upon samples with >100 ppb Au. The smallest gold value attained was 10.00 ppb and because of low background activity its peak was clearly recognizable.

3.1.3 Recommendations for RNAA and INAA

The bulk composition of the samples should be determined prior to activation analysis.

When carrying out RNAA step 8 (described earlier) should be adhered to closely for those samples containing >65 wt % SiO_2 and >10 wt % Al_2O_3.

Of the two instrumental techniques, the latter, requiring only 1 MW hour of irradiation is recommended. Not only does it expose the researcher to less radiation, but it is capable of determining gold values as low as 10 ppb. Since counting can commence within 3 days of irradiation it will undoubtedly, prove to be a satisfactory method in determining even lower values. Finally, those samples high in arsenic should be separated and counted 6 to 8 days after irradiation as this will reduce the Compton interference arising from arsenic.

3.1.4 Accuracy and Comparison of RNAA and INAA

The values obtained for rock standard W-1 are listed in Table 3-2 and with one exception fall within the range of reported values. The one anomolously high determination may reflect heterogeneity of gold distribution in W-1, as it appears to be carried in sulphides (Fritze and Robertson, 1969).

Table 3-3 presents a brief comparison between the two techniques. It can be seen that comparable values were obtained for low Au concentrations, however when values exceeded 200 ppb the variability was almost 25 %. It is noteworthy that sample 25-13 which is high in arsenic exhibited a variability of <5 % over the course of three instrumental analyses.

One further point regarding RNAA. Cross contamination during the wet chemical processing was not a problem even though the range of gold values obtained was 1.0 ppb to 21 ppm. During the course of the 2 days in the lab, samples which were subsequently determined to have low gold abundances (ppb range) were treated next to samples with high gold abundances (ppm range).

TABLE 3-1. Variation in Gold Values (ppb) of Auriferous Samples as a Function of Time.

Sample No.	Gold Content Td= 3 days	Gold Content Td= 7 days	Gold Content Td= 9 days	Δ%
800-01	3317	3239		2.35
80-12A	8755	8777		0.25
80-14	111	120		7.50
80-16	91430	89854		1.72
25-14	1345	1311		2.53
240-B1	2424	2320		4.29
170-B	13103		13627	3.85
240-B2	435		412	5.29
80-07F	60.41		71.42	15.42

Td= Time since irradiation.

Δ%= % difference between 3 and 7 day counts or 3 and 9 day counts.

TABLE 3-2. Au Values (ppb) Determined for Rock Standards W-1 and G-2 (RNAA).

W-1		*Mean	G-2
4.67	4.81	4.73	3.15
3.35	4.48		
5.10	11.10		
5.12	4.80		
5.54			

*- exlcudes 11.10

Reported Values for W-1	3.9 - 6.2	Fritze and Robertson
	3.7 ?	Abbey (1977)
	4.1 - 4.6	Kwong and Crocket (1978)
for G-2	1.0 ?	Abbey (1977)

TABLE 3-3. Accuracy of INAA and Comparison with RNAA.

	INAA	ppb	RNAA
Sample 25-13	285		220
	287		
	309		
Mean	294		
Sample 25-12	10.09		9.70
Sample 17-12			10.00
			8.53
Mean			9.27

3.2 XRF ANALYSIS OF MAJOR AND TRACE ELEMENTS

Rock compositions were obtained using a Philips Model 1450 AHP automatic sequential X-ray fluorescence spectrometer, housed in the Geology Department at McMaster University. The major elements analysed for were Si, Al, total Fe, Mg, Ca, Na, K, Ti, Mn and P. Trace elements analysed for were S, Ni, Rb, Sr, Y, Zr, Nb, Cr, Co, Pb, Cu, Zn, As, Ce, Nd, V, La and Ba. The results can be found in Appendix A.

A thorough discussion of analytical errors can be found in Appendix B.

Rock samples were broken with a jaw crusher and then crushed to -200 mesh using a ceramic pulverizer and shatter box. To reduce the chances of contamination the shatter box was cleaned with silica gel and a decontamination sample was run through the crushing equipment prior to each actual sample. Special care should be taken to make sure the jaws are scraped clean, beaause of the numerous iron sulphides and oxides present in some samples. Pressed powder discs of each sample were then made following the procedure outlined by Marchand (1973).

3.3 DETERMINATION OF VOLATILES

Loss on ignition (L.O.I.) was determined by heating approximately 1.25 g of sample in an electric furnace for one hour at a temperature of 1000°C.

CO_2 was determined by fusing approximately 0.3 g of rock powder in a Leiko induction furnace for 60 seconds.

Total H_2O was then determined as L.O.I.-CO_2.

3.4 X-RAY DIFFRACTION

To assist in the identification of carbonate minerals, several samples were subjected to x-ray diffraction. Whole rock powder was slurried with acetone onto a glass slide. The samples were then scanned on a Phillips diffractometer from 5° to 75° of two theta at a rate of one degree per minute. The two theta angle of each definite peak was measured and its d spacing calculated according to Bragg's equation $\lambda = 2d \sin \theta$; where $\lambda = 1.542$. Minerals were then identified using the Joint Comission of Powder Diffraction Standard Files. The author also found it useful to compare the results with calculated x-ray patterns of silicate minerals (Borg and Smith, 1969).

CHAPTER 4

PETROGRAPHY

4.1 17 Level

The geology of the 17 Level along crosscut 17-1582 as mapped by the author is illustrated in Map 3. All rocks are metamorphosed to upper greenschist-lower amphibolite grade and are highly carbonated. The main primary lithologies inferred are ultramafic komatiitic flows and felsic volcanics. The ore zone sampled on this level occurs within the felsic volcanics and lies approximately 90 m south of the main E. SC. Drift.

4.1.1 Komatiites

The above mentioned 90 m interval consists essentially of a unit with strong komatiitic affinities (see Chapter 5). A pronounced northwest trending schistosity has all but obliterated primary textures. However, it is still possible to recognize and measure some lithologic contacts which appear to be parallel to subparallel, to the northwest foliation. This unit is represented by samples 17-27 through 17-19.

The alteration appears to consist of pervasive carbonitization, followed by minor carbonate veining, opaque-carbonate-chlorite crystallization along shears and then a final period of discordant carbonate veining.

It is difficult to ascertain whether this unit is one large flow or not. Several well defined lithologies occur approximately 60 m north of the sampled zone where meter wide massive carbonate units intercalate with brecciated komatiitic units. The carbonate units are whitish dolomitic rocks with accesory quartz, opaques and fuchsite. The dolomite is variable in grain size and locally appears graded. Quartz is rare and occurs as recrystallized grains in pods. Opaques, dominantly chromite and pyrite occur in bands, with rare fuchsite in <u>in situ</u>[1] veins (Plate 4-1). Secondary coarse grained carbonate veins and opaque-filled shears are rare but present. The light gray komatiites are brecciated, with randomly orientated carbonate and, ocassionally, mafic fragments. Shears within them, contain limonite-pyrite-carbonate-chlorite. Numerous secondary coarse grained carbonate veins are present. Quartz veining is rare.

Near the stratigraphic top of the unit (see Chapter 6), a rock with a distinct texture is evident. It consists of 2 to 5 mm, subangular to subrounded, foliated ovoids of

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[1] <u>in situ</u>. This term is used by the author to indicate veins which have been derived relatively in place. That is the vein constituents have been sweated out of the immediate enclosing volcanics, largely through metamorphism, and are not derived from afar as part of a massive hydrothermal system.

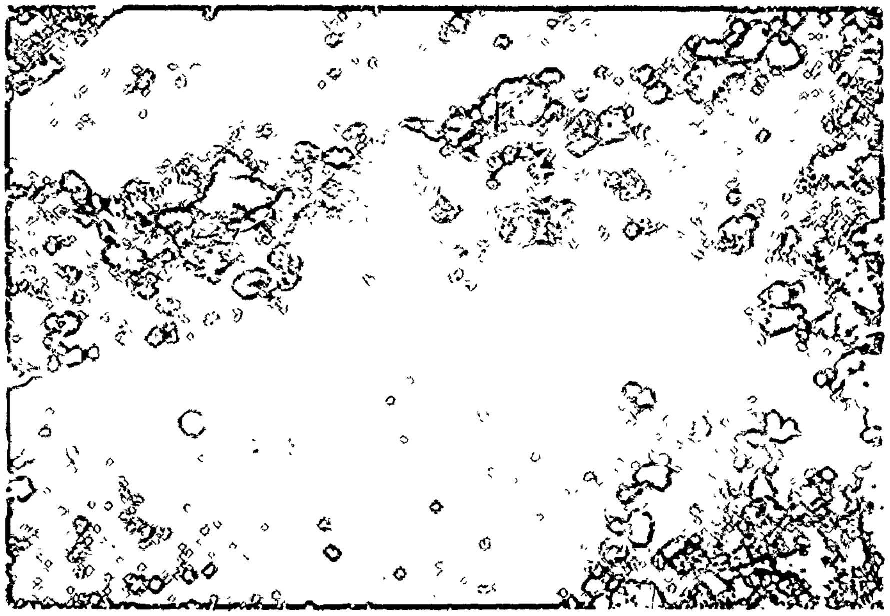


PLATE 4-1. Sample 17-27. Dolomite-quartz rock with locally derived fuchsite-chromite ± pyrite vein. Field of view is 1.6 mm (plain light).

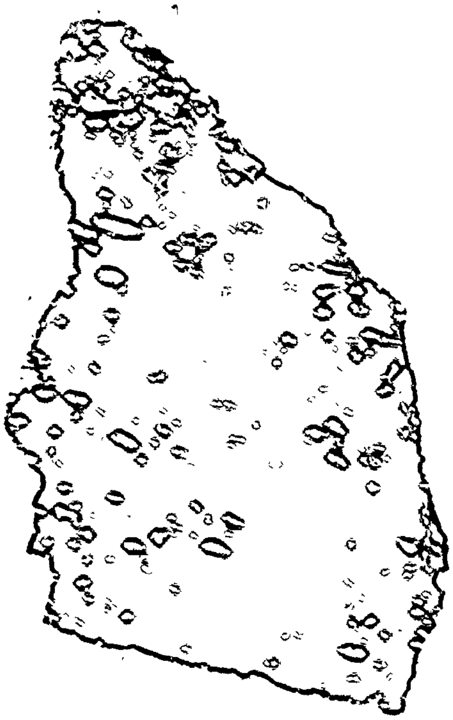
carbonate-quartz in an essentially magnesium chlorite matrix (Plates 4-2 and 4-3). This rock is interpreted as a carbonatized komatiitic flow. Opaques occur disseminated throughout the matrix and commonly outline ovoids. They are also present in minute shears. Secondary carbonate veins are rare and occasionally contain quartz ± tremolite. Locally the veins have the appearence of <u>in situ</u> sweats.

The top of this unit consists of a very fragmental rock with a hyaloclastitic texture (Plate 4-4). Angular carbonate ± quartz fragments of variable size occur in a chlorite-quartz-carbonate-opaque matrix (Plate 4-5). Intercalated with this rock are distinct buff brown siliceous zones up to 30 cm in width (Plate 4-6). They consist of quartz-carbonate ovoids in a recrystallized fine grained quartz matrix with minor quartz-carbonate veining. These zones are interpreted as metamorphosed carbonate-rich cherts.

A sharp contact exists between the flowtop and a 30 cm wide, fine grained black peraluminous rock, which consists of carbonate ± quartz ovoids (up to 1 mm) in a very fine grained matrix of quartz-anorthite-andalusite-biotite-clorite-opaques. Secondary quartz-carbonate veins are rare. Opaques are generally disseminated but occasionally occur in minute layers parallel to the weak banding. Along with the micas they emphasize small kink folds at 40° angles to the banding. This rock is interpreted as a metamorphosed pelitic sediment.

PLATE 4-2. (Sample 17-24, length 6.5 cm). Carbonatized komatiitic flow. White ovoids consist of carbonate-quartz. The matrix is essentially chloritic.

PLATE 4-3. Photomicrograph of Plate 4-2. The dark black interstitial material outlining the ovoids is opaques. Light gray matrix material is essentially a Mg-chlorite. Length of thin section is 4 cm (crossed nicols).



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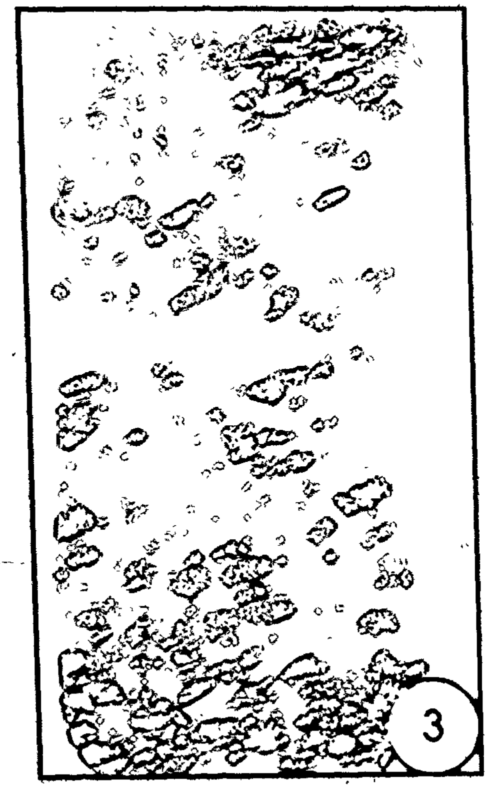

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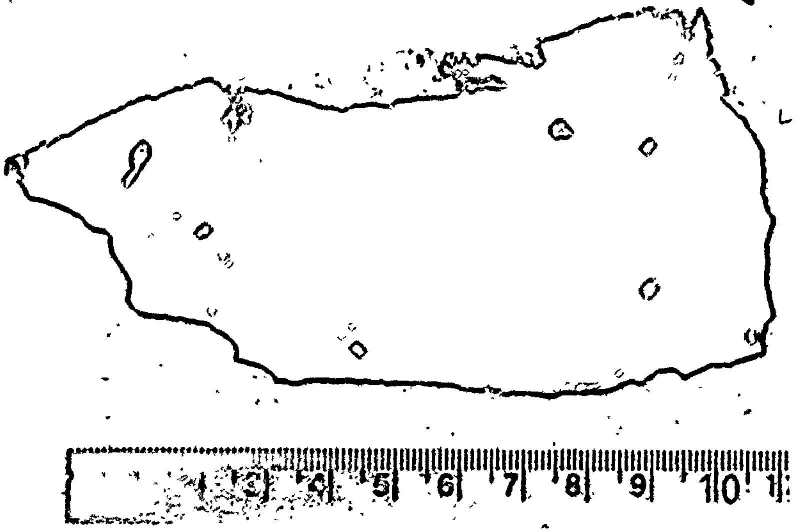
PLATE 4-4. (Sample 17-19, length 12 cm). Highly fragmented komatiitic flowtop.

PLATE 4-5. Photomicrograph of Plate 4-4. Fragments are essentially carbonate-quartz. Matrix is chlorite-quartz-carbonate-opaques. Length of thin section is 4 cm (crossed nicols).



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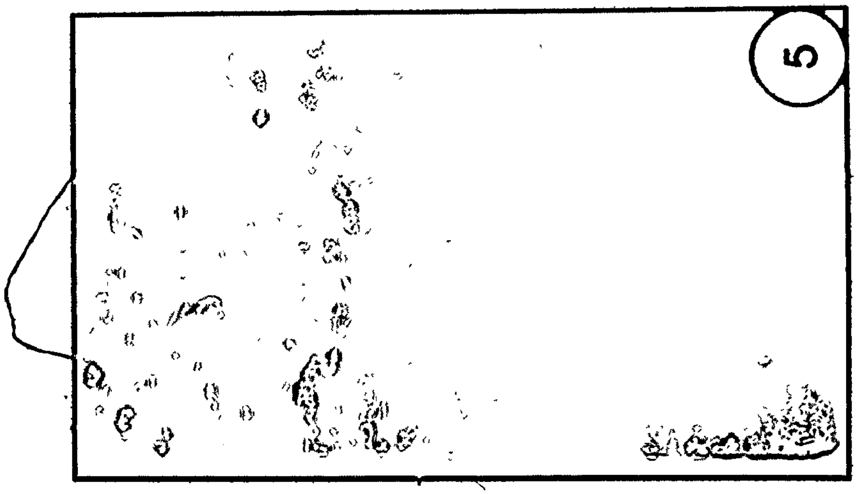

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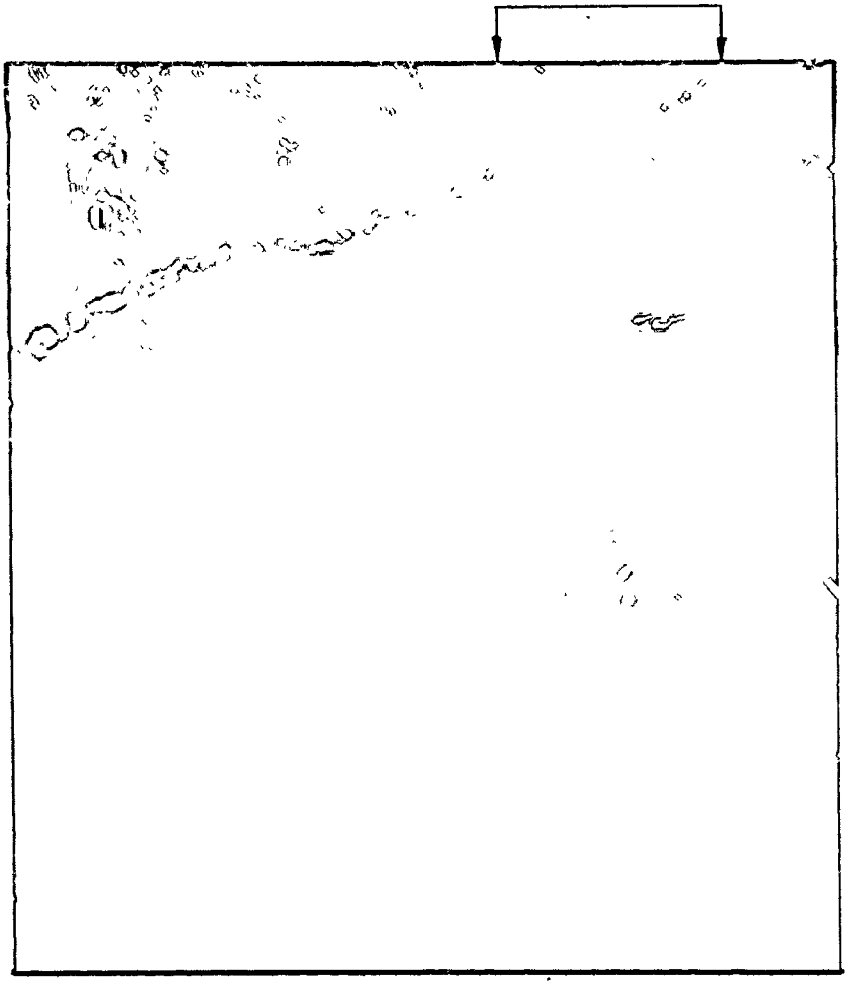

PLATE 4-6. Cr and Ni-rich cherty intercalation (as outlined) near the top of a sheared komatiitic flow. Cherty zone is approximately 30 cm wide. Sample 17-20.

The entire sequence is occasionally cut by post tectonic northwest trending andesitic dykes.

4.1.2 Felsic volcaniclastites

Approximately 6 m of light gray fine to medium grained felsic volcaniclastites occur between the ore zone and the komatiites discussed above.

The matrix is essentially a mosaic of anhedral fine grained quartz. A weak banding is caused by mm to cm size layers of fine grained quartz and andalusite with rare opaques. Micas are a minor constituent and are commonly wrapped around the porphyroblasts.

Clasts occur throughout the matrix as recrystallized subrounded to elongate ovoids of quartz ± andalusite ± chlorite ± biotite ± opaques.

Poikilitic garnets are the dominant porphyroblasts and contain numerous inclusions of quartz and opaques. Although generally subrounded they occasionally exhibit preferential elongate growth. One-half mm size andalusite porphyroblasts with carbonaceous inclusions are also present. Staurolite and amphiboles are rare.

In addition to occuring in fine grained layers, opaques are also observed in mm size recrystallized euhedral rhombs and in aggregates. Pyrite is the dominant opaque with accessory pyrrhotite and magnetite and traces of ilmenite, arsenopyrite and gold. Gold was observed in two samples along pyrite-pyrrhotite grain boundaries.

Veins are rare, slightly discordant and consist of quartz ± andalusite (Plate 4-7). The andalusite occurs as euhedral rhombs up to 1/2 mm in size (Plate 4-8). At the contact with the ore zone carbonate ± opaque veins are common.

South of the ore zone the volcaniclastites consist of dark gray clasts in a light gray matrix. These rocks are massive to well bedded and commonly sheared. They are generally more siliceous and more heavily veined than the volcaniclastites to the north.

The clasts are subparallel, elongate to tabular aggregates consisting of fine grained quartz-biotite ± andalusite ± opaques (Plate 4-9) and garnet-andalusite-quartz ± opaques ± carbonate assemblages. They occur in a very fine grained to fine grained matrix of quartz ± andalusite ± opaques ± micas, with rare anorthite.

Andalusite also occurs as the dominant porphyroblast in the matrix, forming 1/4 to 1/2 mm size euhedral crystals. Staurolite and amphibole are rare.

Concordant to discordant veins commonly consist of quartz and euhedral andalusite rhombs or quartz-biotite-carbonate-opaques. Hematite, limonite and biotite occur along late fractures.

The southernmost 3 m of this crosscut is characterized

PLATE 4-7. Sample 17-16. Discordant quartz-andalusite vein. Field of view is 4 mm (crossed nicols).

PLATE 4-8. Sample 17-16. Euhedral andalusite rhombs in quartz-andalusite vein. Field of view is 1.6 mm (crossed nicols).

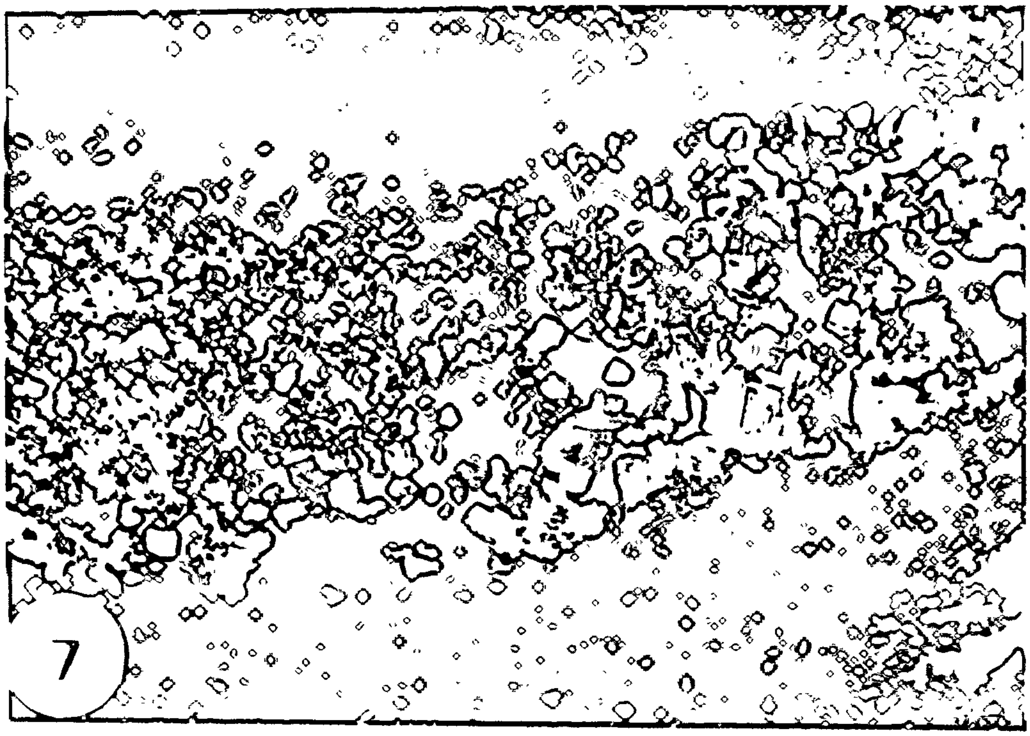

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PLATE 4-9. (Sample 17-03, Length 7 cm). Felsic volcaniclastite. Dark tabular material consists of quartz-biotite± opaques±andalusite. Light colored matrix consists of quartz±andalusite± anorthite±micas±opaques. White reflected material in concordant and discordant veins is opaques.

by numerous cross-cutting veins consisting of carbonate-sulphides-quartz. Pyrrhotite and pyrite are the dominant opaques with trace quantities of chalcopyrite-arsenopyrite-magnetite. A minute gold crystal (20μm) was observed in an aggregate consisting of three of these sulphides (Plates 4-10).

4.1.3 Ore zone

The ore zone is heavily oxidized and occurs within the felsic volcaniclastites. It appears to be stratabound and is less than 3 m wide. The host rock consists of ovoids of medium grained polygonal quartz in a fine grained matrix of quartz, andalusite, garnet, muscovite and opaques. The mica exhibits a pronounced foliation and is commonly wrapped around the ovoids as well as andalusite and garnet porphyroblasts. Relict mafic crystals (2 mm wide) which have been retrogressed to essentially quartz-opaque ± actinolite and rotated garnet-quartz ± opaque pods, are also present.

Pyrite comprises 50% of the opaques and pyrrhotite approximately 35%. There are minor amounts of arsenopyrite and magnetite. Gold and pentlandite occur in trace amounts, with the former occuring along fractures in the pyrite (Plate 4-11) and in the gangue adjacent to it (Plate 4-12). The gold crystals are <5μm in size.

PLATE 4-10. Sample 17-10. Gold (Au) in sulphide aggregate with pyrite (Py), pyrrhotite (Po) and chalcopyrite (Cpy).

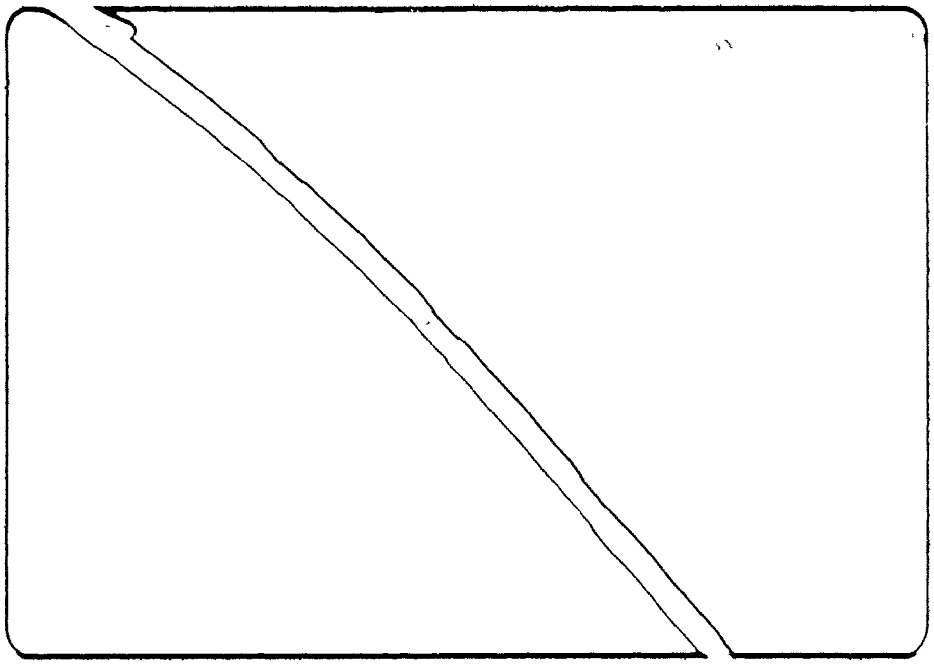
PLATE 4-11. Sample 17-25. Gold along fractures in pyrite. Sample is from the ore zone.

20 µm

PLATE 4-12. Sample 17-25. Gold along pyrite grain boundaries and in gangue.

PLATE 4-13. Displaced mineralized zone (buff brown) at current termination of "E.SC." ore zone. (Scale is in inches).

20 µm



COLOURED PICTURE

4.2 24 Level

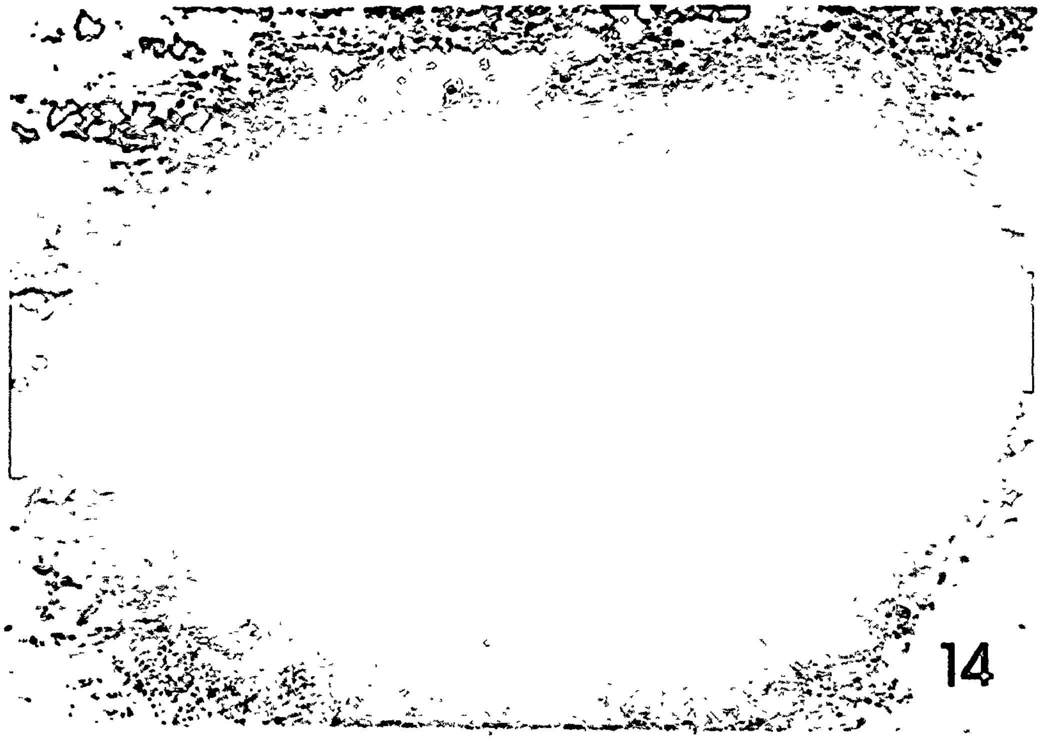
The author examined and obtained several samples from the southeastern end of the northwest trending ore zone on this level (E.SC. - East South C of Dickenson Mines). The mineralized zones are stratabound and discontinuous along strike. Their lateral continuity may be up to 100 m. The ore zones also have a stacked appearence, in that they occur down dip of each other with a parallel trend. At one sampled locality the ore zone is clearly folded with the axial plane parallel to the dominant foliation and the plunge steeply to the northwest. Average width of the ore zones is < 1 m; however, where folded, they may be 2 to 3 m wide. Some of the ore zones are displaced along sub horizontal shears (Plate 4-13). Others exhibit extensional features on both a macro and microscale (Plates 4-14 and 4-15). In the unmineralized portions of the drift slightly elongate, northwest trending pillows are sometimes evident.

The samples from the ore zone are light gray, fine grained and well foliated.

An apparent compositional control on the distribution of sulphides, is evident in both polished and thin sections. Fine grained sulphides occur in 1/4 to 1/2 mm wide bands with plagioclase and andalusite, and they commonly rim the aluminosilicates. These sulphide-rich bands intercalate with 1 to 2 mm wide bands of fine grained quartz-muscovite-carbonate with rare garnets and opaques. Occasionally,

PLATE 4-14. Sample 240-Bl. Boudinaged quartz-carbonate-opaque vein in well foliated sample from the "East South C" ore zone on Level 24. Field of view is 1.6 mm (plain light).

PLATE 4-15. Sample 240-Bl. Carbonate and opaques in the shadow zone with a well developed micaceous shistosity. Field of view is 65 µm (crossed nicols)



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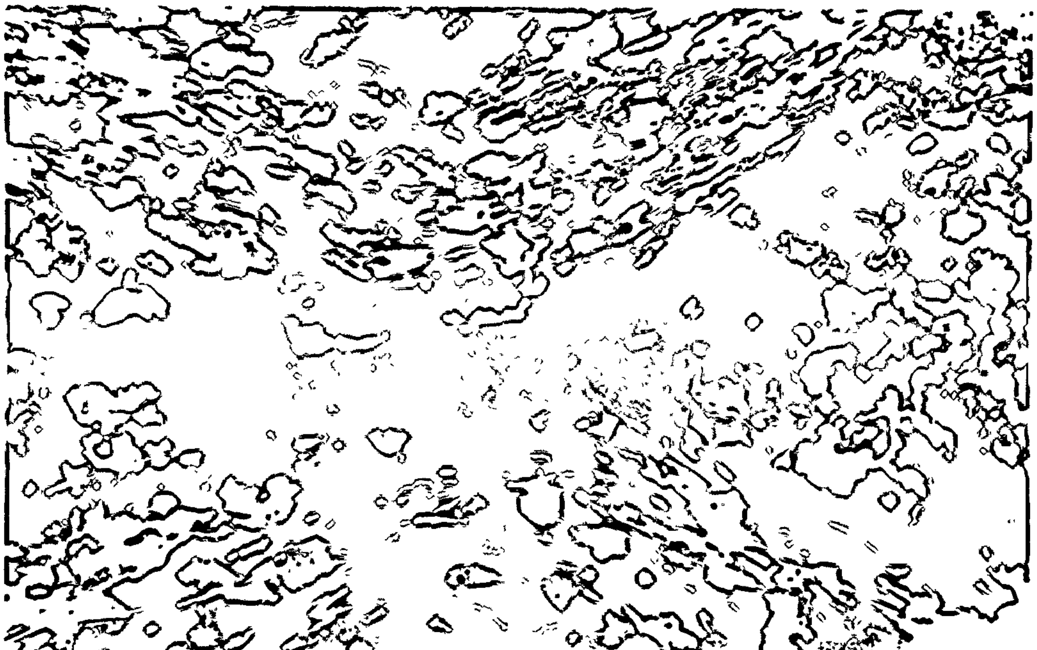

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1/4 mm wide bands of biotite-quartz-sulphides are observed.

A pronounced schistosity is exhibited by the micas which are also wrapped around the few recrystallized quartz ± carbonate ± opaque pods that were observed. Secondary cross-cutting veins are rare and consist of quartz-carbonate-opaque ± biotite ± muscovite.

Opaques constitute up to 10 modal % of the section. The dominant sulphides, pyrite and arsenopyrite occur in distinct bands. Pyrrhotite is a minor accessory and pentlandite is rare. Oxides constitute <3 % of the opaques and consist essentially of magnetite with minor ilmenite.

4.3 25 Level

The geology of the sampled area on 25 level as mapped by the author is presented in Map 2. The main east drift (25-274) is characterized by altered, slightly elongate, pillowed mafic volcanics (magnesium-rich tholeiites) and pillow breccia trending approximately 300°. As the sampled ore body is approached along 25-598 N.XC. primary features are obliterated by younger dykes, northwest trending shear zones and 10 to 15 % secondary quartz ± carbonate veining.

An abrupt and distinct lithologic break is present along this crosscut 95 m northeast of its intersection with 25-274 E.Dr., at sample location 25-03. Here cherty tuffs are intercalated with volcaniclastic komatiites (Plates 4-16, 4-17 and 4-18). The volcaniclastites are well bedded with conformable contacts and range in width from 20 cm to 3 m. The cherts occur as cm wide slivers within the komatiites and as distinct 10 cm to 1 m thick units. This sequence which repeats over a distance of 20 m is mapped on mine plans as "chickenfeed" and diorite.

Northeast of this sequence is a 55 m wide zone consisting of a mixture of volcaniclastites and chemical sediments, with minor mafic volcanics. This zone is very distinctive in that there are little or no secondary quartz-carbonate veins. The ore is finely disseminated and found in stacked, stratabound sulphide rich units, up to 50 m long and 2 m wide.

4.3.1 Magnesium-rich Tholeiites

The magnesium-rich tholeiites in the first 95 m of 25-598 N.XC. are very fine grained black rocks with minor concordant to slightly discordant quartz-carbonate veining. They consist of an aphanitic matrix of quartz, anorthite, biotite, chlorite and opaques. Sheaf-like actinolite occurs in small aggregates and along late fractures. Vesicles are commonly infilled with talc, acicular amphibole and accessory quartz, chlorite and opaques. Quartz also occurs as 1/2 mm discrete crystals throughout the matrix. Garnets are rare and the dominant opaques are pyrrhotite and pyrite.

PLATE 4-16. Intercalated well bedded komatiitic volcaniclastites and cherty tuffs. The entire section was designated "chickenfeed" (mine terminology).

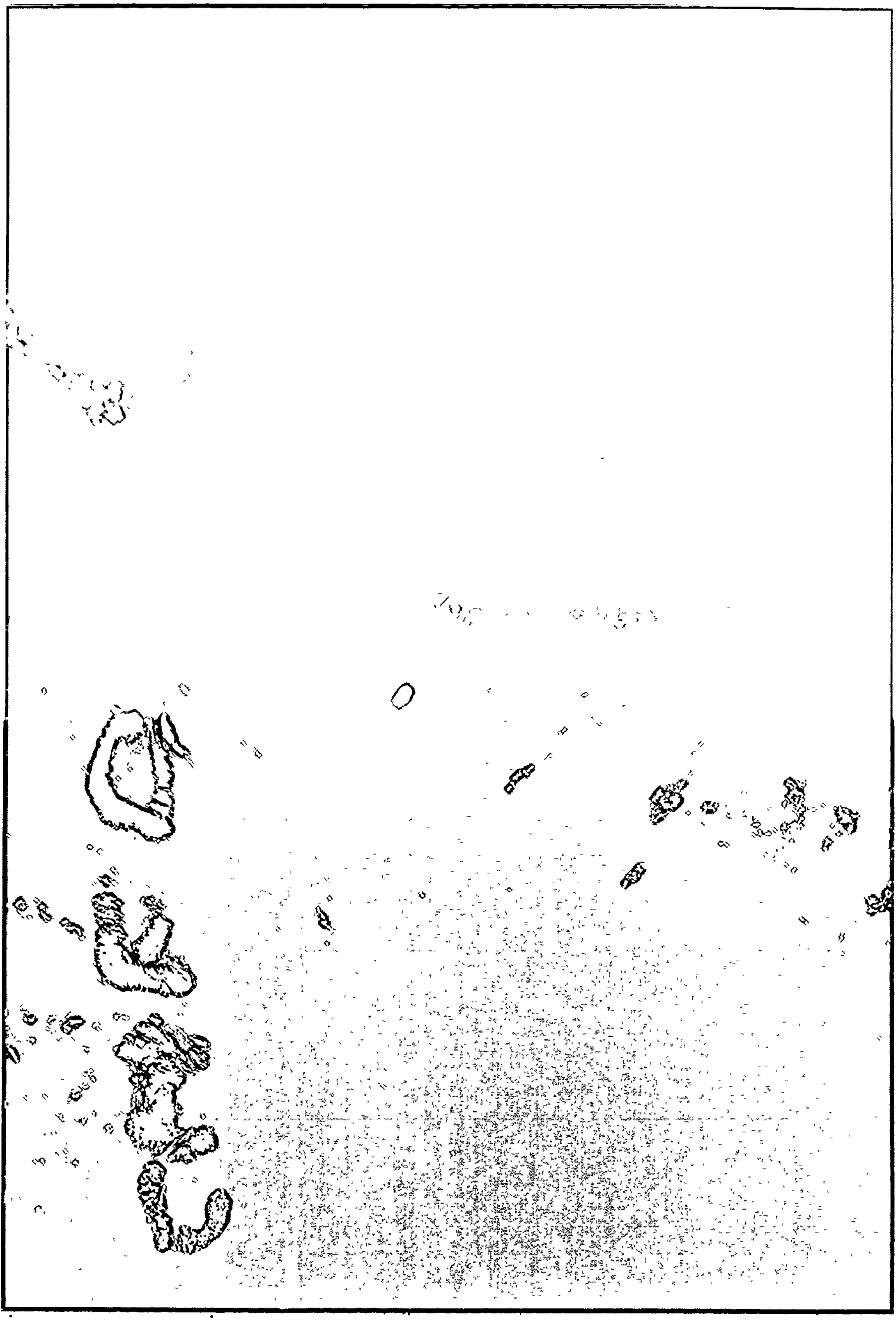
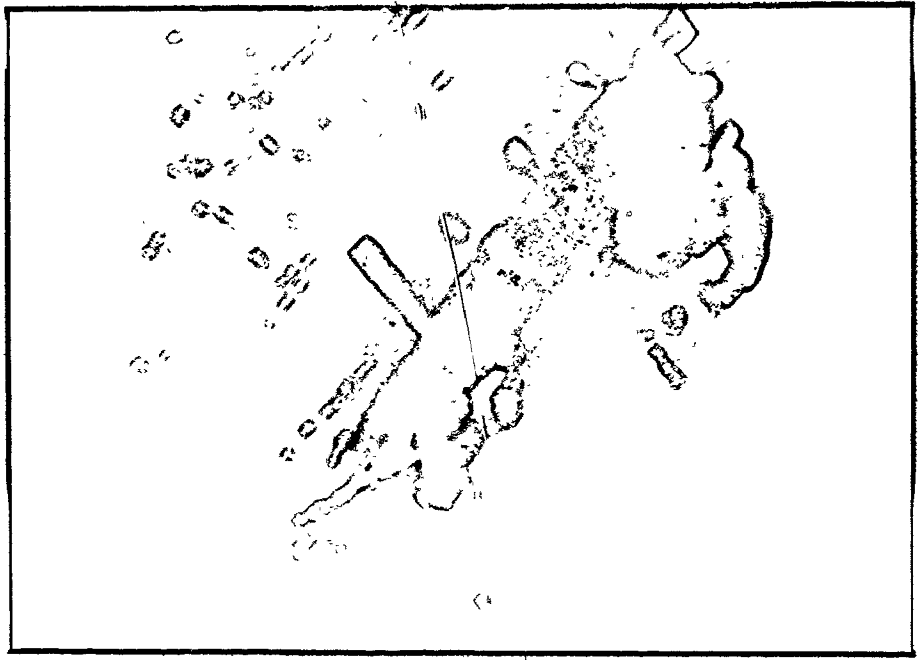


PLATE 4-17. Blurred colour shot of Plate 4-16 (sample location 25-03). Cherty tuffs are buff brown.

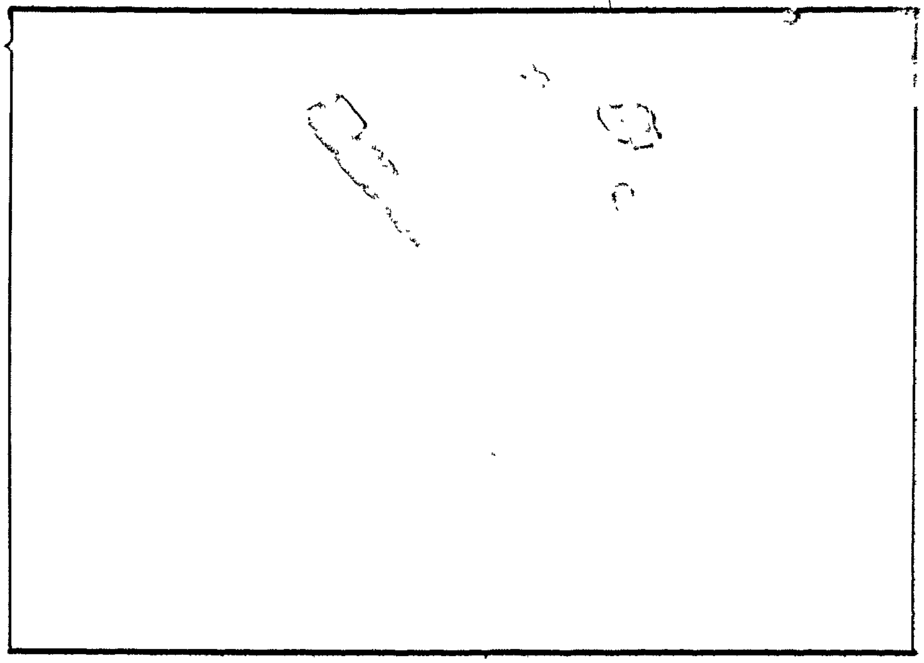
Sample units indicated above.

PLATE 4-18. Sample location 25-03. Narrow carbonatized komatiitic volcaniclastite (25-03B), intercalated with cherty tuffs.

25-03D



80-17



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Veins hosted by these tholeiites, consist of carbonate-amphibole-talc ± quartz. Amphibole and carbonate occur in the wider portions of the vein with aggregates of fibrous talc where it terminates.

4.3.2 Komatiitic Volcaniclastites

The komatiitic volcaniclastites range in composition from ultramafic to basaltic. They are light gray, well bedded and marked by the presence of intercalated cherty tuffs. The more chloritic samples exhibit a greenish tinge.

The ultramafic komatiites are essentially carbonate rocks with lesser amounts of talc, serpentine, quartz, amphiboles and rock fragments. Bedding contacts are distinct (Plates 4-19 and 4-20).

Fine grained dolomite with minor ankerite is the dominant matrix constituent. Carbonates also occur in 2 to 5 mm rectangular to subrounded pods and ovoids (± serpentine) and as discrete 1 to 3 mm subangular crystals within the matrix (Plate 4-21).

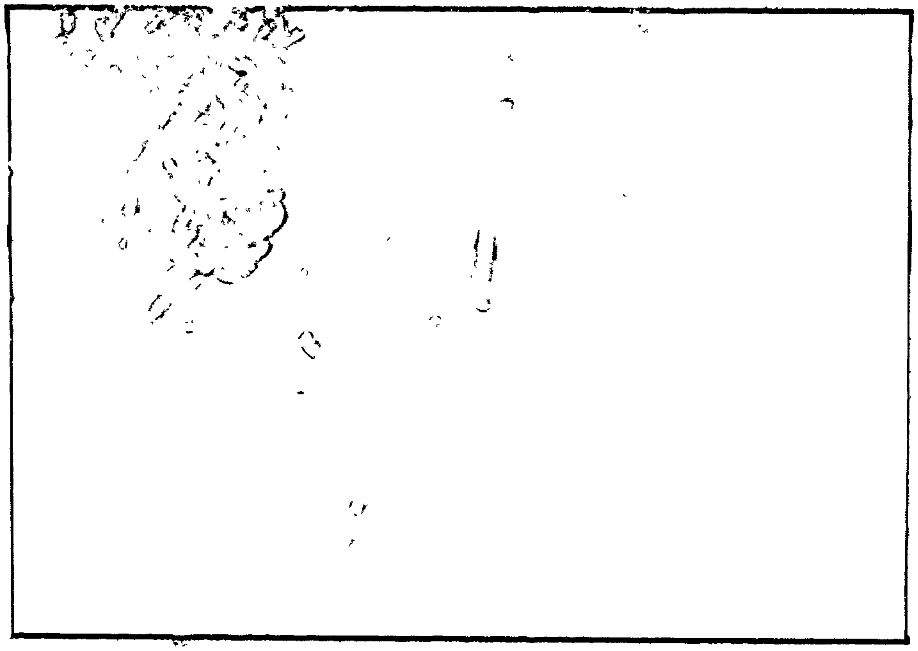
Quartz is rare and occasionally occurs in recrystallized ovoids. Talc, often with serpentine, commonly occurs as a fibrous aggregate in 1 to 4 mm subrounded to elliptical fragments (Plate 4-22). Chlorite is a minor constituent and commonly rims the fragments and ovoids. Occasionally it is associated with the talc or opaques.

Opaques are rare and occur disseminated throughout

PLATE 4-19. Note distinct contact between two komatiitic units. Cherty tuffs are evident in the bottom right of the photo. See also Plates 4-16 and 4-17.

PLATE 4-20. Close-up of erosional contact between two komatiitic units (Samples 25-03D and 25-03C).

25-03D 25-03C



25-03D 25-03C

the matrix or in minute bands with biotite ± chlorite. They consist of pyrrhotite, magnetite, chromite and rarely leucoxene.

Discordant veins of either carbonate-quartz or carbonate-talc are rare but when present they commonly terminate in talc. Numerous concordant 1 mm wide carbonate bands exemplify the foliation which here is clearly parallel to bedding (Plate 4-23).

The basaltic komatiites are similar mineralogically except that they contain more quartz. The quartz occurs as 2 to 10 mm long recrystallized ovoids and in the matrix is associated with minor anorthite. The mineralogy along bedding contacts is commonly serpentine-talc-amphibole and minor opaques (Plate 4-24).

4.3.3 Cherty Tuffs

The cherty tuffs are buff brown and contain numerous mm size mafic fragments (Plate 4-25). These units range in width from 1-2 cm to 1 m, are generally well bedded and intercalate with the komatiitic volcaniclastites. They are also clast-supported in that only about 30 % of the rock is matrix. The clasts are polymictic slightly elongate and average 1 mm in size. They range in composition from mafic fragments consisting of biotite-andalusite-quartz-opaques ± anorthite to recrystallized ovoids of fine grained mosaic quartz (Plate 4-26). Also present are

PLATE 4-21. (Sample 25-03B, length 9.5 cm). Slabbed section of Plate 4-23. Light gray irregular shaped fragments consist of either fine grained carbonate or talc-serpentine or recrystallized quartz.

PLATE 4-22. Sample 25-03B. Talc-serpentine aggregate in a carbonate matrix. Field of view is 1.6 mm (crossed nicols).

PLATE 4-23. (Sample 25-03B, length 9.5 cm). Komatiitic volcaniclastite. "Chickenfeed" (mine terminology). Light bands are carbonate and generally 1 mm wide.

PLATE 4-24. Bedding contact (arrow) between samples 25-01A and 25-01B (length 11.5 cm). Basaltic komatiitic volcaniclastites. "Diorites" (mine terminology). Mineralogy along contact consists of serpentine-talc-amphibole and minor opaques.

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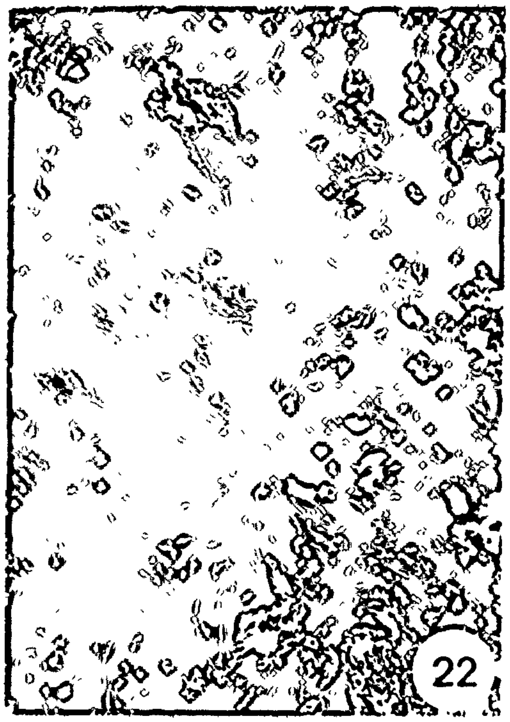

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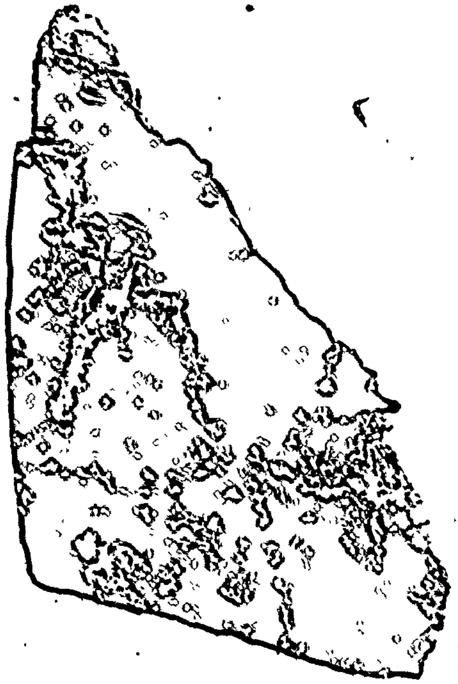

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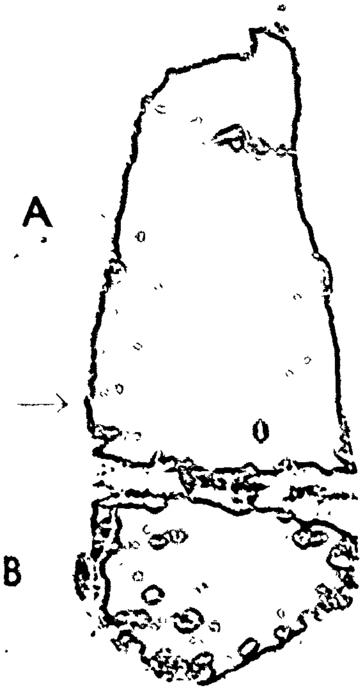

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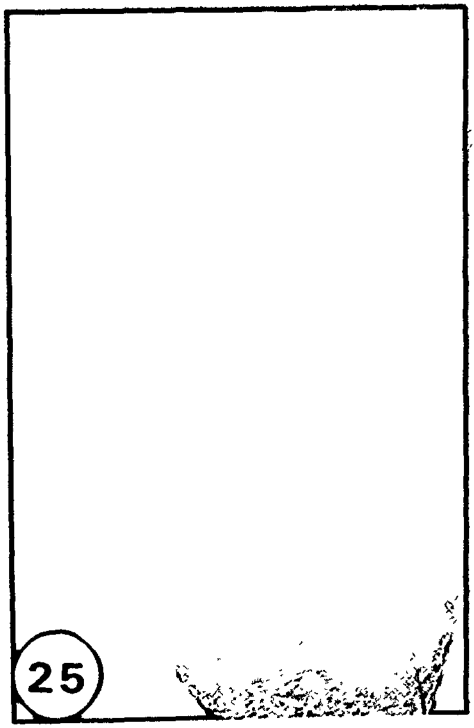
PLATE 4-25. Photomicrograph of sample 25-03A. Cherty tuff. Note the mafic fragments (grayish) and the opaque bands (black). Length of thin section is 4 cm (crossed nicols).

PLATE 4-26. Sample 25-03B. Mafic and siliceous fragments in a fine grained matrix. Note also, siliceous clast in opaque band. Field of view is 4 mm (plain light).

PLATE 4-27. Sample 25-03B. Siliceous clast in an opaque band. Note how the opaque laminations attenuate at the clast boundary and do not truncate it. Field of view is 1.6 mm (plain light).



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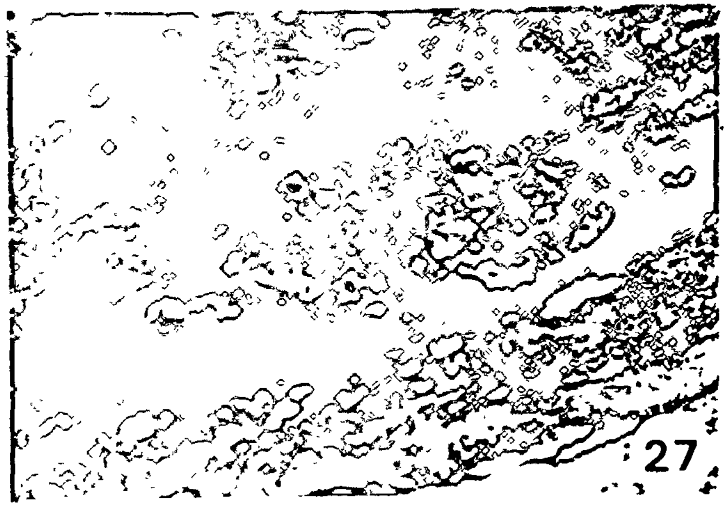

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minute (1/10 to 1/2 mm) subangular felsic pods of one to six crystals.

The matrix consists of polycrystalline quartz with minor andalusite and biotite and traces of anorthite. Opaques occur disseminated throughout the matrix but more commonly in 1/2 to 1 mm wide continuous bands. They have a distinct sedimentary aspect. Siliceous clasts within these bands are enclosed by the opaques and exhibit pseudo-load festures. Plate 4-27 is a good example of how the opaque laminations attenuate at the clast boundary and do not truncate it. Pyrrhotite is the dominant opaque in these bands with minor pyrite and chromite.

Fractures are rare but when present they clearly truncate the mafic fragments. Opaques within them are pyrrhotite and magnetite with traces of leucoxene.

4.3.4 Felsic Volcaniclastites

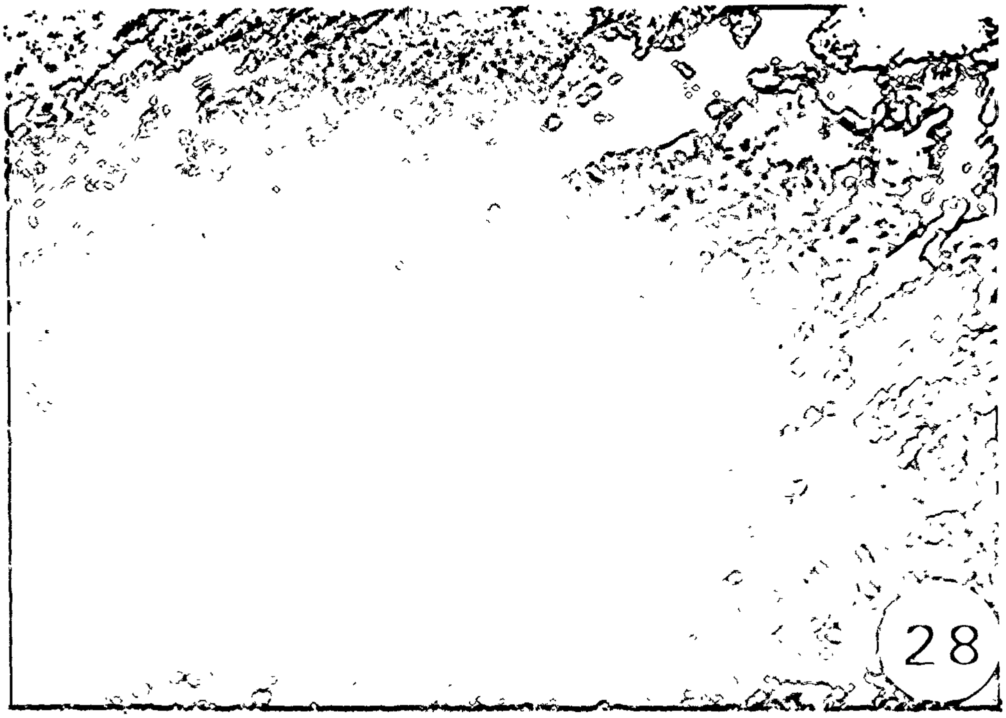
These rocks are a light gray in colour and are characterized by low gold values (<30 ppb), compositional banding and numerous quartz fragments up to 2 cm in length.

The matrix is a recrystallized mosaic of cryptocrystalline quartz with minor andalusite. Recrystallized siliceous fragments are common throughout (Plate 4-28).

They range in size from 5 mm to 2 cm, are slightly flattened, have irregular subangular to subrounded boundaries, and are commonly rimmed by disseminated sulphides with

PLATE 4-28. Sample 25-05. Recrystallized siliceous fragments outlined by opaques. Field of view is 4 mm (plain light).

PLATE 4-29. Sample 25-05. Felsic fragments within poorly banded opaques. Field of view is 1.6 mm (plain light).



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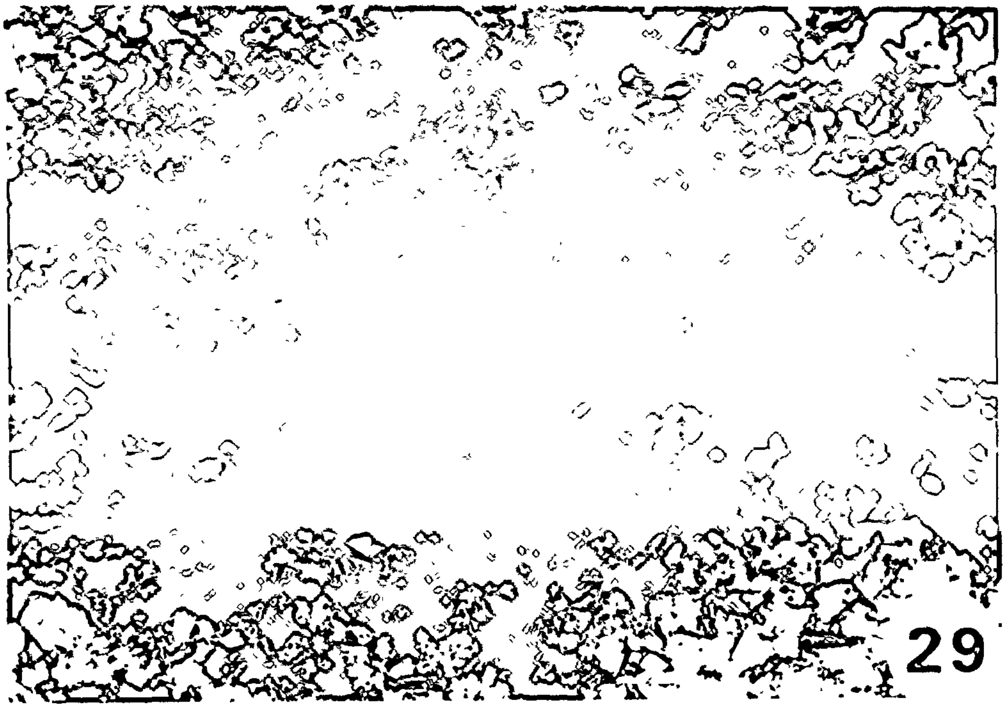

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traces of chlorite.

Mafic minerals, essentially chlorite and biotite comprise up to 30 % of the mineralogy. Chlorite occurs in wavy sheaf-like aggregates and as an alteration product along rare quartz-sulphide infilled fractures. Biotite occurs as short tabular to prismatic crystals. Muscovite and sericite are rare as is amphibole which is commonly altered to talc.

The dominant aluminosilicate is andalusite which occurs as both columnar aggregates and as individual tabular crystals. Occasionally, it exhibits preferential growth in that it is confined to specific compositional bands. Rare staurolite porphyroblasts with numerous quartz inclusions are present. Subrounded poikiloblastic garnets comprise <1 % of the section and are commonly riddled with inclusions of quartz, opaques and occasionally chlorite.

Opaques constitute <5 modal % of the section. Pyrrhotite dominates with lesser amounts of magnetite and trace amounts of pyrite, arsenopyrite, chalcopyrite and leucoxene. The opaques occur disseminated throughout the matrix and as discrete, euhedral, minute crystals in continuous bands parallel to bedding (Plate 4-29).

Veins are rare and generally occur as short, thin localized sweats. One discordant vein containing tremolite-talc-quartz-opaques was observed.

4.3.5 Non-auriferous Sediments

These rocks are highly anomalous in a geochemical sense in regard to their gold content (between 100 and 300 ppb), but are distictly subeconomic. They are gray, fine grained and finely laminated (Plate 4-30), with some compositional banding.

The matrix is a very fine grained mosaic of quartz with minor andalusite. The mafic minerals which are fan shaped to prismatic penninite and biotite rarely exceed 15 % and are aligned parallel to foliation, which is parallel bedding. Muscovite and sericite are rare.

Polygonized quartz ovoids are common. They are 1 to 3 mm in size and relict grain boundaries are clearly visible under plain light. Quartz also occurs as 5 to 10 mm size crystals exhibiting undulatory extinction.

Garnet is the dominant porphyroblast and is usually subrounded and up to 5 mm in diameter. It commonly contains inclusions of quartz, pyrrhotite, magnetite and only rarely chlorite and amphibole. Plate 4-31 is an excellent example of a garnet incorporating gold-bearing opaques during growth. Octahedral staurolite and columnar andalusite (Plate 4-32) also occur as porphyroblasts. They comprise < 3 % of the section and rarely exceed 1/2 mm in diameter or length. Andalusite also occurs in fine grained aggregates (Plate 4-33).

Opaques never exceed 10 modal %. The sulphide/

PLATE 4-30. Photomicrograph of sample 25-12. Note well developed foliation and finely laminated opaques. Thin section is 4 cm long (crossed nicols).

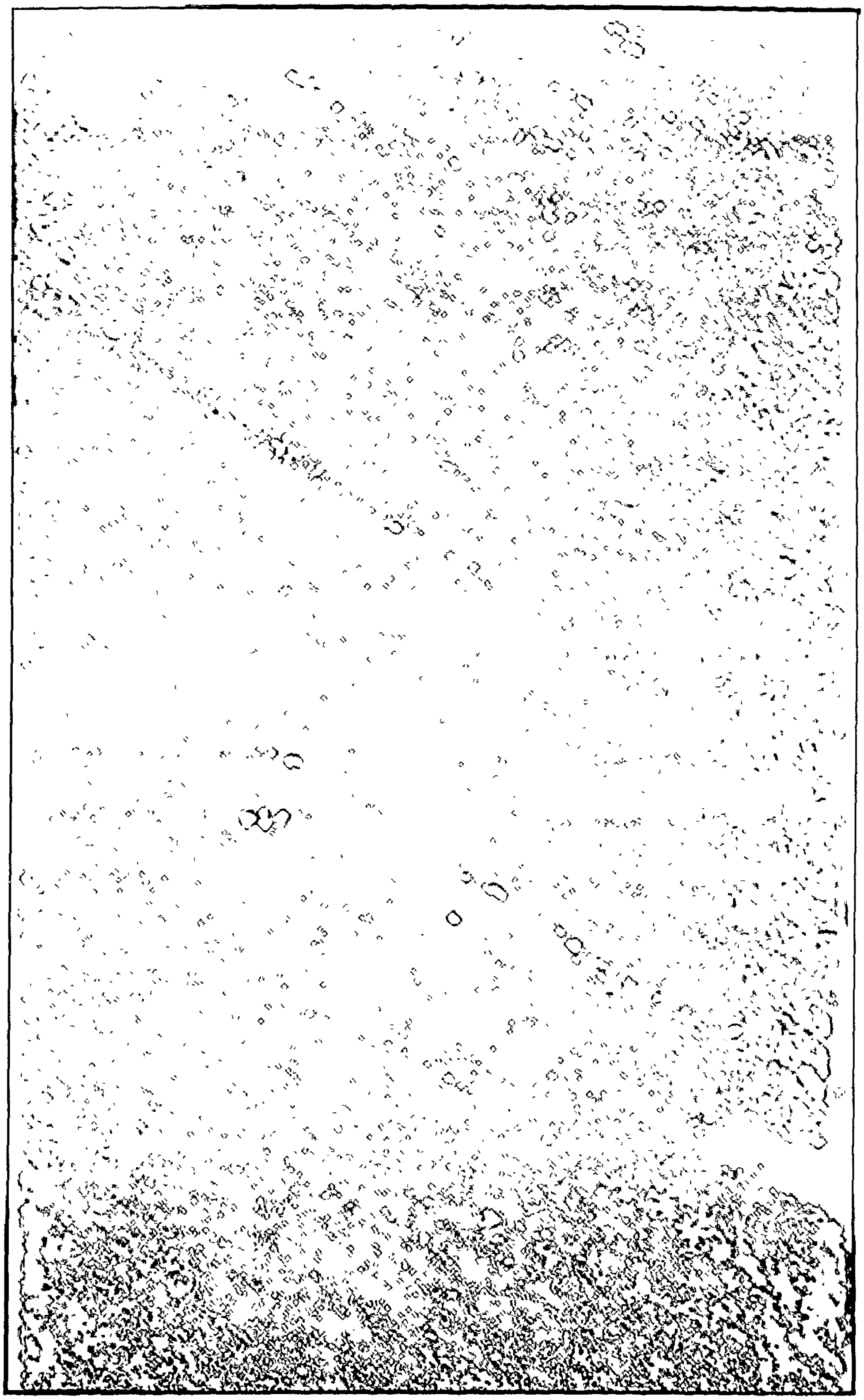

PLATE 4-31. Poikiloblastic garnet with an opaque rim and quartz core. Note the well developed inclusion trains of gold-bearing opaques. Field of view is 4 mm (Sample 25-13; plain light).

PLATE 4-32. Sample 25-13. Euhedral columnar andalusite in non-auriferous sediment. Field of view is 65 µm (plain light).

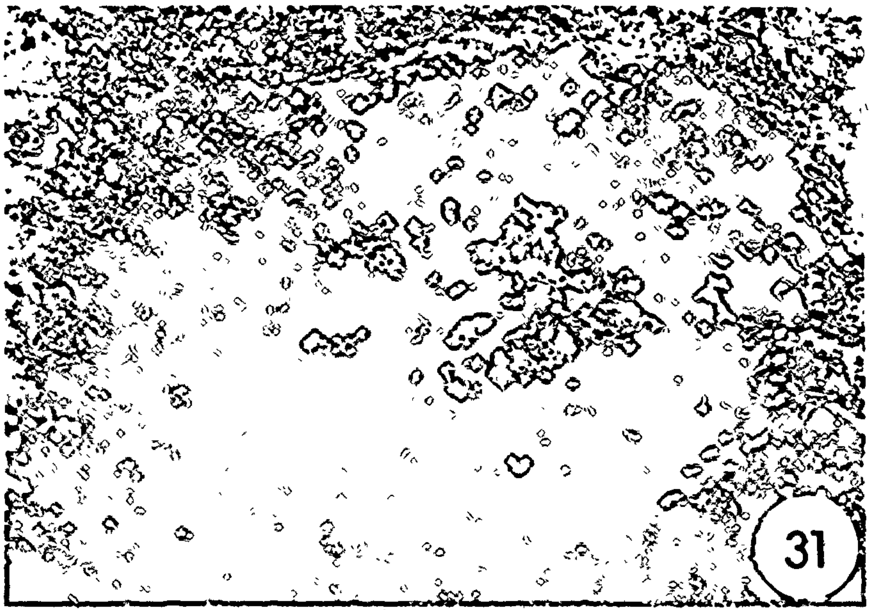

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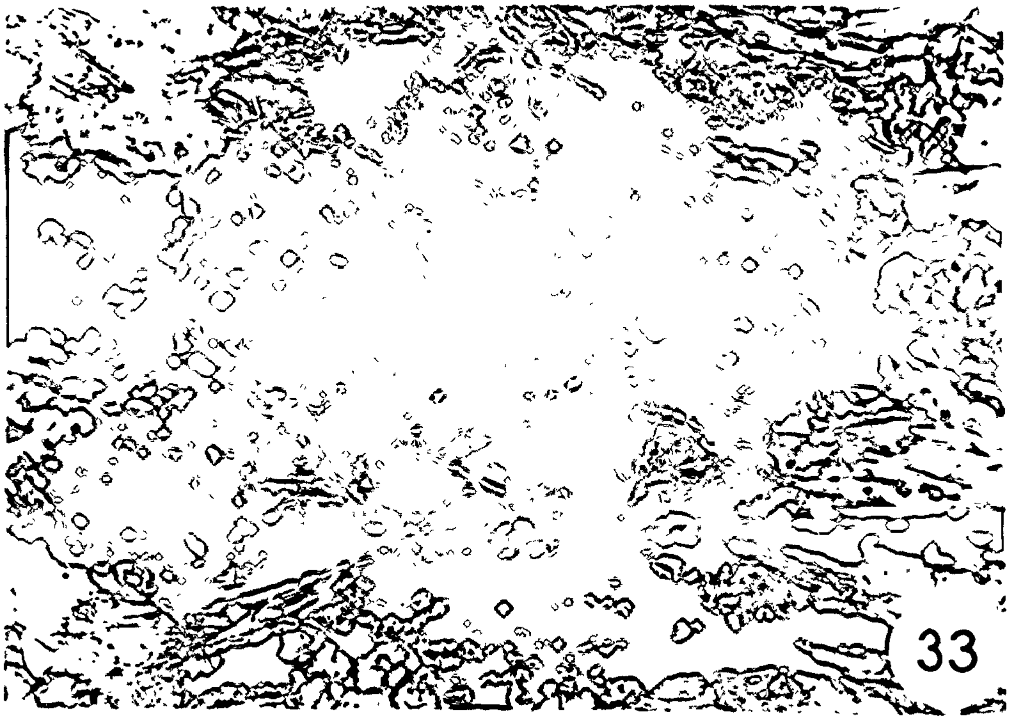
PLATE 4-33. Sample 25-13. Andalusite aggregates (high relief) in non-auriferous sediment. Field of view is 65 µm (plain light).

PLATE 4-34. Sample 25-09. Opaque infilled fracture in almandine. Field of view is 1.6 mm (plain light).



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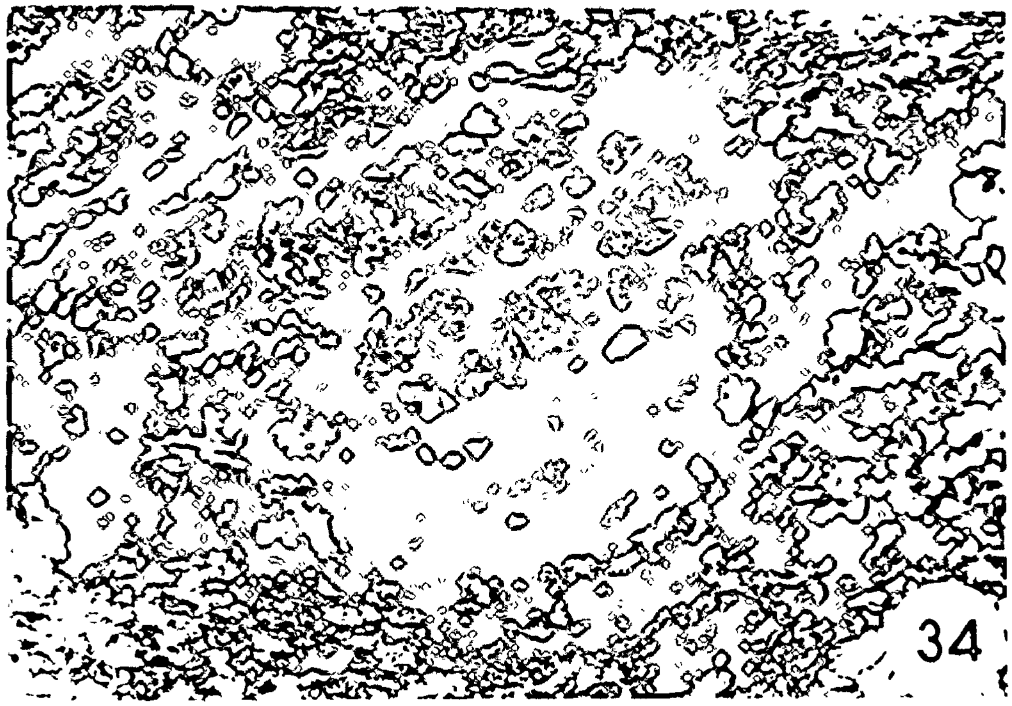

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oxide ratio is about 55/45. Pyrrhotite dominates with minute rhombs of arsenopyrite (<1/20 mm) as the common accessory. Pyrite and chalcopyrite occur in trace amounts as does gold, which was observed along pyrrhotite and pyrrhotite-magnetite grain boundaries. Magnetite is the dominant oxide with lesser amounts of ilmenite. Hematite is rare and was only observed along fractures. Sphene and leucoxene are present in trace amounts.

Veins are rare, but when present they consist of polygonized quartz with minor opaques. They are essentially local metamorphic sweats.

4.3.6 Auriferous Sediments

The auriferous sediments (>1.0 ppm gold) are fine grained, laminated and a light buff brown. Bedding and foliation are parallel and accentuated by some compositional banding and mm thick opaque layers.

The matrix is a very fine grained anhedral mosaic of quartz with minor andalusite. Quartz also occurs in mm to cm size, rounded to ovoidal, polygonized aggregates.

The mafic minerals which never exceed 25 % are dominated by tabular crystals of biotite and commonly occur in thin bands. Tabular to fan shaped penninite is a common accessory. Amphiboles and sericite are rare.

Almandine is the dominant porphyroblast and is pervaded with numerous inclusions of quartz, pyrrhotite and magnetite. Occasionally, it is associated with biotite ± amphibole ± carbonate ± staurolite. The garnets vary in size and comprise 1-2 % of the rock. They have irregular boundaries and are commonly subrounded to slightly elongated 1 1/2 x 2 mm crystals. Rarely do they exceed 4 mm in diameter, although in one instance they seemed to exhibit preferential growth in an elongate fashion reaching 7 mm in length. Occasionally the garnets contain opaques in fractures which do not extend beyond grain boundaries (Plate 4-34). Andalusite porphyroblasts are uncommon but occur as mm wide rectangular to subrounded crystals.

Opaques constitute up to 30 % of the rock. The sulphide/oxide ratio is about 50/50. Pyrrhotite is the dominant sulphide with accessory rhombs of very fine grained arsenopyrite and pyrite (10 to 20μm), and traces of pentlandite. The sulphides occur disseminated throughout the matrix and in distinct bands. Magnetite is the dominant oxide and is occasionally rimmed by ilmenite.

Small kink bands at 45° to the principal foliation, were occasionally observed and accentuated by opaque and biotite bands.

Secondary veins are rare and consist of recrystallized quartz with accessory biotite-carbonate ± andalusite. They were developed in situ and clearly post date the garnet growth.

4.3.7 Dykes

Several dykes with similar field characteristics were observed cross-cutting the various lithologies. The only one sampled was a 2 1/2 m wide, black tholeiitic basaltic dyke that truncates the auriferous sediments at the back of 25-1298 E.Dr. It is a massive, medium grained, equigranular rock and contains 80 % mafic minerals. Hornblende is the dominant amphibole with minor amounts of actinolite. Chlorite occurs as an alteration product. These crystals are dominantly columnar and rarely acicular. Plagioclase is the felsic mineral and is commonly saussauritized. Carbonate and sericite are common accessories.

Opaques are rare. They occur disseminated throughout the matrix as pyrrhotite and along minute fractures as hematite and leucoxene.

4.4 30 Level

The geology of the sampled area on the 30 Level as mapped by the author is presented in Map 4. Mafic flows occur as the dominant rock type, with lesser amounts of felsic volcaniclastites, mafic sediments and post tectonic intrusives. The ore zones observed occur within felsic horizons, enclosed by pillowed, mafic flows.

4.4.1 Mafic Flows

4.4.1.1 Introduction

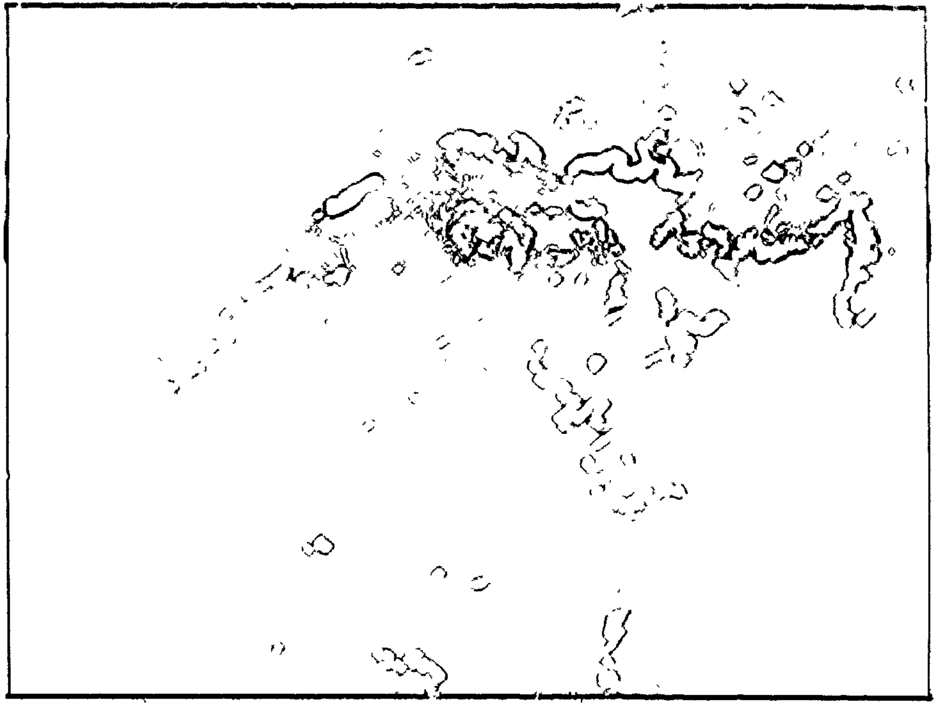
The mafic flows are well foliated, fine to medium grained, black, occasionally pillowed and rarely amygdaloidal. Some flows are capped by flowtop breccia or are in contact with felsic volcaniclastites.

The flows are cut by at least three periods of carbonate ± quartz veining, tectonic breccias, small shear zones, sulphide-bearing joints and fractures, and younger dykes. In both crosscuts, particularly the northern one, there is up to 30% (locally 40%) secondary concordant to discordant carbonate-quartz veining (Plates 4-35 and 4-36), making it difficult to delineate lithologic contacts. Extensional features and quartz sweats, often leading to the formation of pseudo-amygdules, are common.

Pillows are slightly elongate parallel to foliation with a length/width ratio of approximately 3 to 1. Their length varies from about 20 cm to 1 1/2 m. Selvages commonly

PLATE 4-35. Carbonate-quartz veining in mafic volcanics. North crosscut, 30 Level.

PLATE 4-36. Carbonate veining in mafic volcanics. South crosscut, 30 Level.



consist of chlorite and garnets (Plate 4-37). In one instance amygdules were observed just inside the pillow rim, slightly elongated parallel to foliation. Also, totally felsic pillows with mafic selvages were observed occasionally.

Amygdules are generally slightly flattened parallel to foliation and occur in distinct bands. Minerallogically they consist of quartz-calcite ±chlorite ± amphibole ± talc ± opaques.

Narrow shear zones (4 to 8 cm wide) parallel foliation and result in the flattening of the enclosing lithology (Plate 4-38). A good cataclastic texture is evident and in one example the zone was auriferous. Wider silicified shear zones are rare. Plate 4-39 shows an example of one which is 30 cm wide. Their trend is parallel to the strike of the foliation, but they dip at low angles to it (15-20°).

Flowtop breccia consists of fragmented mafic material in a stratabound carbonate and quartz matrix. It is also common to observe distinct narrow tectonic breccia zones (10 to 20 cm wide) at small angles to the foliation. Mafic fragments consisting of biotite-anorthite-talc and relict amphibole are rotated about in a matrix of carbonate (dolomite and siderite), talc and serpentine (Plate 4-40). Opaques occur in the fragments and matrix, and are dominantly pyrrhotite. In an auriferous sample, gold was observed as an inclusion in pyrrhotite. Hematite was observed along minute shears within these zones.

PLATE 4-37. Pillows "on the back" in mafic volcanics. Selvage consists of chlorite±garnet. South crosscut 30 Level.

PLATE 4-38. (Sample 30-19, Length 9.5 cm). Strongly sheared auriferous magnesium tholeiite. North crosscut.

PLATE 4-39. Silicified shear zone at low angles to the dip of the foliation which is indicated by numerous carbonate-quartz veins. North crosscut, 30 Level.

PLATE 4-40. (Sample 30-14, Length 9.5 cm). Carbonate breccia. Wall-rock fragments in dolomite±siderite matrix.

4.4.1.2 Mineralogy

The mafic flows are characterized by a matrix of fine grained quartz, plagioclase (dominantly anorthite), biotite and disseminated opaques with minor carbonate and chlorite. The dominant mafic minerals are colorful fibrous amphiboles, including tremolite-actinolite with lesser hornblende and talc. Minute crystal aggregates of andalusite and poikilitic garnets are rare. Opaque minerals constitute < 1% of the rock and consist of pyrite and pyrrhotite with minor amounts of chalcopyrite, arsenopyrite and magnetite.

Concordant to discordant veins are common and exhibit a wide mineralogical range. Generally they consist of talc-carbonate-opaques±tremolite±actinolite±serpentine±plagioclase. Veins consisting of sutured quartz±plagioclase±carbonate±opaques are rare as are recrystallized quartz pods. Late fractures are commonly infilled with hematite.

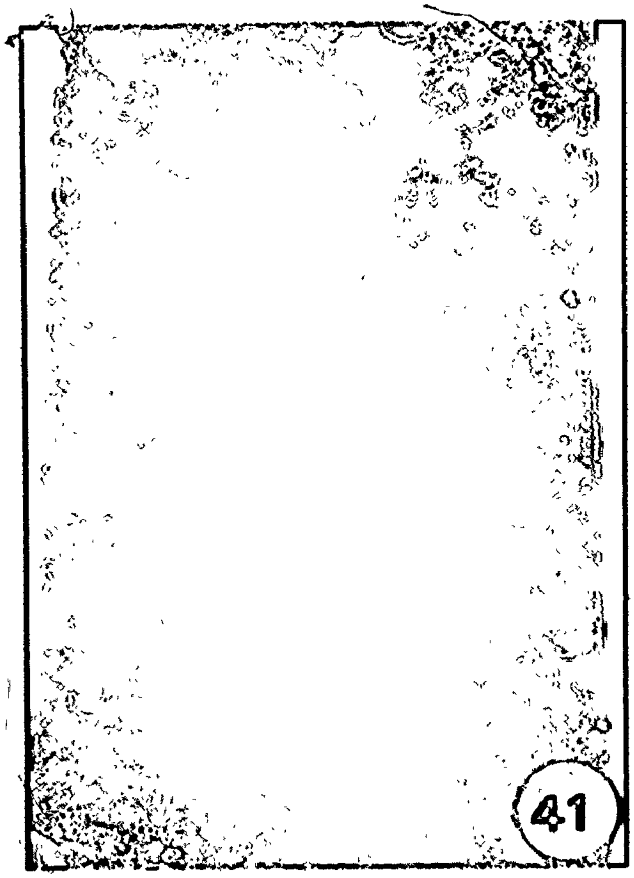
Drill core of a 50 m wide "chickenfeed" unit was examined. The unit comes within 4 m of the north crosscut, is capped by a flowtop breccia and consists of essentially skeletal olivine crystals, now completely altered to talc in a serpentine matrix (Plates 4-41 and 4-42).

4.4.2 Felsic Volcaniclastites

The felsic volcaniclastites occur as distinct fine to medium grained, yellowish buff brown units, ranging in thickness from 7 cm to 2 m. They are most common in the south crosscut,

PLATE 4-41. Photomicrograph of sample DC-01. Note the relict olivine crystals in a serpentine matrix. Length of thin section is 4 cm (crossed nicols).

PLATE 4-42. Sample DC-01. Relict olivine is now totally altered to talc. Field of view is 1.6 mm (crossed nicols).



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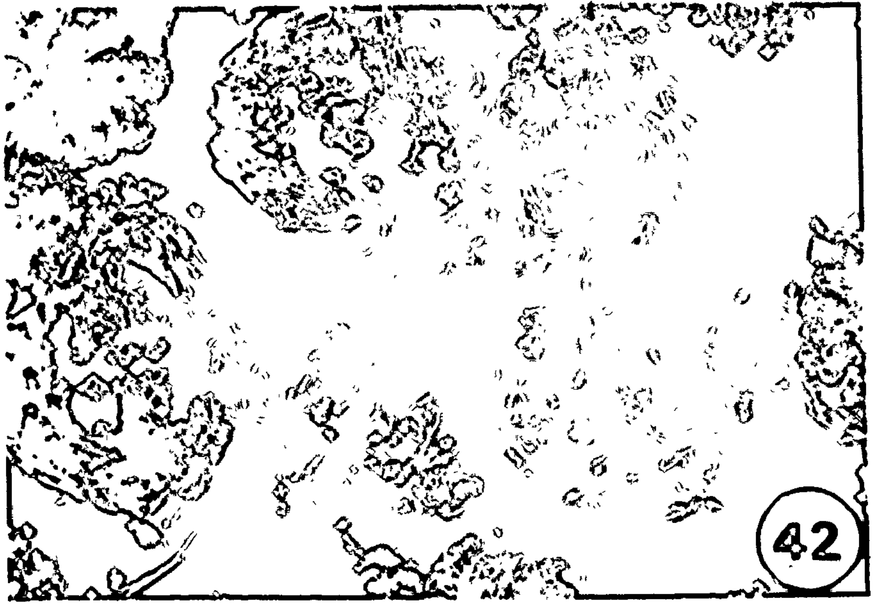

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particularly at its southern extremity, where they intercalate with iron-rich sediments. In the first 100 m of this crosscut they occur occasionally as thin conformable beds, intercalated with massive and pillowed magnesium tholeiitic flows (Plate 4-43).

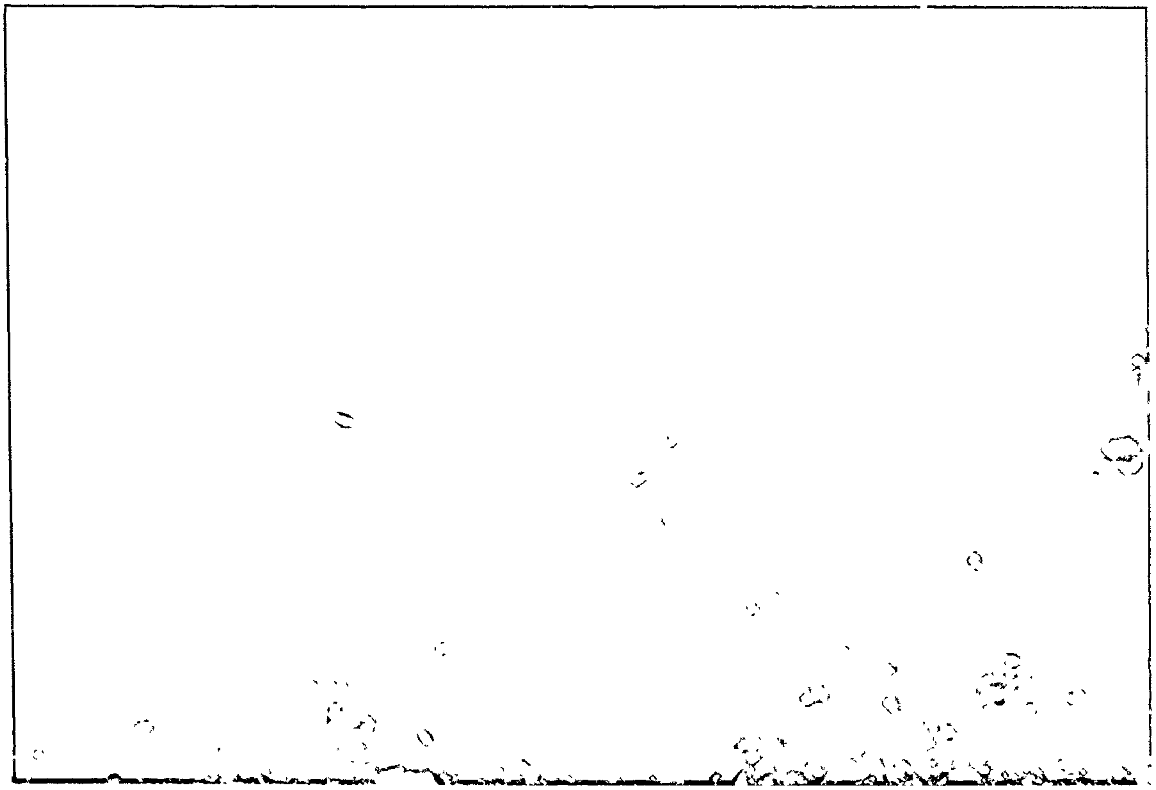
Texturally these rocks are massive to well foliated with mm to cm wide compositional bands (Plate 4-44). Two samples from units intercalated with the mafic flows are analogous to the cherty tuffs on the 25 Level, in that well defined recrystallized ovoids of quartz ± andalusite ± carbonate ± mica are commonly rimmed by opaques, and lie within a fine to to medium grained matrix of quartz-andalusite and traces of anorthite (Plate 4-45). Also within the matrix are minute bands of opaques, including chromite.

For the most part these volcaniclastites consist of a fine to medium grained matrix of quartz and andalusite, with accessory muscovite and traces of biotite, chlorite, anorthite and opaques. The opaques (pyrrhotite and pyrite) also occur in minute bands along with medium grained quartz and andalusite. Further compositional control on mineralogy is evident by the occurrence of poikilitic garnets and porphyroblastic andalusite in individual distinct bands. Relict quartz ovoids are poorly defined, and chlorite-andalusite aggregates were occasionally observed.

Distinct cross-cutting veins are rare and consist of quartz-garnet ± chlorite ± carbonate. Also present are

PLATE 4-43. Felsic volcaniclastites intercalated with mafic flows. South crosscut, 30 Level.

PLATE 4-44. Well developed compositional banding in felsic volcaniclastite. Black pen top is scale.



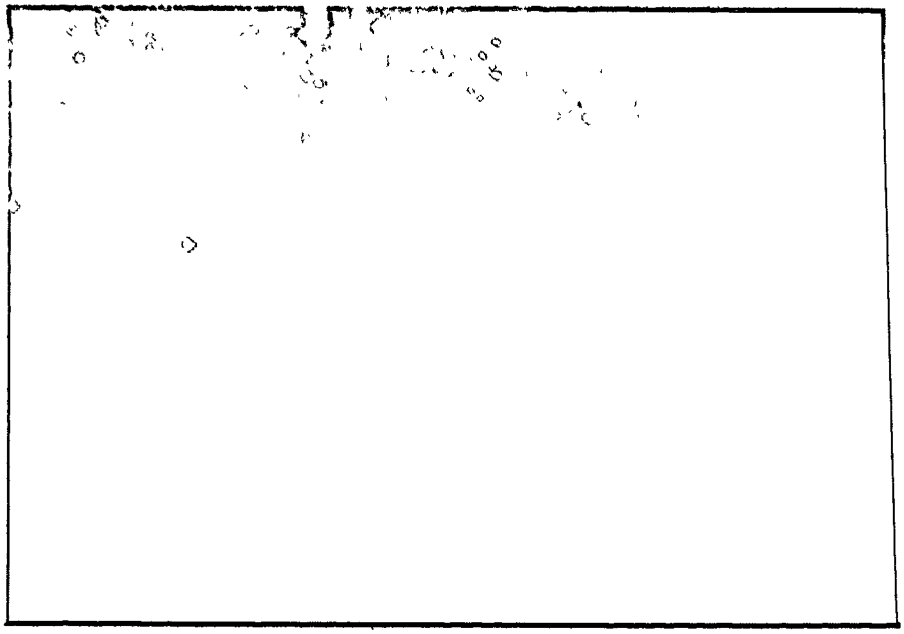
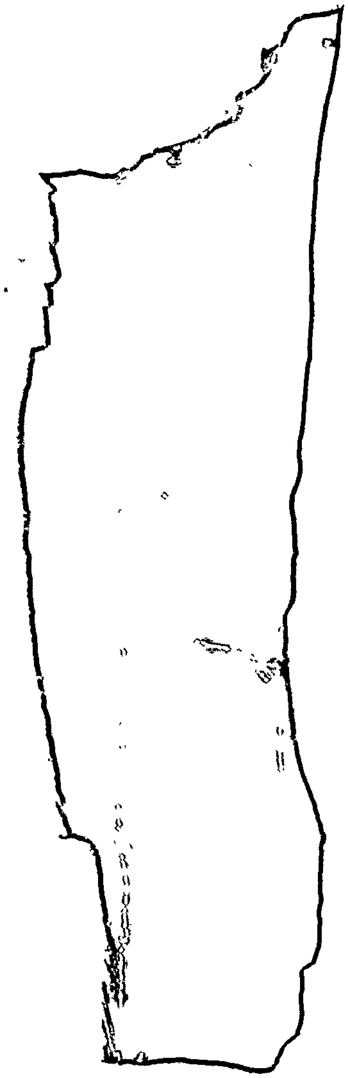


PLATE 4-45. Sample 30-47. Cherty tuff. White ovoids consist of essentially fine grained quartz, with accessory carbonate, micas and andalusite. Dark interstitial material is fine to medium grained quartz-andalusite± anorthite. Sample length is 9 cm.



locally derived, lithologically controlled veins (see Chapter 6), consisting of medium grained quartz and euhedral andalusite rhombs.

4.4.3 Mafic Sediments

Mafic sediments are rare and essentially of two types. In the north crosscut they occur as well banded, carbonate-rich units within the volcanic flows, and are less than 1 m in thickness.

The matrix consists of fine grained quartz-biotite-carbonate-opaques, with traces of anorthite. Poikilitic garnets are common and are generally found in mafic bands. Andalusite rhombs and fibrous actinolite are rare. Opaques generally occur disseminated throughout the matrix but rarely occur in fine bands or veins. Pyrrhotite is the dominant opaque, with minor arsenopyrite which occurs as minute rhombs and as inclusions in pyrrhotite. Magnetite is also a minor constituent with trace quantities of pyrite and chalcopyrite.

Concordant to discordant veins are common and generally of three types; a) actinolite, b) carbonate ± talc, c) quartz ± biotite ± muscovite ± opaques. Occasionally the quartz veins are boudinaged.

In the south crosscut the mafic sediments are much thicker units than in the north crosscut. Here they are intercalated with felsic volcaniclastites. They are greenish black and range in thickness from 20 cm to 5 m (Plate 4-46).

The matrix is dominated by penninite with minor biotite, quartz and opaques, and traces of carbonate and amphibole.

Almandine constitutes up to 15% of the rock. The garnet cores are commonly riddled with quartz and rarely carbonate and opaques. Occasionally recrystallized quartz rims the garnets. A younger stage of garnet growth occurs along fractures, where fresh undeformed garnets with some associated talc, form overgrowths on poiklitic garnets. Talc is also the main constituent in secondary concordant veins. Associated with it are minor amounts of garnet-chlorite-opaques-actinolite ± quartz.

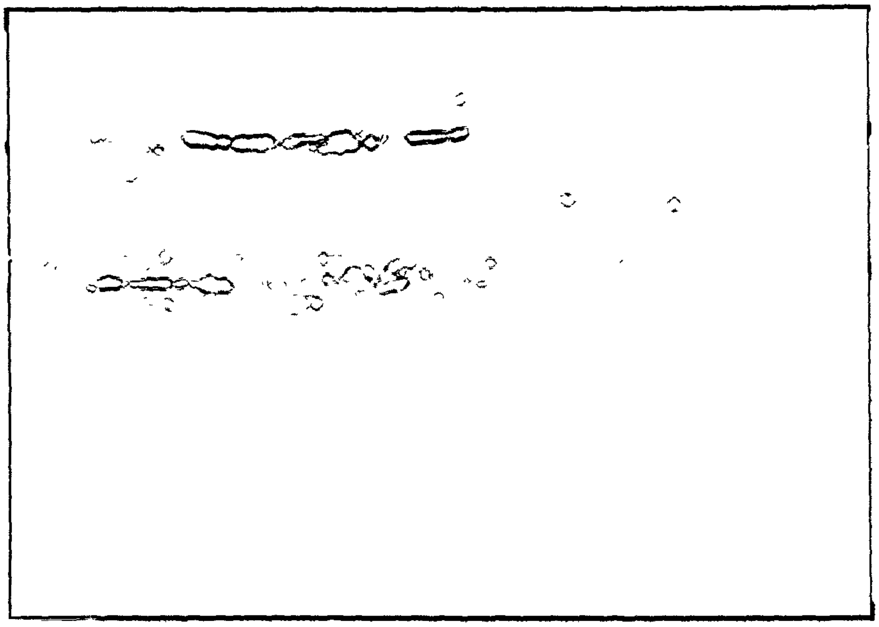
4.4.4 Ore Zones

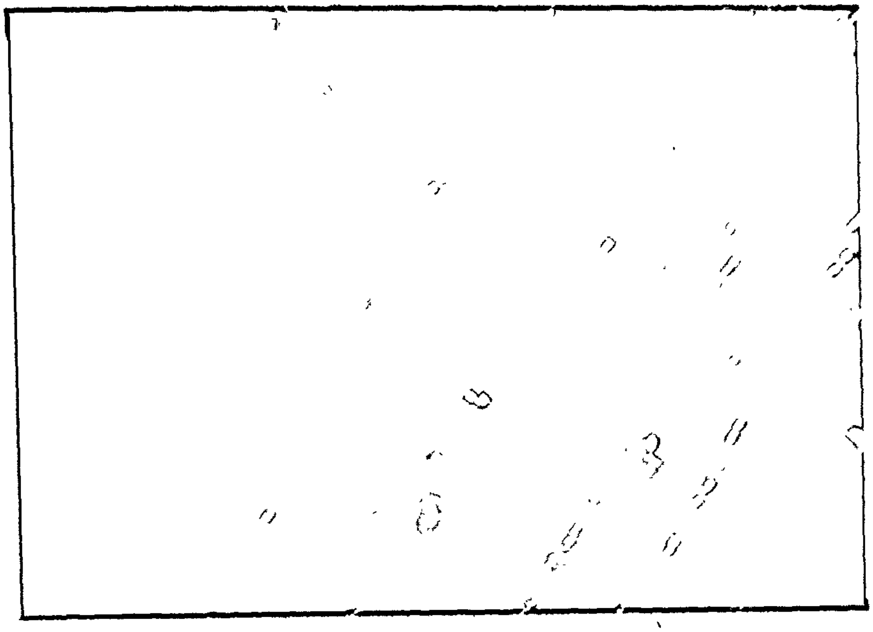
The ore zone in the main drift lies within a felsic horizon intercalated with a sequence of pillowed mafic flows. It is stratabound, trends northwesterly and is generally about 0.5 m wide (Plate 4-47). Texturally and mineralogically it is similar to a subsidiary zone termed lean iron formation (mine terminology), which is parallel to and 122 m to the south at the termination of the south crosscut (Plate 4-48). Although more discontinuous both zones exhibit similar dimensions to the 24 Level ore zones. Extensional features are both megascopic and microscopic in scale, with carbonate

PLATE 4-46. Garnetiferous sediments intercalated with felsic volcanics. South cross-cut, 30 Level. Field of view is approximately 0.5 m .

PLATE 4-47. Ore zone (buff brown, approximately 0.5 m wide), in main east drift, 30 Level. Photo is looking up at "back".

PLATE 4-48. Well foliated "lean Fe formation" (mine terminology) at termination of south crosscut, 30 Level. Field of view is approximately 1 m.





and opaques being remobilized into shadow zones.

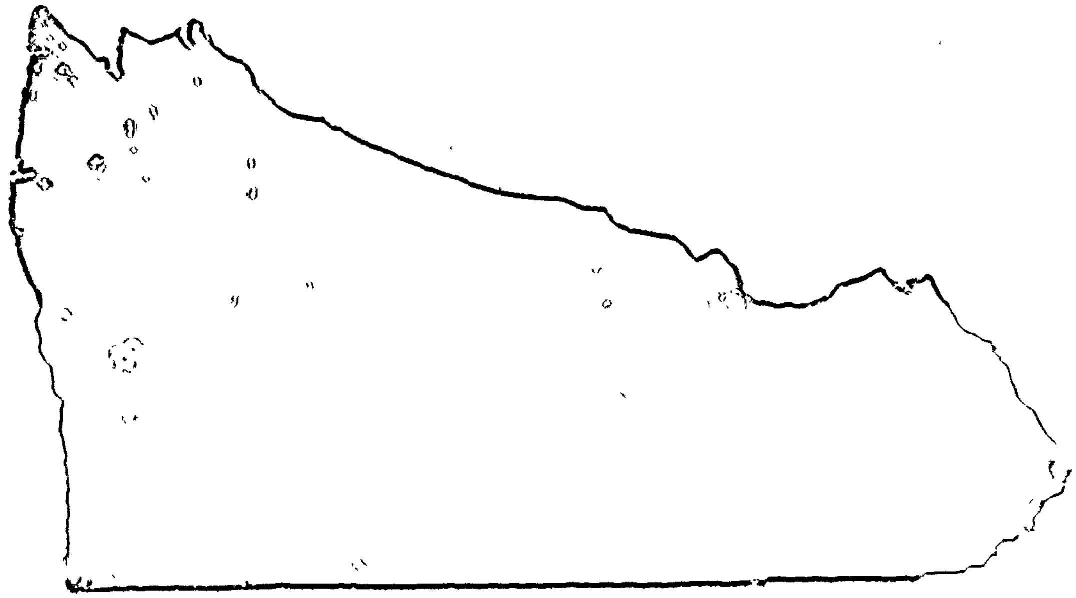
The ore bearing rocks are well banded to fragmental in appearence (Plate 4-49). Banding is indicated by distinct compositional variations. Siliceous zones containing very fine grained quartz-muscovite ± carbonate occur on a cm scale and intercalate with mm wide mafic bands consisting of an iron cordierite-opaques-biotite ± tourmaline ± garnets ± carbonate. Garnets also exhibit preferential elongate growth. Wispy bands of finely laminated disseminated opaques, with accessory andalusite and cordierite are common (Plates 4-50 and 4-51).

The banded ore zone grades into one of a more fragmental character. Here siliceous fragments, several cms in size, have been slightly flattened and rimmed by mafic material (Plate 4-52). The fragments consist of very fine grained muscovite and quartz with rare porphyroblasts of andalusite and garnet. The mafic material is essentially biotite-opaques-garnet-quartz ± andalusite ± tourmaline.

The opaques which constitute up to 15% of the rocks are essentially pyrite and arsenopyrite with minor pyrrhotite. The latter two minerals are more abundant in the main ore zone. Minute pyrite ($< 5\ \mu m$) and arsenopyrite rhombs ($< 2\ \mu m$) commonly occur as discrete euhedral crystals (Plate 4-53), occasionally in fine bands.

Secondary veins are rare. They are both concordant and discordant, and consist of carbonate-quartz-micas-opaques.

PLATE 4-49. Two views of Sample 800-01 ("lean Fe formation"). Note finely banded to fragmental aspect, especially on the polished surface. Opaques are the white reflecting disseminations. Sample length is 16 cm.



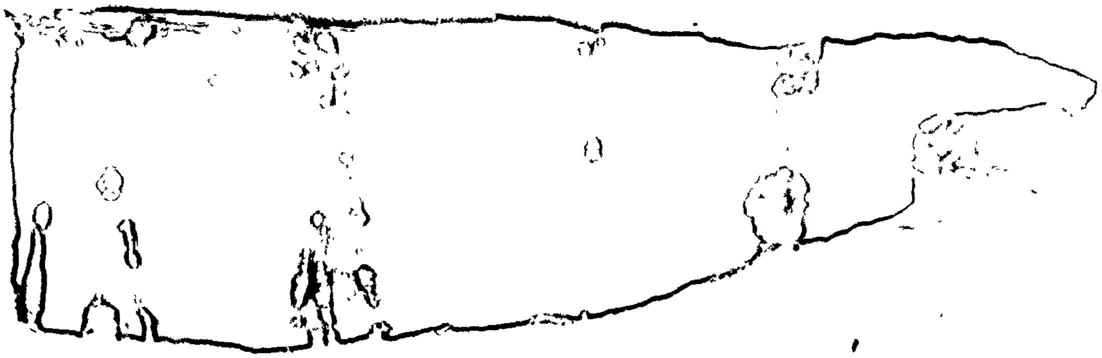
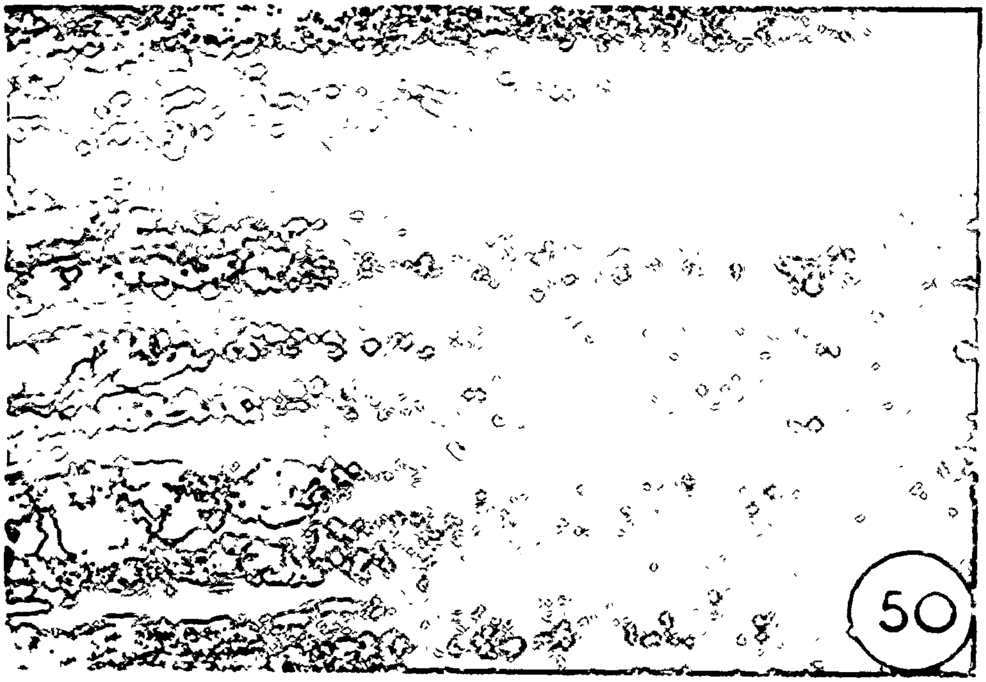
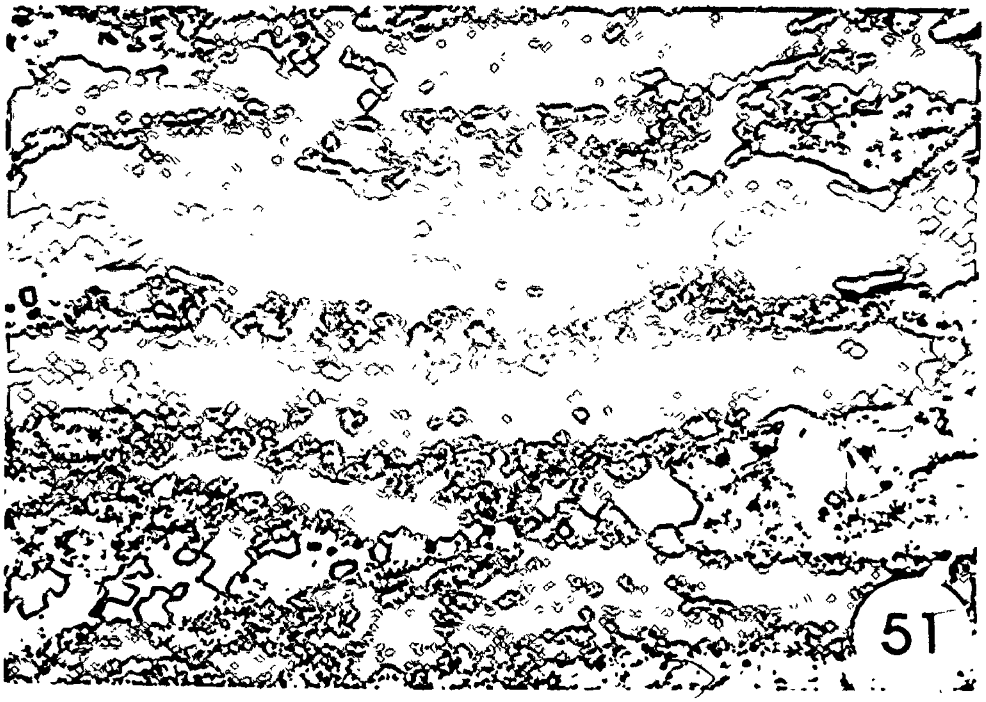


PLATE 4-50. Sample 80-02. Note the finely laminated disseminated opaques. Field of view is 4 mm (plain light).

PLATE 4-51. Sample 80-02. "Lean iron formation" (mine terminology). Note the disseminated opaques in the trough-like structures and the coarse grained recrystallized opaques which occur essentially in the veins. Field of view is 1.6 mm (plain light).



50



51

PLATE 4-52. Sample 80-12 A. Main ore zone, 30 Level. Fragments are dacitic composition and rimmed by biotite-opaques-garnet-quartz±andalusite ± tourmaline. Length of thin section 38 mm (crossed nicols).

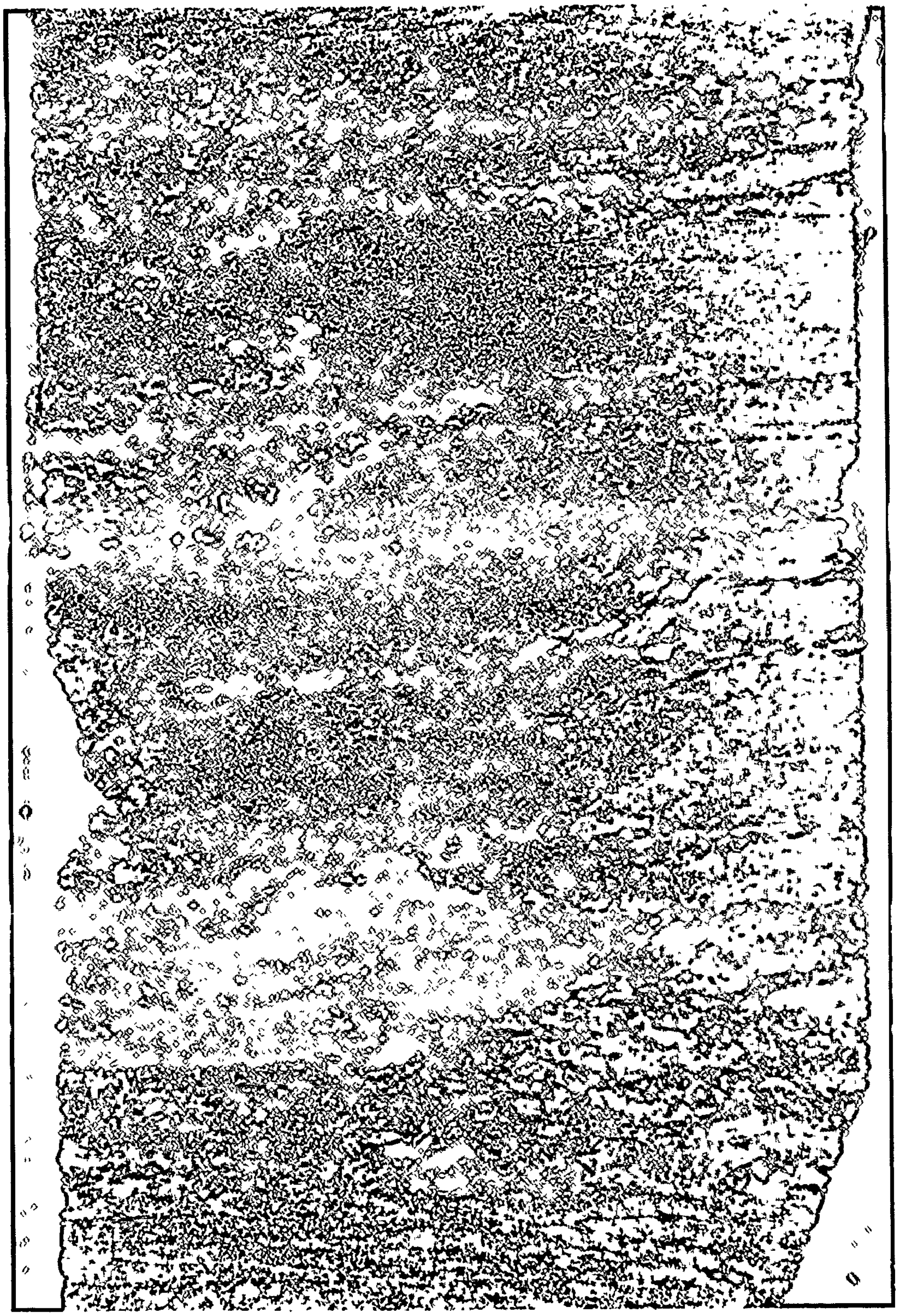


PLATE 4-53. Sample 80-11. White arsenopyrite rhombs in gangue. Sample is from the main 30 Level ore zone.

PLATE 4-54. Sample 30-33. Andesitic dyke. Pyrrhotite infilled fractures in pyrite host. Light gray oxide is magnetite.

20 μm

Hematite filled fractures are the final alteration product.

4.4.5 Intrusives

4.4.5.1 Andesitic Dykes

These fine grained light gray, massive dykes range from 1/2 to 4 m in width and are both concordant and discordant to the dominant foliation. The matrix consists of anhedral quartz, anorthite, biotite, disseminated opaques and rarely carbonate with occasional relict amphibole crystals. Elongate euhedral pods (3 x 1/2 mm), of biotite-chlorite-opaques are commonly observed. Pyrite is the dominant opaque with minor pyrrhotite which occurs in veins and fractures as a replacement (Plate 4-54). Chalcopyrite and magnetite occur in trace amounts.

4.4.5.2 Basaltic Dykes

A 25 cm wide calc-alkalic basaltic dyke was observed in the south crosscut. It is concordant to stratigraphy and consists of an aphanitic matrix, although 2 to 3 mm elongate greenish pods are readily observable and exhibit a weak foliation.

The matrix consists of very fine grained anhedral quartz and plagioclase, with minor disseminated carbonate and opaques. The numerous greenish pods are elongate biotite and opaque clots. Carbonate clots are rare and commonly rimmed by opaques.

A crosscutting veinlet consisted of carbonate-quartz-opaques-biotite.

4.4.5.3 Quartz Feldspar Porphyry (Mine Terminology)

A 3 1/2 m wide spotty textured felsic body containing quartz-carbonate infilled, sub-horizontal tension gashes was observed in the south crosscut. Mine plans indicate that it cuts stratigraphy,and minerallogically it is similar to the dykes. The matrix consists of fine grained quartz, feldspar, biotite and sericite. Biotite occasionally occurs in clots and relict amphibole crystals are rare, as are opaques. Sericite also occurs in fractures. Cross-cutting quartz-carbonate veins are rare.

CHAPTER 5

GEOCHEMISTRY

The mafic-ultramafic flows, volcaniclastites and intrusives were classified using the cation diagram of Jensen (1976) as illustrated in Figure 5-1. Most of the flows on the 30 Level are magnesium tholeiites with some basaltic komatiites. The post tectonic dykes are calc-alkalic basalts and andesites, and the single quartz-feldspar porphyry sample plots in the calc-alkalic dacite field. The provenance for the mafic volcaniclastites on the 25 Level is clearly komatiitic, as these rocks plot in the ultramafic to basaltic komatiite field. The mafic flows are magnesium-rich tholeiites. The carbonatized flows (flow?) on the 17 Level range in composition from ultramafic to basaltic komatiite.

The komatiitic affinity exhibited by some of the mafic volcanics, is further demonstrated in a TiO_2 vs MgO plot (Fig. 5-2). The relatively high Ni and Cr contents of all the rocks on these three levels is illustrated in Figure 5-3.

5.1 17 Level

The range and mean major and trace element values, for the various rock types on the 17 Level are presented in

FIGURE 5-1. Jensen Cation Plot for samples from Dickenson Mine; Levels 30, 25 and 17.

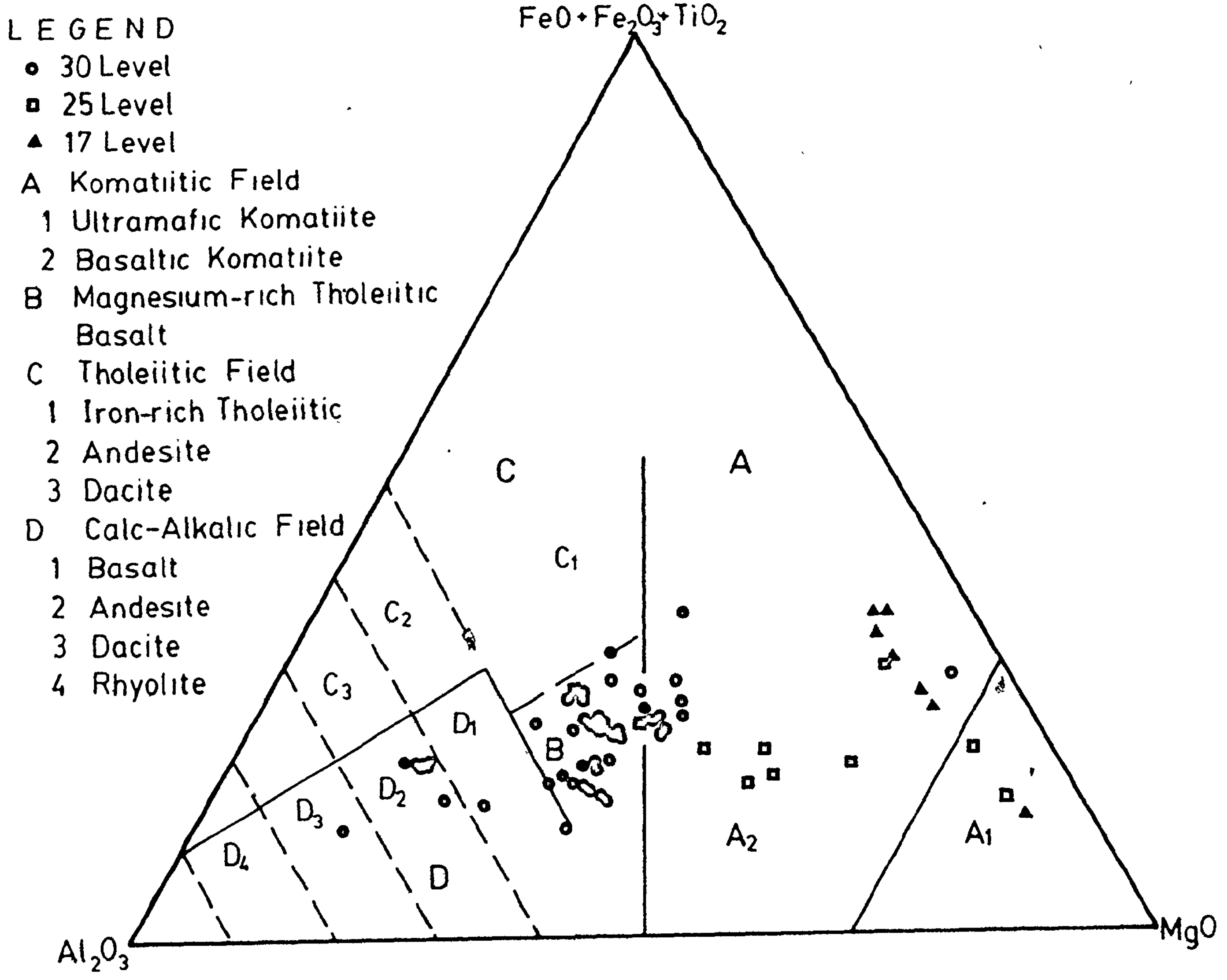

LEGEND
○ 30 Level
□ 25 Level
▲ 17 Level
A Komatiitic Field
1 Ultramafic Komatiite
2 Basaltic Komatiite
B Magnesium-rich Tholeiitic Basalt
C Tholeiitic Field
1 Iron-rich Tholeiitic
2 Andesite
3 Dacite
D Calc-Alkalic Field
1 Basalt
2 Andesite
3 Dacite
4 Rhyolite
FeO + Fe2O3 + TiO2
Al2O3
MgO
A
A1
A2
B
C
C1
C2
C3
D
D1
D2
D3
D4

FIGURE 5-2. TiO_2 vs. MgO .
Dashed line discriminates between
tholeiitic and komatiitic fields
(after Arndt et al., 1977).

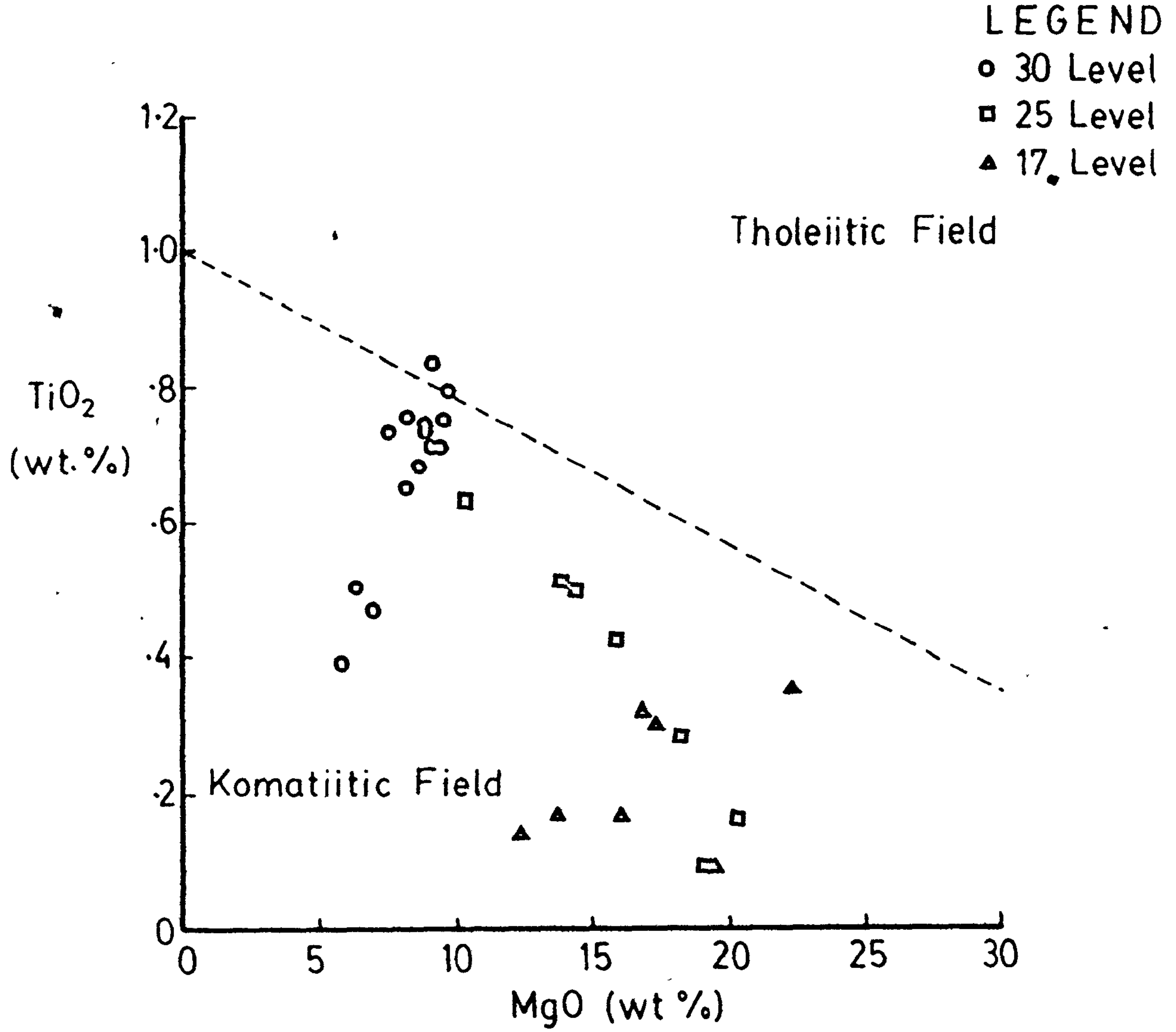

LEGEND
30 Level
25 Level
17 Level
Tholeiitic Field
Komatiitic Field
TiO_2 (wt.%)
1·2
1·0
·8
·6
·4
·2
0
0
5
10
15
20
25
30
MgO (wt %)

FIGURE 5-3. Chromium vs. Nickel, 17, 25 and 30 Levels, Dickenson Mine

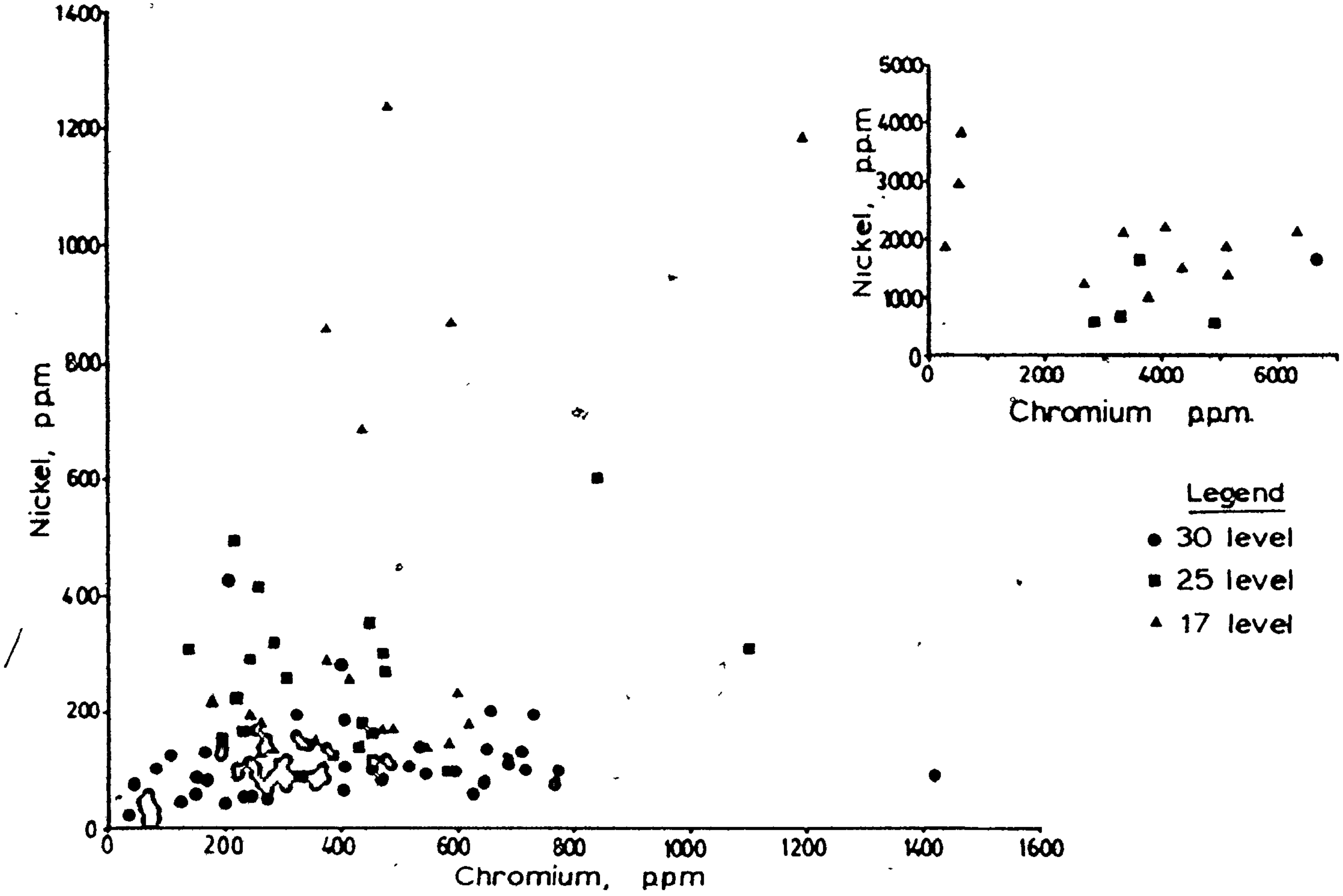


Table 5-1. The komatiites are characterized by high Ni (900 to 2100 ppm), Cr (3300 to 6300 ppm), MgO (12.32 to 22.24 wt %) and CO_2 (14.42 to 23.08 wt %) values. Gold values are low (8.0 to 43 ppb, mean 18) and are not correlated with degree of alteration (L.O.I.), S, As (Figure 5-4) or SiO_2. A comparison of these komatiites with peridotitic and pyroxenitic flows from Munro Township (Table 5-2) indicates that the former are enriched in volatiles (mainly CO_2) by a factor of 2.5 to 5. This variation in alteration intensity makes comparisons between bulk chemistry difficult and speculative. However both groups of komatiites contain high Ni and Cr and low Rb and Sr values.

The peraluminous unit (24 wt % Al_2O_3) separating the komatiites from the felsic volcanics is also high in Ni (1170 ppm) and Cr (1180 ppm); however, it is low in CO_2 (<1.0 wt %) and SiO_2 (38.55 wt %).

The felsic volcanics which overlie this unit exhibit a wide range in composition as does the ore zone which is found within them. Tables 5-3(a) and 5-3(b) list average compositions of Archean andesites, dacites and rhyolites, according to Condie (1976) and Nockolds <u>et al</u>. (1978). It is evident that in terms of bulk composition the 17 Level volcaniclastites do not compare well with the average compositions for silicic volcanics (rhyolites and rhyodacites) in the following respects: 1) total Fe and MnO are higher by a factor of 2 to 5, 2) MgO and TiO_2 are much too high, 3) Ni, Cr and

TABLE 5-1: Variations in Major and Trace Elements for Main Lithologic Units on Level 17.

	1		2	3
		In Weight Percent		
SiO_2	28.00-35.75	(33.21)	59.16	38.55
Al_2O_3	2.27-4.32	(3.33)	6.96	24.10
Fe_2O_3	8.62-18.90	(15.48)	5.59	11.57
MgO	12.32-22.24	(16.18)	7.75	9.91
CaO	3.18-22.80	(11.20)	10.18	8.20
Na_2O	<0.20	(<0.20)	<0.20	0.95
K_2O	<0.20 -0.29	(0.22)	1.16	1.01
TiO_2	0.14-0.35	(0.23)	0.55	0.82
MnO	0.42-0.97	(0.58)	0.26	0.36
P_2O_5	0		0	0.04
L.O.I.	16.23-23.08	(19.45)	8.02	4.30
CO_2	14.42-23.08	(18.85)	7.97	0.99
H_2O	0 -1.81	(0.60)	0.05	3.31
S	0.02-0.08	(0.04)	0.13	0.13
As	0.03-0.05	(0.03)	0.08	0.06
		In ppm		
Ni	909-2078	(1548)	1802	1169
Rb	<20	(<20)	54	27
Sr	47-48	(62)	77	324
Y	<20	(<20)	<20	27
Zr	40-41	(40)	48	93
Nb	<20	(<20)	0	<20
Cr	3321-6294	(4551)	5044	1183
Co	45-151	(107)	81	86
Pb	<20	(<20)	<20	21
Cu	21-53	(30)	80	110
Zn	48-244	(112)	254	66
		In ppb		
Au	8.20-42.83	(17.69)	26.37	184

1. Range in chemical composition of 5 carbonatized komatiites.
2. Chemical composition of intercalated cherty unit.
3. Chemical composition of peraluminous sediment.

Values in parentheses are average composition.

TABLE 5-1: Variations in Major and Trace Elements for Main Lithologic Units on Level 17.
(cont'd)

	4		5	
	In Weight Percent			
SiO_2	51.00-71.69	(62.44)	60.11-73.16	(67.08)
Al_2O_3	7.78-15.02	(11.13)	10.96-13.27	(12.01)
Fe_2O_3	9.21-18.40	(14.28)	7.00-10.14	(8.12)
MgO	3.37-10.83	(5.37)	0.94-2.17	(1.66)
CaO	0.28-7.33	(1.16)	0.16-0.37	(0.23)
Na_2O	<0.20	(<0.20)	<0.20-0.31	(0.21)
K_2O	<0.20-1.50	(0.41)	0.33-2.58	(1.71)
TiO_2	0.25-0.96	(0.75)	0.63-0.91	(0.80)
MnO	0.19-0.61	(0.30)	0.08-0.14	(0.10)
P_2O_5	0 -0.03	(0.02)	0.02-0.04	(0.03)
L.O.I.	1.99-5.84	(3.44)	2.47-10.70	(6.52)
CO_2	0.72-5.84	(2.15)	1.53-10.70	(6.20)
H_2O	0 -2.43	(1.27)	0.94	(0.94)
S	0.09-1.86	(0.64)	0.77-1.43	(1.03)
As	0.01-0.30	(0.07)	0.28-0.63	(0.50)
		In ppm		
Ni	125-3719	(802)	198-854	(424)
Rb	<20-36	(<20)	<20-41	(32)
Sr	<20-119	(44)	30-43	(38)
Y	<20-24	(<20)	<20-25	(<20)
Zr	40-69	(55)	<20-70	(48)
Nb	<20	(<20)	<20	(<20)
Cr	265-681	(455)	174-585	(336)
Co	47-617	(159)	<40-43	(<40)
Pb	<20	(<20)	<20	(<20)
Cu	34-250	(126)	103-123	(115)
Zn	<20-1157	(241)	44-216	(136)
Ce	n.d.		94-166	(130)*
Nd	n.d.		<20-24	(<20)*
V	n.d.		235-309	(272)*
La	n.d.		<20	(<20)*
Ba	n.d.		143-213	(178)*
		In ppb		
Au	4.09-2140	(160)	1110-13,365	(6332)

4. Range in chemical composition of 16 felsic volcaniclastites.
5. Range in chemical composition of 3 samples from the ore zone.
*- 2 samples analysed.
Values in parentheses are average compositions.
n.d. not determined.

FIGURE 5-4. Au vs. L.O.I., S and As
for the 17 Level komatiites.

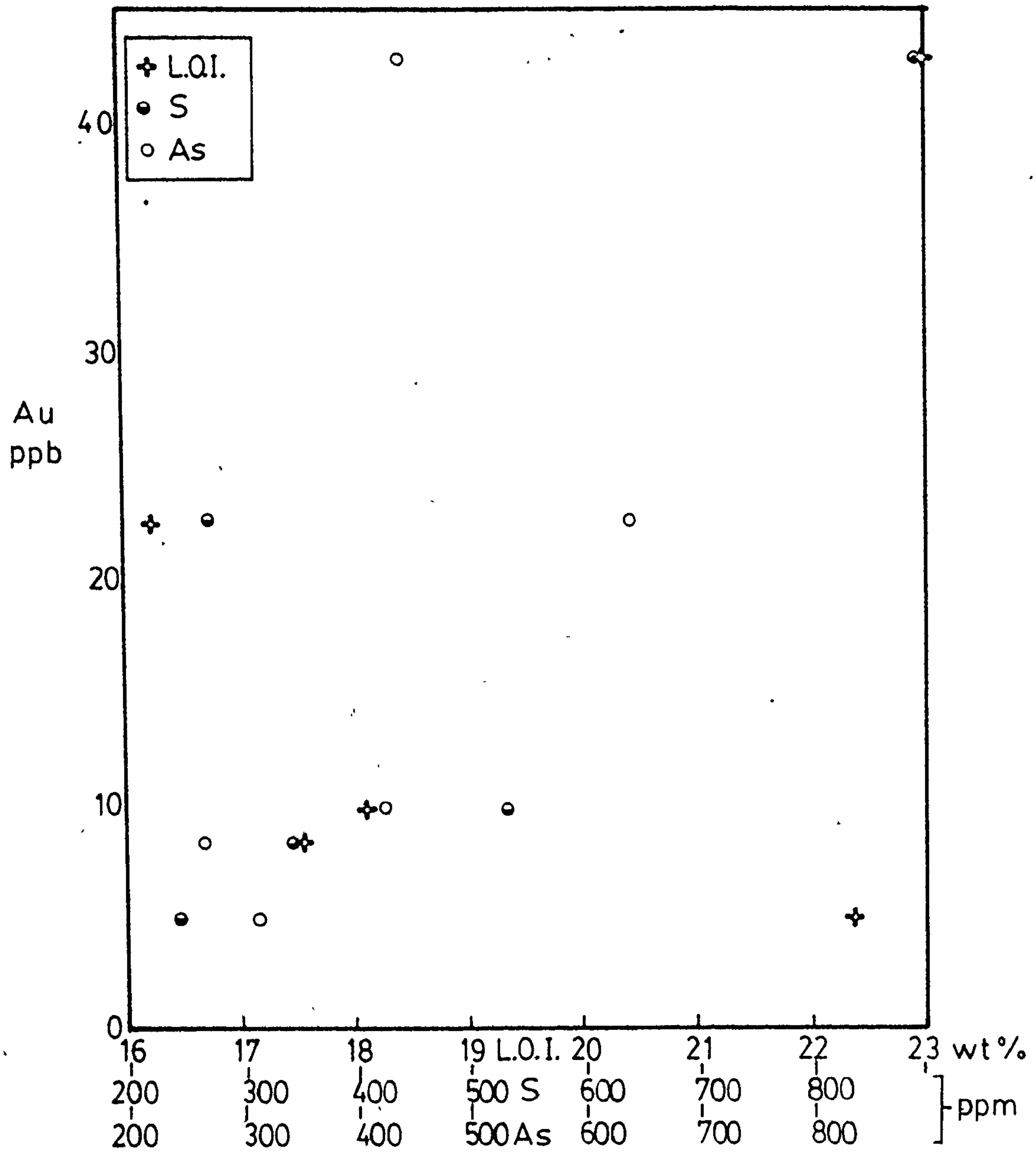

L.O.I.
S
As
Au ppb
0
10
20
30
40
16
17
18
19
L.O.I.
20
21
22
23
wt %
200
300
400
500 S
600
700
800
200
300
400
500 As
600
700
800
ppm

TABLE 5-2: Representative analyses of basic and ultrabasic flows in Munro Township.

	1	2	3	4
		In Weight Percent		
SiO_2	42.2	45.6	50.2	48.3
Al_2O_3	6.1	8.4	11.6	10.8
Fe_2O_3	10.5	2.46	11.11	2.35
FeO		8.2		7.4
MgO	26.3	20.6	14.3	13.9
CaO	5.83	8.1	9.6	10.0
Na_2O	0.19	0.46	2.34	2.24
K_2O	0.11	0.03	0.05	0.00
TiO_2	0.28	0.46	0.61	0.62
MnO	0.22	0.19	0.19	0.18
P_2O_5	n.d.	n.d.	n.d.	n.d.
L.O.I.	7.8	5.2	n.d.	3.9
CO_2	n.d.	0.36	n.d.	0.74
H_2O	n.d.	4.85	n.d.	3.18
S	0.08	0.04	n.d.	0.02
As	n.d.	n.d.	n.d.	n.d.
		In ppm		
Ni	1706	986	n.d.	647
Rb	7	5	n.d.	1
Sr	22	15	n.d.	41
Y	n.d.	n.d.	n.d.	n.d.
Zr	n.d.	n.d.	n.d.	n.d.
Nb	n.d.	n.d.	n.d.	n.d.
Cr	2263	2009	n.d.	1460
Co	118	93	n.d.	80
Pb	n.d.	n.d.	n.d.	n.d.
Cu	n.d.	n.d.	n.d.	n.d.
Zn	73	80	n.d.	n.d.
		In ppb		
Au	n.d.	n.d.	n.d.	n.d.

1. Spinifex-free peridotitic komatiitic lava (Arndt et al.,1977).
2. Spinifex-free peridotitic komatiitic lava (Arndt et al.,1977).
3. Average composition of pyroxenitic komatiites (Arndt et al., 1977).
4. Olivine-rich pyroxenitic komatiitic lava (Arndt et al.,1977).

n.d. not determined.

TABLE 5-3(a): Average composition of Archean andesites, dacites and rhyolites.

	1	2	3	4	5	6
			In Weight Percent			
SiO_2	56.7	58.9	66.2	64.0	71.7	73.5
Al_2O_3	14.0	15.5	16.5	15.8	16.4	12.7
Fe_2O_3	2.3	1.5	0.9	2.6	0.7	0.9
FeO	7.0	4.5	1.0	2.9	0.9	1.2
MgO	5.4	4.5	1.6	3.0	0.5	0.8
CaO	6.6	5.1	3.9	3.2	1.7	1.1
Na_2O	3.4	4.0	5.2	4.0	5.0	3.3
K_2O	0.67	1.9	2.0	2.7	2.0	3.0
TiO_2	0.92	0.65	0.28	0.5	0.19	0.14
MnO P_2O_5			see Table 5-3(b)			
			In ppm			
Ni	70	60	25	25	10	10
Rb	22	75	33	68	41	43
Sr	278	580	600	390	110	100
Y	25	35	2	8	2	30
Zr	150	190	50	260	30	350
Nb	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Cr	125	88	30	45	12	12
Co	25	23	8	15	3	3
Pb	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Cu	60	36	n.d.	n.d.	n.d.	n.d.
Zn	97	81	n.d.	n.d.	n.d.	n.d.
Ce	31	70	30	100	35	95
Nd	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
V	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
La	13	34	n.d.	n.d.	17	46
Ba	230	547	590	1090	480	750
			In ppb			
Au	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

1. Fifteen low alkali Archean andesites (Condie, 1976).
2. Eighteen high alkali Archean andesites (Condie, 1976).
3. Seven rare earth depleted dacites to rhyodacites (Condie, 1976).
4. Six undepleted dacites to rhyodacites (Condie, 1976).
5. Five rare earth depleted Archean rhyolites (Condie, 1976).
6. Six undepleted Archean rhyolites (Condie, 1976).

n.d. Not determined.

TABLE 5-3(b): Average values of MnO and P_2O_5 in Archean andesites, dacites and rhyolites. (Nockolds *et al.*, 1978).

	MnO	P_2O_5	Number of Analyses
Andesite	0.15	0.26	50
Dacite	0.12	0.16	32
Rhyodacite	0.07	0.17	115
Rhyolite	0.05	0.11	80

Co are up to 200 times higher. These rocks are as siliceous as a dacite suggesting the occurrence of felsic metavolcanic or cherty metasedimentary rocks in the source region. They also carry Fe, Mn, Mg, Ti, Ni, Cr and Co contents characteristic of mafic rocks. In other words, the chemical composition of this group suggests a bimodal source region containing both felsic and mafic rocks.

A comparison of the composition of the ore zone and the enclosing volcaniclastites (Table 5-1, columns 4 and 5) indicates that the ore zone contains more SiO_2, K_2O, CO_2, S, As and Au and less total Fe, MgO, CaO, MnO, Ni, Cr, Co and Zn.

Gold values for individual samples are plotted against S, As and SiO_2 in Figures 5-5 and 5-6. There is a weak correlation for Au and S, in that both are high in the same samples. There is no correlation of Au with As or SiO_2. Profiles of Au, S and As about the ore zone suggest a similar relationship (Figures 5-7 and 5-8). The main features of these profiles is that the gold values are high in one or in a few adjacent samples and exhibit no systematic gradient away from the ore zone.

The massive carbonate 60 m north of the ore zone is quite auriferous (1.2 ppm) and plots in the ultramafic komatiite field in Figure 5-1. It is high in MgO (19.26 wt %), CaO (32.06 wt %), CO_2 (32.66 wt %), Ni (1132 ppm) and Cr (2677 ppm), and is one of the few rocks of ultramafic composition

FIGURE 5-5. Au vs. S, As and SiO_2 in samples south of the East Drift, 17 Level.

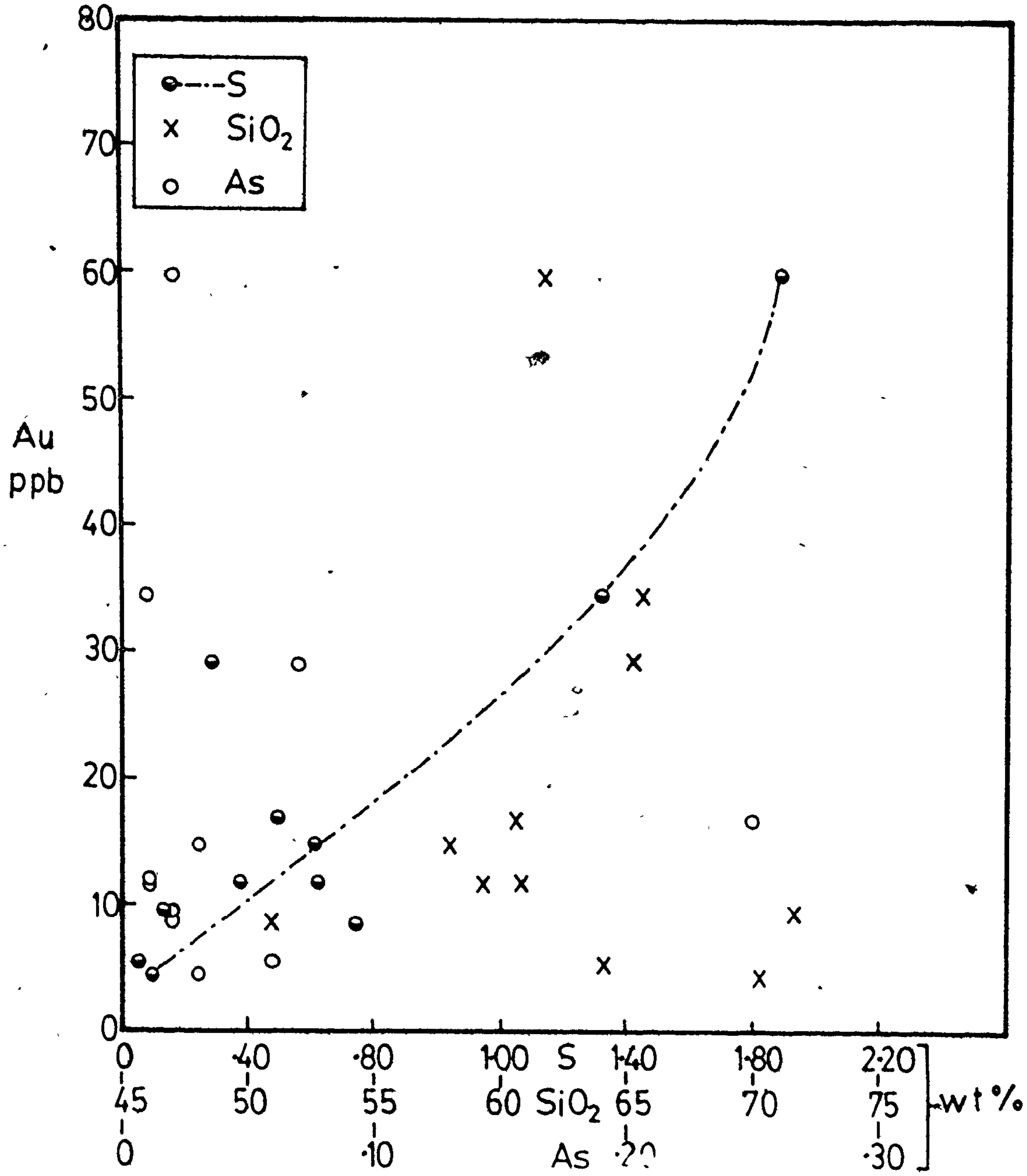

S
SiO2
As
Au ppb
80
70
60
50
40
30
20
10
0
0
·40
·80
1·00
S
1·40
1·80
2·20
45
50
55
60
SiO2
65
70
75
0
·10
As
·20
·30
wt %

FIGURE 5-6. Au vs. S, As and SiO_2 in samples north of the East Drift, 17 Level.

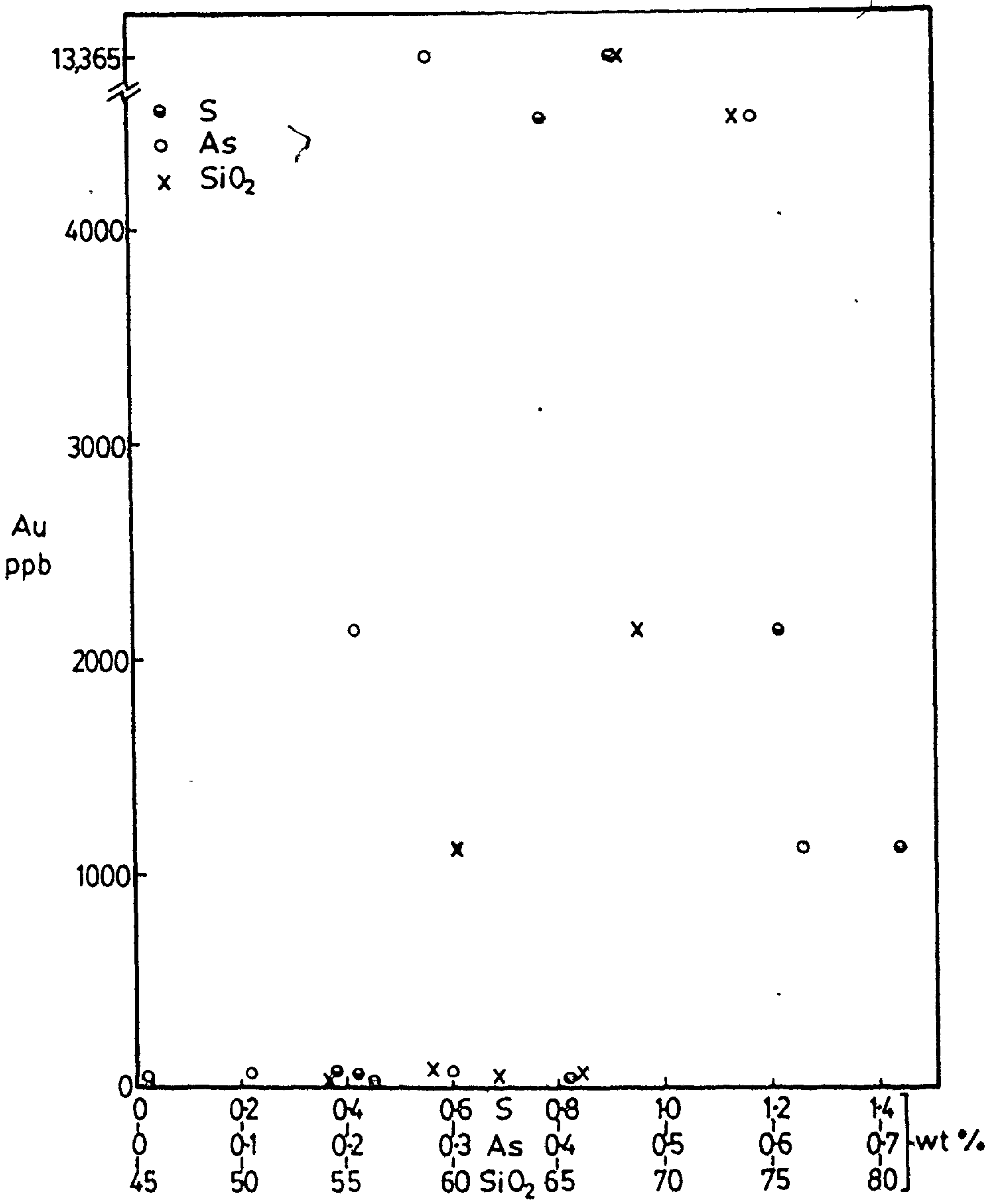

13,365
4000
3000
2000
1000
0
Au
ppb
● S
○ As
x SiO₂
0
0·2
0·4
0·6
0·8
1·0
1·2
1·4
S
0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
As
45
50
55
60
65
70
75
80
SiO₂
wt %

FIGURE 5-7.

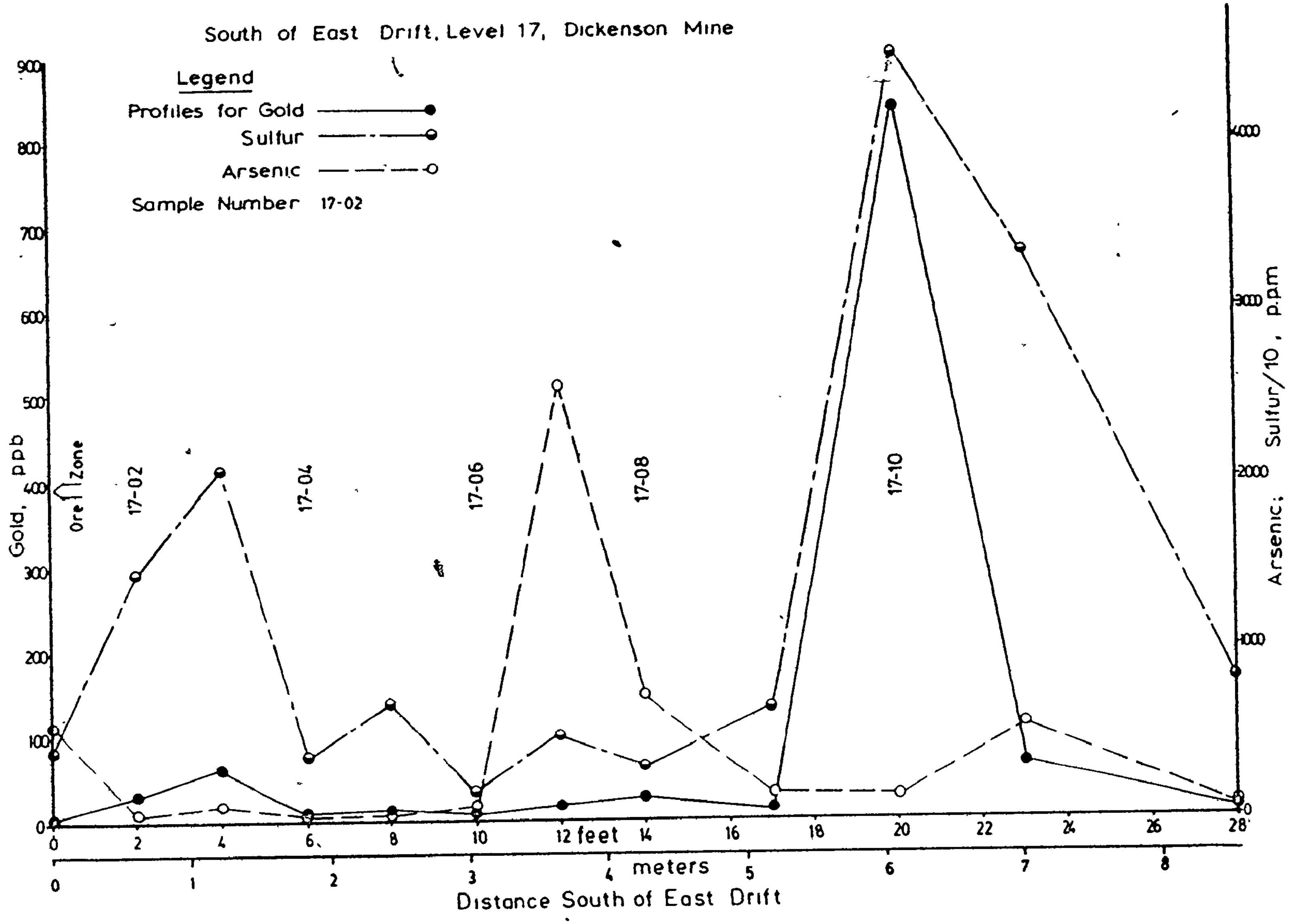
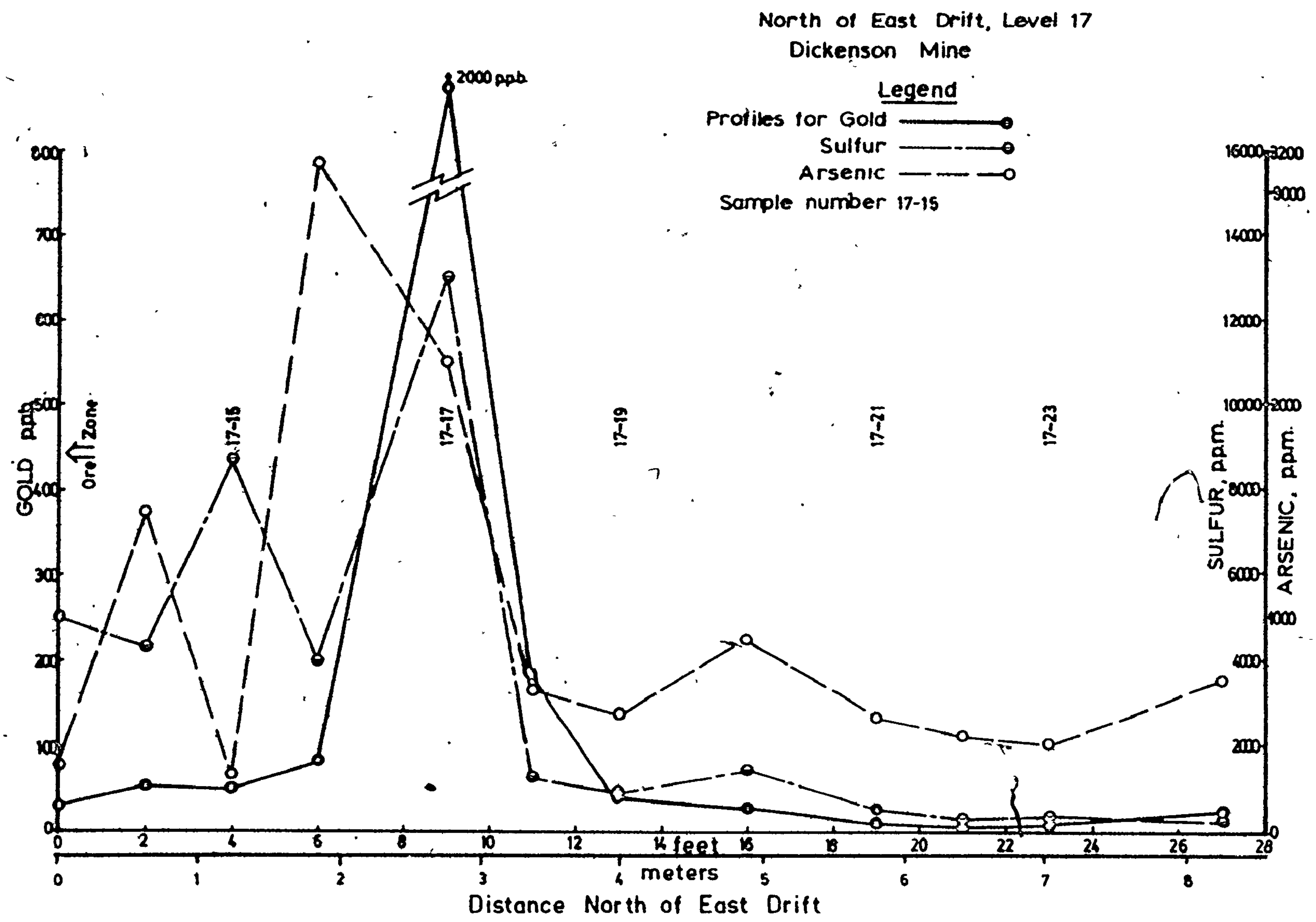

South of East Drift, Level 17, Dickenson Mine
Legend
Profiles for Gold
Sulfur
Arsenic
Sample Number 17-02
Gold, ppb
0
100
200
300
400
500
600
700
800
900
Ore Zone
17-02
17-04
17-06
17-08
17-10
Arsenic; Sulfur/10, p.pm
0
1000
2000
3000
4000
0
2
4
6
8
10
12 feet
14
16
18
20
22
24
26
28
0
1
2
3
4
meters
5
6
7
8
Distance South of East Drift

FIGURE 5-8.


North of East Drift, Level 17
Dickenson Mine
Legend
Profiles for Gold
Sulfur
Arsenic
Sample number 17-15
2000 ppb
GOLD ppb
0
100
200
300
400
500
600
700
800
Ore Zone
17-15
17-17
17-19
17-21
17-23
SULFUR, ppm.
0
2000
4000
6000
8000
10000
12000
14000
16000
ARSENIC, ppm.
4000
2000
3000
3200
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
feet
0
1
2
3
4
5
6
7
8
meters
Distance North of East Drift

which has a high (ppm level) gold content.

5.2 24 Level

The range and mean for two samples from the mineralized zones on this level are given in Table 5-4. Some of the average values are as follows; SiO_2 (61.14 wt %), Al_2O_3 (10.74 wt %), total Fe (7.51 wt %), MgO (6.28 wt %), L.O.I. (3.74 wt %), S (0.63 wt %) and As (0.67 wt %).

5.3 25 Level

The range and mean values for the major lithologic units on the 25 Level are presented in Table 5-5. The magnesium tholeiites exhibit some alkali depletion but otherwise are relatively unaltered (1.85 to 3.56 wt % L.O.I.) and non-auriferous (10-11 ppb).

The komatiitic volcaniclastites vary in composition from ultramafic to basaltic as is reflected in the wide range in some of their major and trace element values, SiO_2 (16.31 to 48.99 wt %), MgO (10.12 to 20.22 wt %), CaO (15.99 to 27.22 wt %), CO_2 (9.70 to 27.44 wt %), Ni (300 to 1550 ppm) and Cr (140 to 4845 ppm). Their gold value range is low (0.59 to 7.1 ppb) and is not related to the degree of alteration.

The cherty tuffs intercalated with these komatiites have high mean values for SiO_2 (71.91 wt %), Al_2O_3 (13.22 wt %), TiO_2 (1.06 wt %), Ni (1197 ppm) and Cr (4984 ppm). Their mean gold value is low (12 ppb).

TABLE 5-4: Variations in Major and Trace Elements for samples from Main Ore Zone on Level 24.

	In Weight Percent	
SiO_2	56.26-66.02	(61.14)
Al_2O_3	10.37-11.10	(10.74)
Fe_2O_3	6.98-8.03	(7.51)
MgO	4.91-7.65	(6.28)
CaO	5.71-9.60	(7.66)
Na_2O	0.23-0.26	(0.25)
K_2O	1.67-2.07	(1.87)
TiO_2	0.67-0.82	(0.75)
MnO	0.13-0.26	(0.20)
P_2O_5	0.03-0.05	(0.04)
L.O.I.	3.34-4.13	(3.74)
CO_2	2.00-2.19	(2.10)
H_2O	1.15-2.13	(1.64)
S	0.46-0.80	(0.63)
As	0.28-1.06	(0.67)
	In ppm	
Ni	155-161	(158)
Rb	33-35	(34)
Sr	93-101	(97)
Y	<20	(<20)
Zr	45-53	(49)
Nb	<20	(<20)
Cr	197-228	(213)
Co	<40	(<40)
Pb	<20	(<20)
Cu	113-131	(122)
Zn	92-369	(231)
Ce	89-288	(189)
Nd	<20	(<20)
V	209-252	(231)
La	<20	(<20)
Ba	58-123	(91)
	In ppb	
Au	420-2370	(1400)

Range in chemical composition of 2 samples.
Values in parentheses are average compositions.

TABLE 5-5: Variations in Major and Trace Elements for Main Lithologic Units on Level 25.

	1		2	
		In Weight Percent		
SiO_2	16.31-48.99	(27.31)	67.54-76.27	(71.91)
Al_2O_3	1.97-13.88	(6.66)	10.63-15.81	(13.22)
Fe_2O_3	6.30-17.43	(10.57)	4.68-6.09	(5.39)
MgO	10.12-20.22	(15.95)	4.01-5.32	(4.67)
CaO	15.99-27.22	(21.27)	1.80-1.91	(1.86)
Na_2O	<0.20	(<0.20)	<0.20	(<0.20)
K_2O	0 -0.22	(<0.20)	0.40-1.23	(0.82)
TiO_2	0.09-0.63	(0.37)	0.78-1.34	(1.06)
MnO	0.21-0.64	(0.40)	0.05-0.10	(0.08)
P_2O_5	0 -0.02	(0.01)	0.02-0.03	(0.03)
L.O.I.	10.43-27.84	(17.46)	1.58-1.67	(1.63)
CO_2	9.70-27.44	(16.82)	0.33-1.31	(0.82)
H_2O	0 -1.60	(0.64)	0.36-1.25	(0.81)
S	0.02-0.18	(0.08)	0.27-0.35	(0.31)
As	0 -0.02	(0.01)	0.01-0.04	(0.03)
		In ppm		
Ni	300-1550	(619)	780-1610	(1197)
Rb	<20	(<20)	20-38	(29)
Sr	51-180	(98)	26-48	(37)
Y	<20	(<20)	<20	(<20)
Zr	37-51	(43)	40-49	(42)
Nb	<20	(<20)	<20	(<20)
Cr	140-4845	(1929)	3399-6569	(4984)
Co	<40-107	(48)	50-115	(58)
Pb	<20	(<20)	<20	(<20)
Cu	<20-95	(51)	131-141	(136)
Zn	31-89	(49)	35-48	(42)
*Ce	n.d.		0*	
*Nd	n.d.		<20*	
*V	n.d.		301*	
*La	n.d.		0*	
*Ba	n.d.		93*	
		In ppb		
Au	0.59-7.1	(3.1)	5.8-18.0	(12.0)

1. Range in chemical composition of 7 komatiitic volcaniclastites
2. Range in chemical composition of 2 cherty tuffs.

*- 1 sample analysed.

n.d. not determined.

Values in parentheses are average compositions.

TABLE 5-5: Variations in Major and Trace Elements for Main Lithologic Units on Level 25.

(cont'd)

	3		4		5	
			In Weight Percent			
SiO_2	59.20-69-62	(64.42)	51.51-66.42	(58.58)	51.51-59.15	(55.54)
Al_2O_3	9.88-12.56	(11.27)	9.63-12.18	(11.01)	10.10-12.03	(10.64)
Fe_2O_3	10.61-18.09	(14.87)	12.88-23.43	(18.54)	16.54-23.43	(20.51)
MgO	1.87-5.52	(3.39)	3.14-6.77	(4.93)	4.84-6.77	(5.54)
CaO	0.52-3.74	(1.31)	0.41-1.08	(0.74)	0.52-1.04	(0.78)
Na_2O	<0.20-0.31	(<0.20)	<0.20	(<0.20)	<0.20	(<0.20)
K_2O	<0.20-1.61	(1.12)	<0.20-1.70	(1.09)	0.75-1.60	(1.08)
TiO_2	1.01-1.25	(1.15)	1.01-1.16	(1.10)	1.01-1.16	(1.07)
MnO	0.24-0.43	(0.33)	0.28-0.64	(0.45)	0.28-0.64	(0.50)
P_2O_5	0.02-0.05	(0.04)	0 -0.08	(0.04)	0.02-0.08	(0.04)
L.O.I.	1.37-2.06	(1.67)	1.47-3.28	(2.30)	1.91-3.28	(2.58)
CO_2	0.35-1.49	(0.95)	0.34-3.28	(1.68)	1.55-3.28	(2.10)
H_2O	0.03-1.71	(0.74)	0 -1.13	(0.62)	0 -0.88	(0.48)
S	0.10-0.19	(0.13)	0.20-1.71	(0.89)	1.11-1.71	(1.29)
As	0.03-0.04	(0.03)	0.09-0.44	(0.26)	0.20-0.44	(0.33)
			In ppm			
Ni	123-284	(182)	98-416	(242)	174-345	(300)
Rb	<20-30	(22)	<20-34	(<20)	<20	(<20)
Sr	38-101	(72)	21-75	(49)	28-53	(44)
Y	<20-34	(<20)	21-49	(31)	22-36	(30)
Zr	51-104	(71)	58-75	(65)	56-67	(61)
Nb	<20	(<20)	<20	(<20)	<20	(<20)
Cr	214-430	(320)	256-585	(411)	256-473	(416)
Co	<40-73	(58)	49-106	(83)	80-106	(94)
Pb	<20	(<20)	<20	(<20)	<20	(<20)
Cu	101-148	(124)	111-241	(153)	111-241	(164)
Zn	73-113	(99))	174-642	(311)	174-642	(343)
Ce	<20	(<20)*	29-133	(81)*	133+	
Nd	<20	(<20)*	<20	(<20)*	20+	
V	278-311	(295)*	353-400	(377)*	400+	
La	<20	(<20)*	<20	(<20)	<20+	
Ba	37-240	(139)*	37-44	(41)*	44+	
			In ppb			
Au	9.5-32.0	(160)	100-90,700	(12,000)	1000-90,700	(21,000)

3. Range in chemical composition of 5 felsic volcaniclastites.
4. Range in chemical composition of 9 sediments with >100 ppb.
5. Range in chemical composition of 5 auriferous sediments (>1.0 ppm) from 4 above.

*- 2 samples analysed.

+- 1 sample analysed.

Values in parentheses are average compositions.

The felsic units in and about the ore zone exhibit a wide range in most major and trace elements, the most significant of which are SiO_2, (51.51 to 69.62 wt %), total Fe (10.61 to 23.43 wt %) and MgO (1.87 to 6.77 wt %). TiO_2 values are high (1.01 to 1.25 wt %) and CO_2 values are low (0.34 to 3.28 wt %).

Some very noteworthy trends are illustrated in Table 5-5 (columns 3, 4 and 5). It is quite evident that with increasing gold content there is a strong enrichment in total Fe, MnO, S, As, Zn and Ce, with moderate increases in MgO, CO_2, Ni, Co, Cu, Cr and V. There is also a strong depletion in SiO_2, CaO and Ba, with moderate depletions in Al_2O_3, Zr and Sr.

The relationship between Au, As and S is shown in Figure 5-9. Two trends are evident: a) a strong positive correlation between Au, As and S for S >0.8 wt % and As >0.2 wt %; b) a weak correlation (with different slope) between Au, As and S for low Au values.

5.4 30 Level

The range and mean compositional values for the various rock types on the 30 Level are presented in Table 5-6.

5.4.1 Mafic volcanics

A comparison of the mafic volcanics on this level with similar flows from Munro Township (Table 5-7), indicates that the Dickenson rocks are significantly depleted in Na_2O

FIGURE 5-9. Au vs. S and As, 25 Level Dickenson Mine.

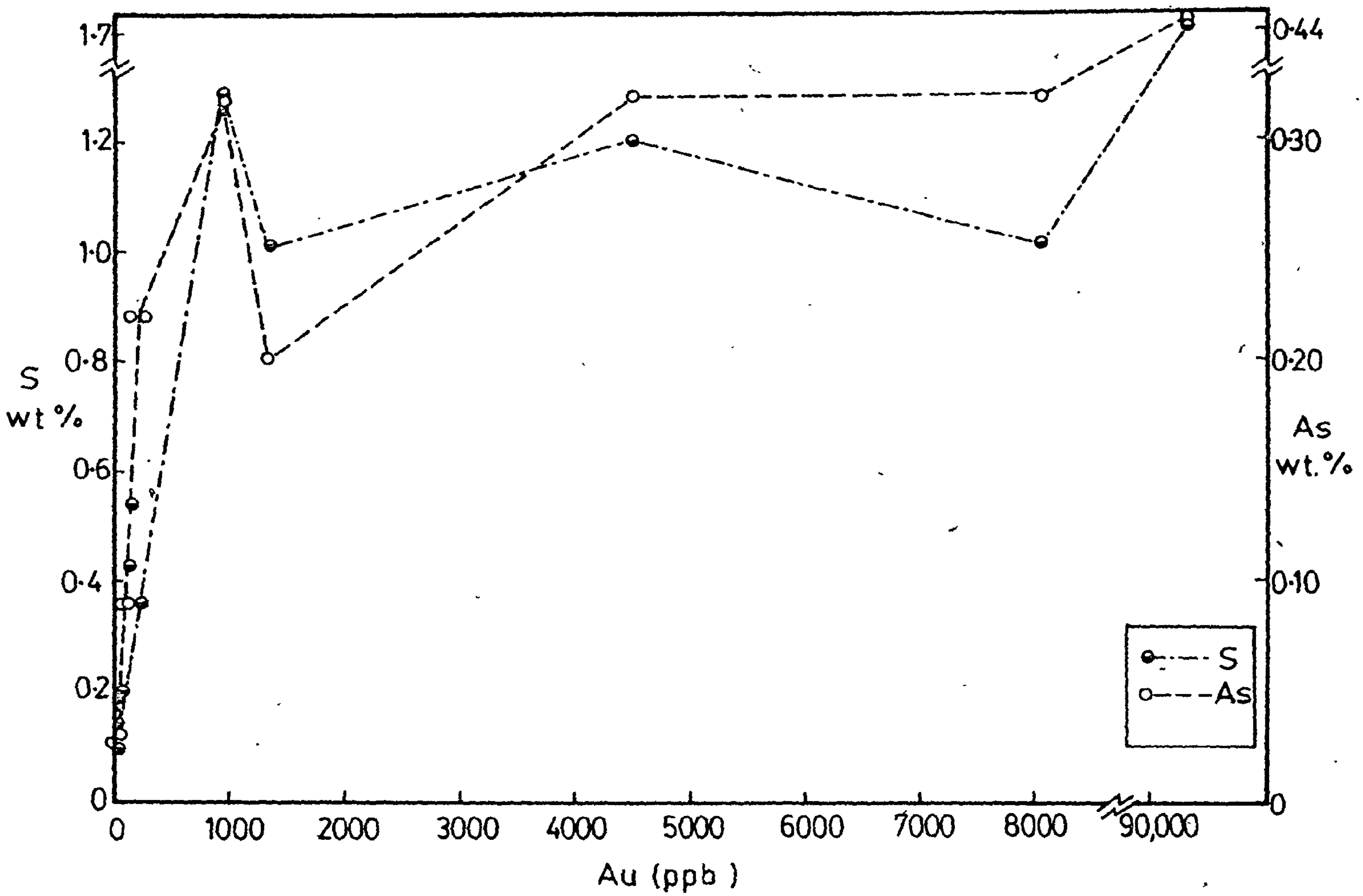

S
wt %
1·7
1·2
1·0
0·8
0·6
0·4
0·2
0
As
wt.%
0·44
0·30
0·20
0·10
0
0
1000
2000
3000
4000
5000
6000
7000
8000
90,000
Au (ppb)
S
As

TABLE 5-6: Variations in Major and Trace Elements for Main Lithologic Units on Level 30.

	1		2		3
		In Weight Percent			
SiO_2	41.27-60.74	(47.80)	51.46-62.45	(55.87)	37.48
Al_2O_3	6.04-11.53	(9.74)	9.82-14.63	(12.54)	2.59
Fe_2O_3	6.27-16.04	(10.53)	5.24-13.87	(9.33)	14.31
MgO	5.86-10.05	(8.68)	5.65-9.06	(7.53)	33.01
CaO	8.23-16.29	(13.48)	6.98-11.90	(9.45)	1.49
Na_2O	<0.20	(<0.20)	<0.20-0.25	(<0.20)	<0.20
K_2O	<0.20-1.98	(0.72)	<0.20-2.59	(0.75)	<0.20
TiO_2	0.39-0.83	(0.69)	0.61-1.02	(0.83)	0.19
MnO	0.23-0.32	(0.25)	0.14-0.33	(0.21)	0.31
P_2O_5	0 -0.03	(0.01)	0 -0.05	(0.01)	0
L.O.I.	2.88-12.17	(7.69)	1.23-6.84	(3.29)	10.71
CO_2	2.88-12.17	(7.66)	0.75-6.79	(3.08)	4.90
H_2O	0 -0.34	(0.34)	0 -0.95	(0.91)	5.81
S	0.66-1.08	(0.22)	0.05-0.33	(0.14)	0
As	0 -0.08	(0.02)	0.01-0.04	(0.01)	0
		In ppm			
Ni	50-164	(92)	61-200	(94)	2467
Rb	<20-56	(22)	<20-67	(<20)	0
Sr	85-169	(115)	69-167	(106)	20
Y	<20-26	(<20)	20-27	(<20)	<20
Zr	49-76	(65)	44-97	(83)	<20
Nb	<20	(<20)	<20	(<20)	<20
Cr	129-685	(368)	200-770	(431)	3825
Co	<40-61	(<40)	<40-59	(<40)	177
Pb	<20	(<20)	<20	(<20)	<20
Cu	32-135	(96)	33-148	(97)	20
Zn	50-1296	(190)	45-257	(80)	46
*Ce	n.d.		<20	(<20)	n.d.
*Nd	n.d.		<20	(<20)	n.d.
*V	n.d.		207-306	(255)	n.d.
*La	n.d.		<20	(<20)	n.d.
*Ba	n.d.		<20-127	(27)	n.d.
		In ppb			
Au	34-880	(233)	5.7-580	(55)+	2.7

1. Range in chemical composition of 11 basaltic komatiites.
2. Range in chemical composition of 30 magnesium tholeiitic basalts.
3. Chemical composition of serpentinized basaltic komatiite (drill core sample).

*- 11 samples analysed.

+- 29 samples analysed.

n.d. not determined.

Values in parentheses are average compositions.

TABLE 5-6: Variations in Major and Trace Elements for Main
(cont'd) Lithologic Units on Level 30.

	4		5		6	
			In Weight Percent			
SiO_2	47.79-58.93	(53.04)	49.41-57.82	(53.78)	58.90-79.74	(72.07)
Al_2O_3	8.75-9.12	(8.45)	9.44-11.57	(10.43)	9.88-18.78	(13.53)
Fe_2O_3	7.29-13.82	(10.77)	15.88-29.32	(23.68)	1.91-16.93	(7.57)
MgO	6.41-8.14	(7.18)	5.33-6.02	(5.76)	0.48-4.53	(1.76)
CaO	9.18-12.01	(10.38)	0.65-5.51	(2.56)	0.23-5.20	(1.18)
Na_2O	<0.20	(<0.20)	<0.20	(<0.20)	0 -0.35	(<0.20)
K_2O	0.48-1.57	(1.19)	0.39-0.57	(0.46)	<0.20 -0.39	(0.21)
TiO_2	0.47-0.75	(0.57)	0.85-1.03	(0.92)	0.70-1.24	(0.98)
MnO	0.18-0.35	(0.27)	0.24-0.41	(0.30)	0.04-0.46	(0.21)
P_2O_5	0 -0.02	(0.02)	0		0.01-0.07	(0.05)
L.O.I.	5.92-7.17	(6.36)	1.48-2.55	(1.85)	0.92-5.70	(2.36)
CO_2	5.92-7.17	(6.36)	0.38-1.08	(0.62)	0.30-3.30	(0.95)
H_2O	0		0.40-2.15	(1.23)	0.53-2.40	(1.41)
S	0.49-1.43	(1.05)	0.09-0.22	(0.16)	0.04-0.20	(0.13)
As	0.03-1.67	(0.63)	0.01-0.05	(0.03)	0.01-0.02	(0.01)*
			In ppm			
Ni	60-101	(83)	144-195	(175)	57-112	(81)*
Rb	<20-36	(28)	<20	(<20)	<20	(<20)
Sr	64-115	(98)	54-69	(64)	37-66	(53)*
Y	<20-22	(<20)	33-36	(34)	<20	(<20)*
Zr	41-65	(52)	62-66	(64)	35-86	(60)*
Nb	<20	(<20)	0 -<20	(<20)	0 -<20	(<20)*
Cr	150-370	(290)	326-403	(358)	242-1412	(564)*
Co	<40-56	(<40)	87-175	(137)	<40-51	(<40)*
Pb	0 -<20	(<20)	<20	(<20)	0 -<20	(<20)*
Cu	45-127	(99)	31-69	(50)	45-170	(139)*
Zn	90-135	(107)	86-158	(124)	21-103	(46)
Ce	50'		21-25	(23)	<20	(<20)+
Nd	<20'		<20	(<20)	<20-21	(<20)+
V	237'		298-370	(336)	238-331	(278)+
La	<20'		<20	(<20)	<20	(<20)+
Ba	<20'		21-39	(32)	38-80	(53)+
			In ppb			
Au	1000-21,000	(9270)	5.6-12,900	(4310)	15-60	(26)

4. Range in chemical composition of 3 mafic sediments, North x-cut.
5. Range in chemical composition of 3 mafic sediments, South x-cut.
6. Range in chemical composition of 8 felsic volcaniclastites.

*- 5 samples analysed.
+- 4 samples analysed.
'- 1 sample analysed.

Values in parentheses are average compositions.

TABLE 5-6: Variations in Major and Trace Elements for Main
(cont'd) Lithologic Units on Level 30.

	7		8	9
		In Weight Percent		
SiO_2	55.47-57.82	(56.25)	57.39	69.37
Al_2O_3	15.82-16.11	(15.90)	13.51	13.96
Fe_2O_3	5.80-7.67	(7.05)	4.39	3.24
MgO	3.37-5.55	(4.01)	7.40	2.22
CaO	6.43-7.18	(6.83)	8.67	5.67
Na_2O	2.29-3.31	(3.01)	1.53	1.56
K_2O	2.29-2.52	(2.36)	1.68	1.45
TiO_2	1.06-1.14	(1.10)	0.68	0.44
MnO	0.11-0.13	(0.12)	0.10	0.05
P_2O_5	0.31-0.35	(0.33)	0.30	0.08
L.O.I.	1.57-2.71	(2.29)	3.03	1.97
CO_2	1.57-2.71	(2.29)	3.03	1.73
H_2O	0-0.03	(0)	0	0.24
S	0.06-0.12	(0.08)	1.31	0.02
As	<0.01	(<0.01)	0	<0.01
		In ppm		
Ni	15-40	(31)	89	24
Rb	50-66	(55)	32	51
Sr	603-739	(683)	840	458
Y	<20-25	(20)	<20	<20
Zr	187-208	(199)	133	177
Nb	<20-23	(<20)	<20	<20
Cr	64-82	(73)	157	35
Co	<40	(<40)	<40	<40
Pb	<20-23	(20)	21	<20
Cu	<20-43	(23)	35	<20
Zn	98-117	(112)	57	54
Ce	108-110	(109)*	n.d.	40
Nd	41-44	(43)*	n.d.	20
V	108-109	(109)*	n.d.	50
La	42-60	(51)*	n.d.	27
Ba	743-799	(761)*	n.d.	400
		In ppb		
Au	1.11-3.21	(2.12)	15.70	17.31

7. Range in chemical composition of 8 samples from andesitic dykes.
8. Chemical composition of 1 sample from a basaltic dyke.
9. Chemical composition of 1 sample of quartz feldspar porphyry (mine terminology).

*- 2 samples analyzed.

n.d. not determined.

Values in parentheses are average compositions.

TABLE 5-6 (cont'd) : Variations in Major and Trace Elements for Main Lithologic Units on Level 30.

	10		11	
In Weight Percent				
SiO_2	66.80-70.27	(68.24)	62.59-63.42	(63.07)
Al_2O_3	8.60-9.82	(9.29)	10.07-11.07	(10.47)
Fe_2O_3	5.08-9.29	(7.42)	6.60-7.60	(7.18)
MgO	1.78-4.54	(2.73)	1.67-2.74	(2.08)
CaO	0.44-5.61	(2.18)	1.21-2.69	(1.78)
Na_2O	0.24-0.45	(0.38)	0.47-0.76	(0.60)
K_2O	1.19-2.61	(2.09)	1.92-2.73	(2.46)
TiO_2	0.51-0.65	(0.59)	0.71-0.74	(0.73)
MnO	0.11-0.17	(0.13)	0.04-0.05	(0.04)
P_2O_5	0.02	(0.02)	0.03-0.08	(0.05)
L.O.I.	5.01-6.63	(6.04)	9.83-10.30	(10.14)
CO_2	5.01-6.63	(6.04)	9.83-10.30	(10.14)
H_2O	0		0	
S	0.61-1.19	(0.90)	1.33-1.53	(1.42)
As	0.59-1.08	(0.88)	0.48-1.59	(0.94)
In ppm				
Ni	137-194	(163)	128-424	(229)
Rb	29-51	(42)	41-54	(46)
Sr	76-89	(81)	99-180	(143)
Y	<20	(<20)	<20	(<20)
Zr	29-40	(34)	27-43	(38)
Nb	0		0	
Cr	266-326	(304)	198-207	(201)
Co	<40-40	(<40)	<40-54	(41)
Pb	<20	(<20)	<20	(<20)
Cu	44-114	(81)	<20-53	(38)
Zn	75-1383	(739)	58-123	(81)
Ce	207-369	(299)	182-610	(358)
Nd	<20	(<20)	<20	(<20)
V	144-215	(190)	208-290	(244)
La	<20	(<20)	<20	(<20)
Ba	95-128	(111)	93-145	(120)
In ppb				
Au	3400-8760	(6220)	2760-3320	(3070)

10. Range in chemical composition of 3 samples from the main ore zone (30-S580 E.Drift).

11. Range in chemical composition of 3 samples from the lean iron formation (mine terminology).

Values in parentheses are average compositions.

TABLE 5-7: Representative Analyses of Mafic Flows in Munro Township.

	1	2	3	4
	In Weight Percent			
SiO_2	50.4	51.2	50.4	48.6
Al_2O_3	12.0	13.9	12.6	12.0
Fe_2O_3	1.9	2.58	13.9	2.8
FeO	9.4	8.2		12.0
MgO	10.2	7.5	5.11	4.67
CaO	11.1	10.8	11.9	9.4
Na_2O	0.56	1.77	1.21	4.6
K_2O	0.28	0.02	0.77	0.05
TiO_2	0.57	0.80	1.39	1.51
MnO	0.17	0.17	0.24	0.21
P_2O_5	n.d.	n.d.	n.d.	n.d.
L.O.I.	3.33	3.48	2.3	4.3
CO_2	0.2	0.1	n.d.	1.37
H_2O	3.13	3.38	n.d.	2.93
S	0.12	0.10	0.10	0.27
As	n.d.	n.d.	n.d.	n.d.
	In ppm			
Ni	93	89	67	99
Rb	8	2	13	1
Sr	97	94	130	67
Y	n.d.	n.d.	n.d.	n.d.
Zr	n.d.	n.d.	n.d.	n.d.
Nb	n.d.	n.d.	n.d.	n.d.
Cr	143	227	82	209
Co	66	47	70	346
Pb	n.d.	n.d.	n.d.	n.d.
Cu	n.d.	n.d.	n.d.	n.d.
Zn	79	n.d.	125	n.d.
	In ppb			
Au	n.d.	n.d.	n.d.	n.d.

1. Basaltic komatiite lava (Arndt et al., 1977).
2. Basaltic komatiite lava (Arndt et al., 1977).
3. Tholeiitic basalt (Arndt et al., 1977).
4. Tholeiitic basalt (Arndt et al., 1977).

n.d. not determined.

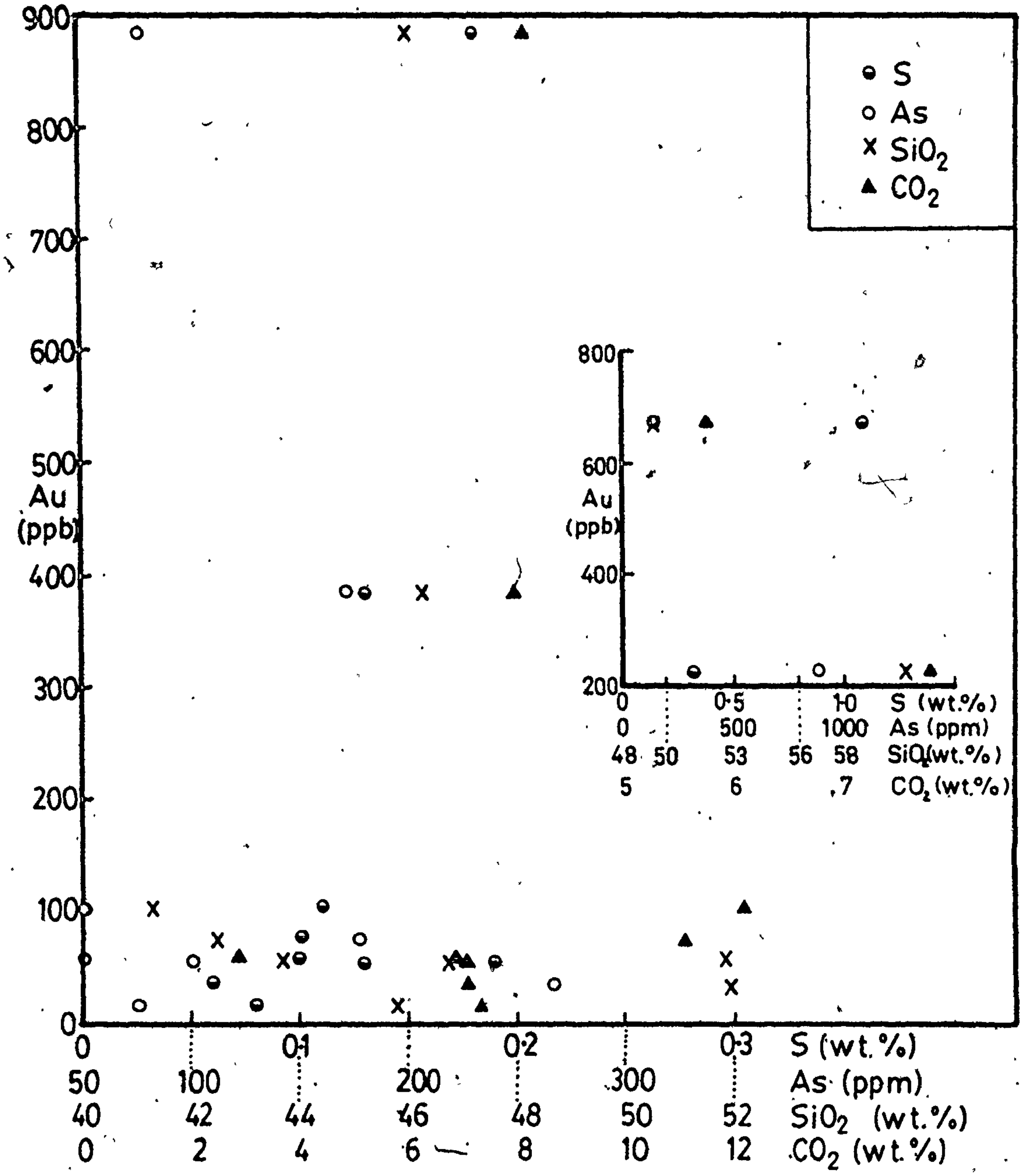
(<0.20 wt %) and enriched in Cr. In the 30 Level volcanics, carbonate alteration is twice as great in the basaltic komatiites (mean 7.66 wt %) and gold values are greater by a factor of 4 (mean 233 ppb)

The drill core sampled and logged as "chickenfeed" (mine terminology) is clearly komatiitic with high MgO (33.01 wt %), Ni (2467 ppm) and Cr (3825 ppm) values. Gold content is low (2.3 ppb).

In an attempt to determine an indicator of gold mineralization and to better understand the effects of alteration, Au was plotted against S, As, SiO_2 and CO_2 for the mafic flows on the 30 Level (Figures 5-10 and 5-11). Although no distinct linear trends are evident some broad generalizations can be made. In the case of the basaltic komatiites high gold values (>100 ppb) are generally accompanied by high S (>0.1 wt %) and occasionally high As and CO_2 contents (Fig. 5-10). There is no correlation between Au and SiO_2. In the magnesium tholeiites (Fig. 5-11) high gold values (>40 ppb) are generally accompanied by high S (>0.15 wt %) and occasionally high As (>200 ppb) contents. There is no correlation between Au and CO_2 or SiO_2.

Profiles taken about the ore zone in the north and south crosscuts indicate similar relationships, and better exemplify the positive correlation between some of these elements. In the south crosscut (Fig. 5-12) there is a positive correlation between Au and S (with one exception, sample 30-02), and to a lesser extent between Au and As in

FIGURE 5-10. Au vs. S, As, SiO_2 and CO_2 for the basaltic komatiites, 30 Level, Dickenson Mine.



900
800
700
600
500
400
300
200
100
0
Au (ppb)
S
As
SiO2
CO2
800
600
400
200
Au (ppb)
0 0·5 1·0 S (wt.%)
0 500 1000 As (ppm)
48 50 53 56 58 SiO2 (wt.%)
5 6 7 CO2 (wt.%)
0 0·1 0·2 0·3 S (wt.%)
50 100 200 300 As (ppm)
40 42 44 46 48 50 52 SiO2 (wt.%)
0 2 4 6 8 10 12 CO2 (wt.%)

FIGURE 5-11. Au vs. S, As and SiO_2 for the magnesium tholeiites, 30 Level, Dickenson Mine.

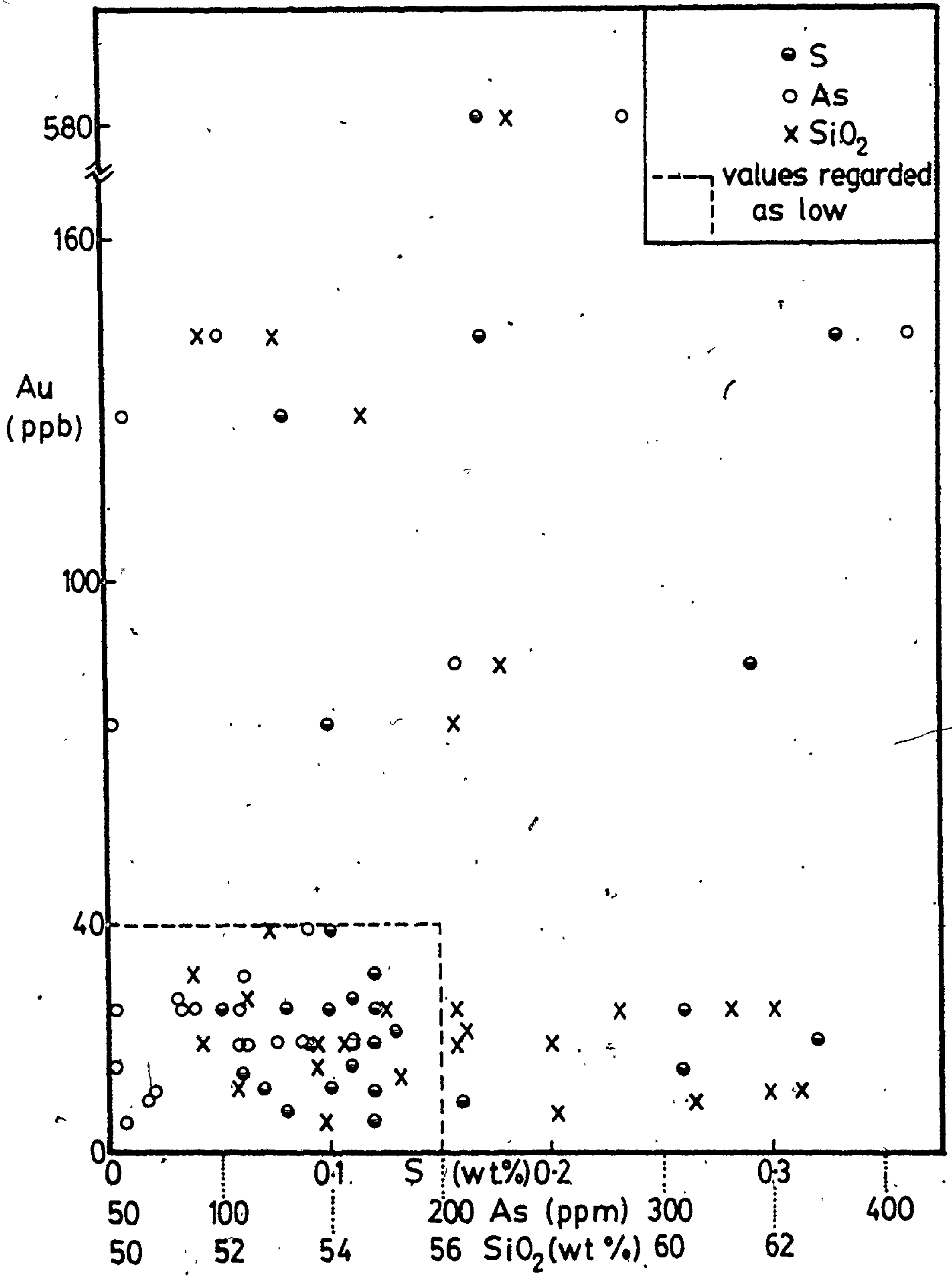
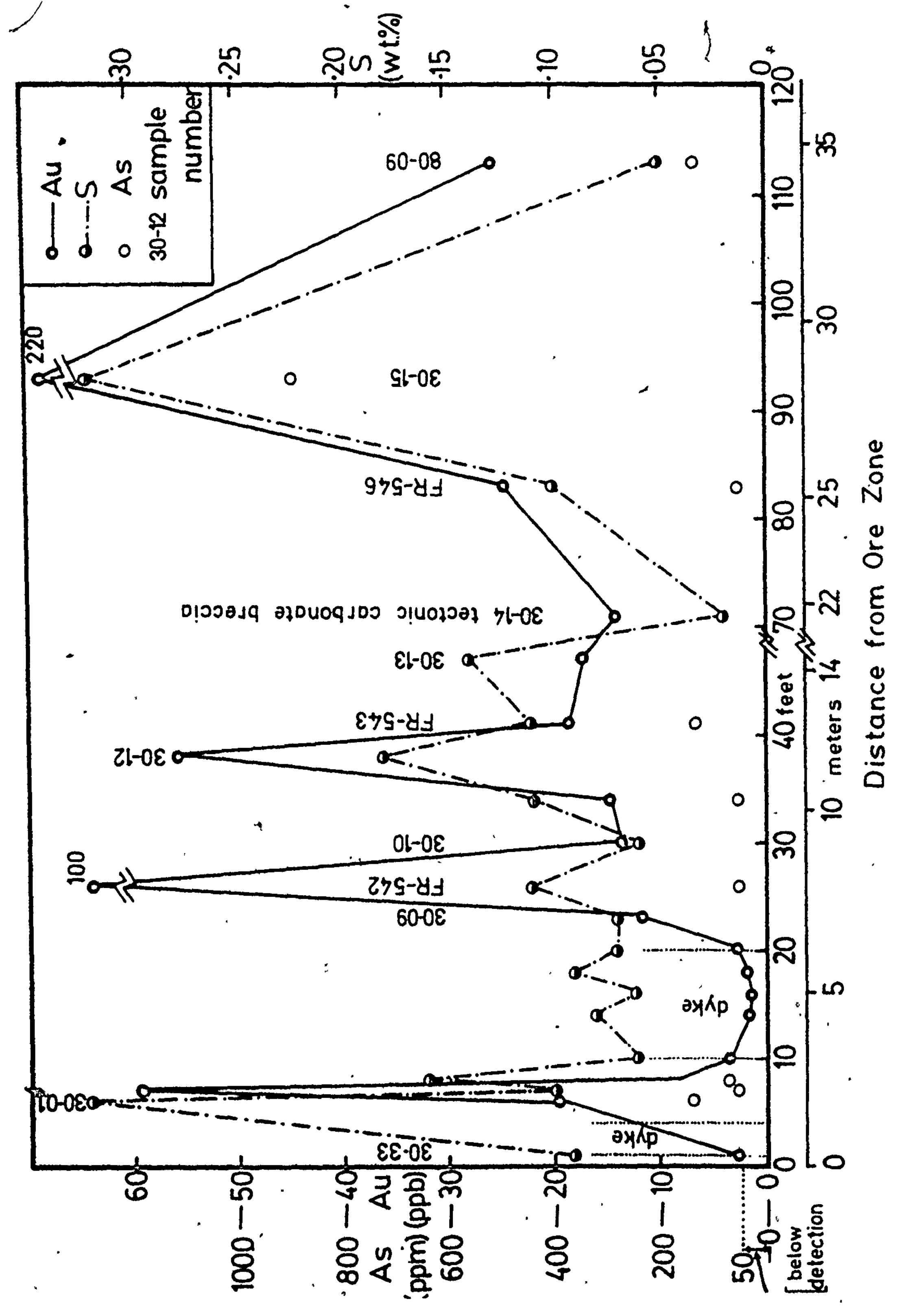

● S
○ As
x SiO₂
values regarded as low
Au (ppb)
580
160
100
40
0
0
0·1
S (wt%)
0·2
0·3
50
100
200 As (ppm)
300
400
50
52
54
56 SiO₂(wt %)
60
62

FIGURE 5-12. Profiles for Au, As and S;
South crosscut, 30 Level.


Au
S
As
30-12 sample number
S (wt.%)
.30
.25
.20
.15
.10
.05
0
As (ppm)
1000
800
600
400
200
50
0
Au (ppb)
60
50
40
30
20
10
0
below detection
Distance from Ore Zone
feet
0
10
20
30
40
70
80
90
100
110
120
meters
0
5
10
14
22
25
30
35
30-33
30-01
dyke
30-09
FR-542
100
30-10
30-12
FR-543
30-13
30-14 tectonic carbonate breccia
FR-546
220
30-15
80-09

that all three metals are often well above the profile background level in the sample. Sample 30-02 is high in CO_2. In the same crosscut Figure 5-13 illustrates a positive correlation of Au with carbonate alteration and a negative correlation with SiO_2. Profiles of the north crosscut (Figures 5-14 and 5-15) indicate a strong positive correlation between Au, As and S and to a lesser extent CO_2. There is also a strong negative correlation with SiO_2, in that as silica increases, gold decreases. Figures 5-16 and 5-17 are a compilation of these profiles and also illustrate the geology about the ore zone.

Profiles of the altered volcanics taken about the ore zone in two drilling stations 12 m west of the south crosscut are illustrated in Figure 5-18 and 5-19. Samples from the south drilling stations are low in Au, As and S and no trends are evident. SiO_2 and CO_2 are highly variable. Samples from the north drilling station however, exhibit a positive correlation with Au, S and to a lesser extent As and CO_2, with one exception (sample 30-38). There is generally a negative correlation with SiO_2.

The following generalizations are drawn from the profiles:

1) There is little suggestion of a systematic gradient of metal values away from the ore zone into hanging and footwall rocks. The most distinctive feature of the profiles is occasional high gold content (often accompanied by high S and As values) confined to one sample or to a few adjacent samples.

FIGURE 5-13. Profiles for Au, SiO_2, and CO_2; South crosscut, 30 Level.

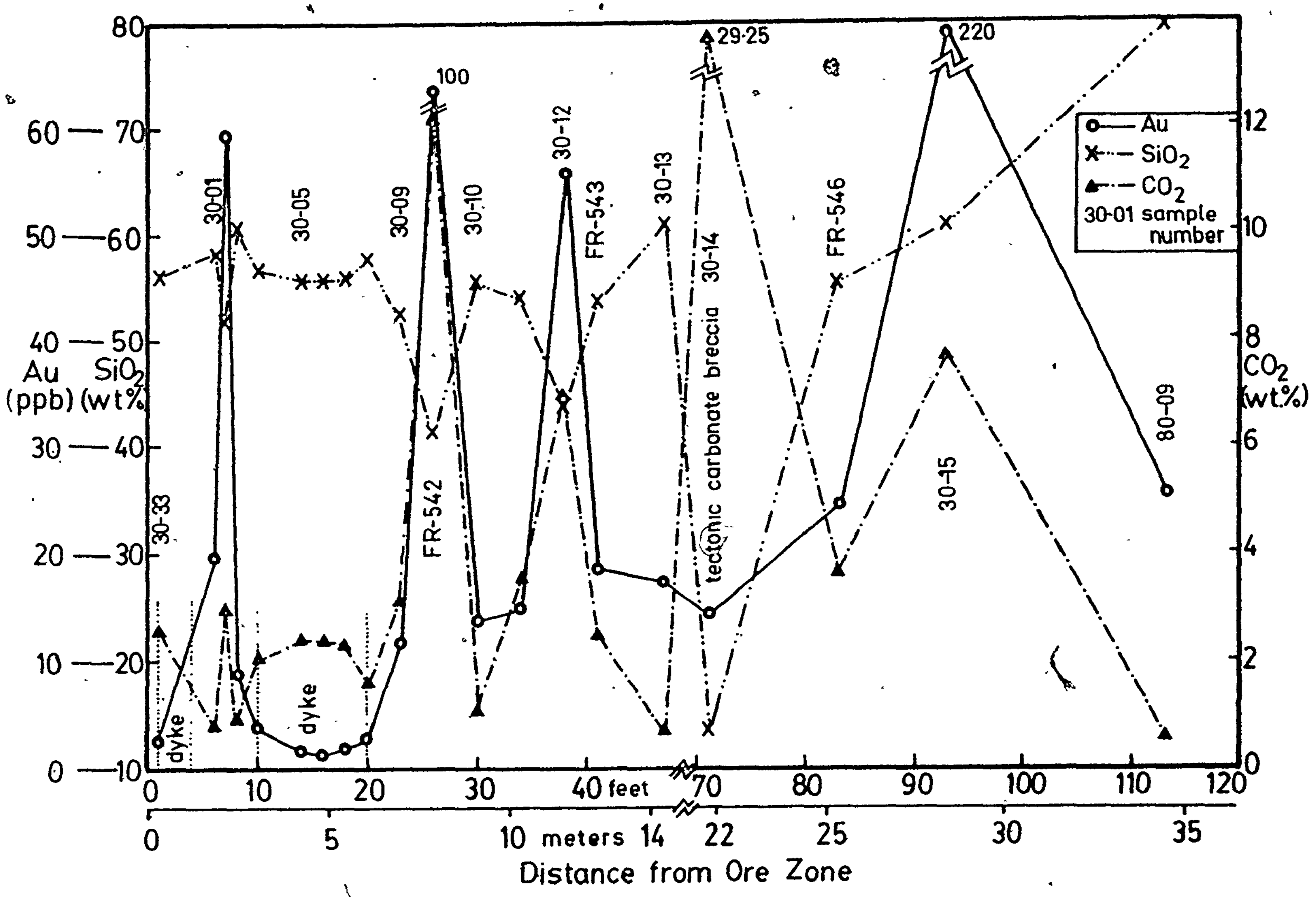
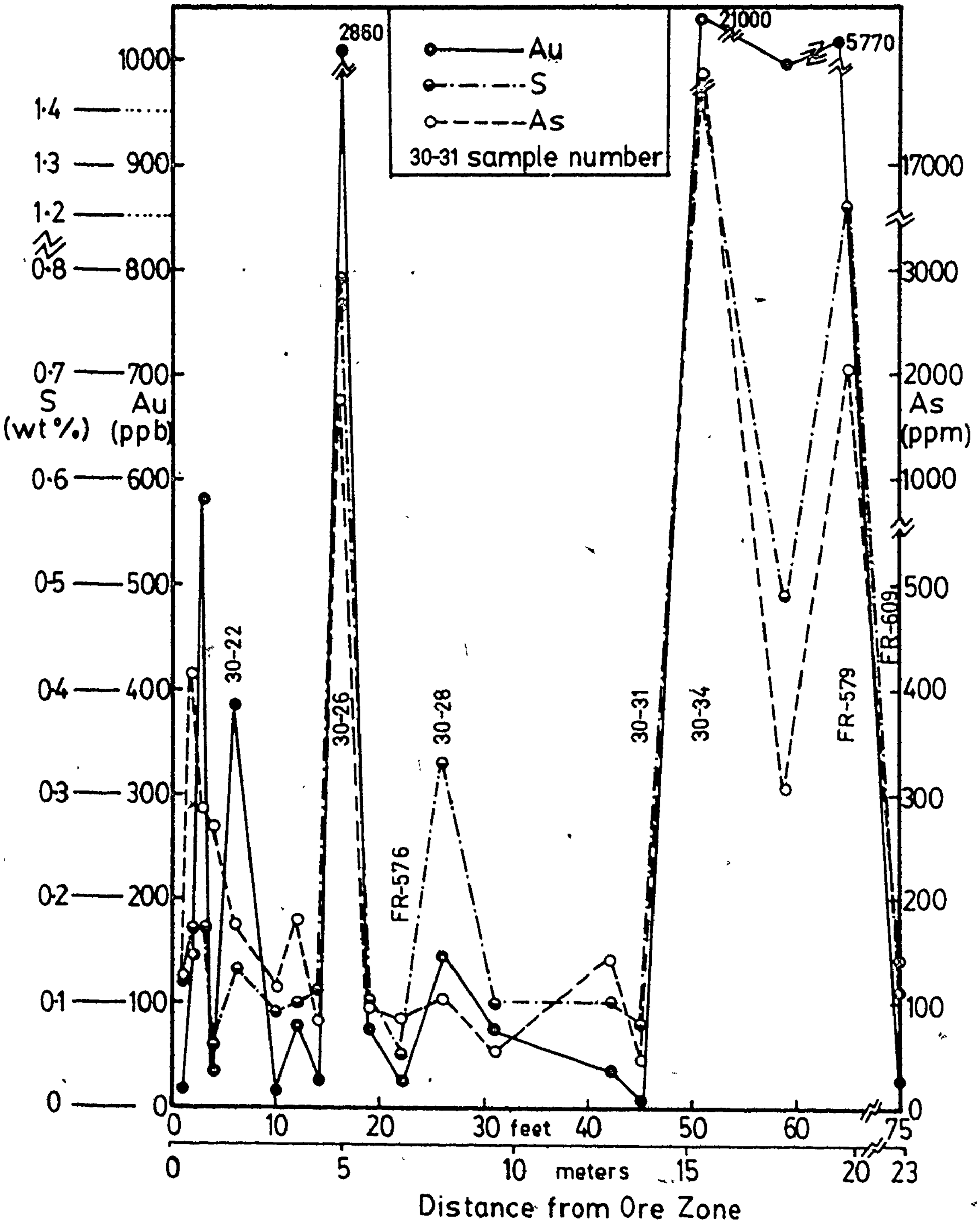

Au
SiO₂
CO₂
30-01 sample number
Au (ppb)
SiO₂ (wt%)
CO₂ (wt%)
0 10 20 30 40 50 60
10 20 30 40 50 60 70 80
0 2 4 6 8 10 12
0 10 20 30 40 feet 70 80 90 100 110 120
0 5 10 meters 14 22 25 30 35
Distance from Ore Zone
30-33
dyke
30-01
30-05
dyke
30-09
100
FR-542
30-10
30-12
FR-543
30-13
30-14
29·25
tectonic carbonate breccia
FR-546
220
30-15
80-09

FIGURE 5-14. Profiles for Au, S and As;
North crosscut, 30 Level.



Au
S
As
30-31 sample number
2860
21000
5770
1000
900
800
700
600
500
400
300
200
100
0
1·4
1·3
1·2
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0
S (wt%)
Au (ppb)
17000
3000
2000
1000
500
400
300
200
100
0
As (ppm)
30-22
30-26
FR-576
30-28
30-31
30-34
FR-579
FR-609
0
10
20
30 feet
40
50
60
75
0
5
10 meters
15
20
23
Distance from Ore Zone

FIGURE 5-15. Profiles for Au, SiO_2 and CO_2; North crosscut, 30 Level.

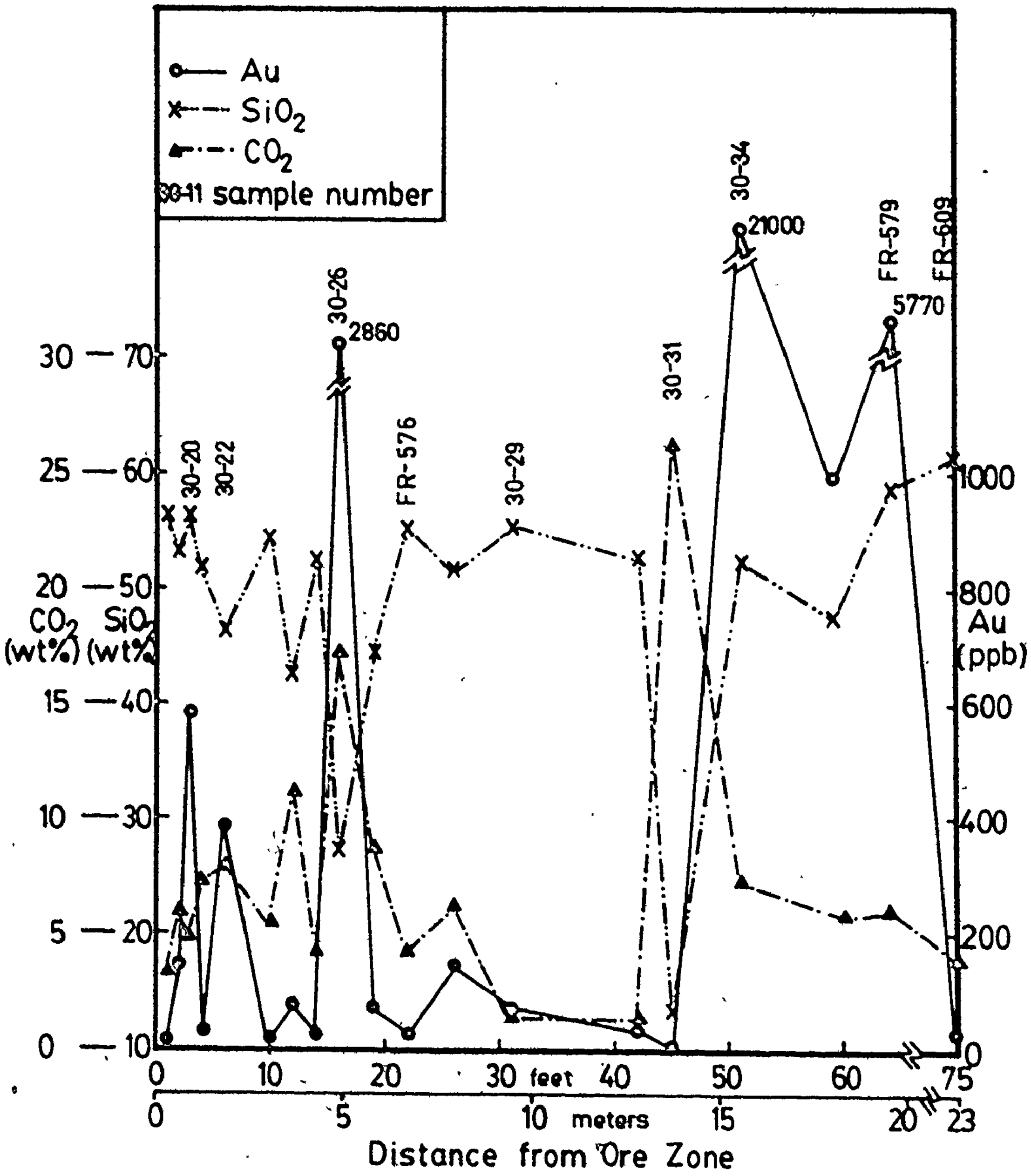
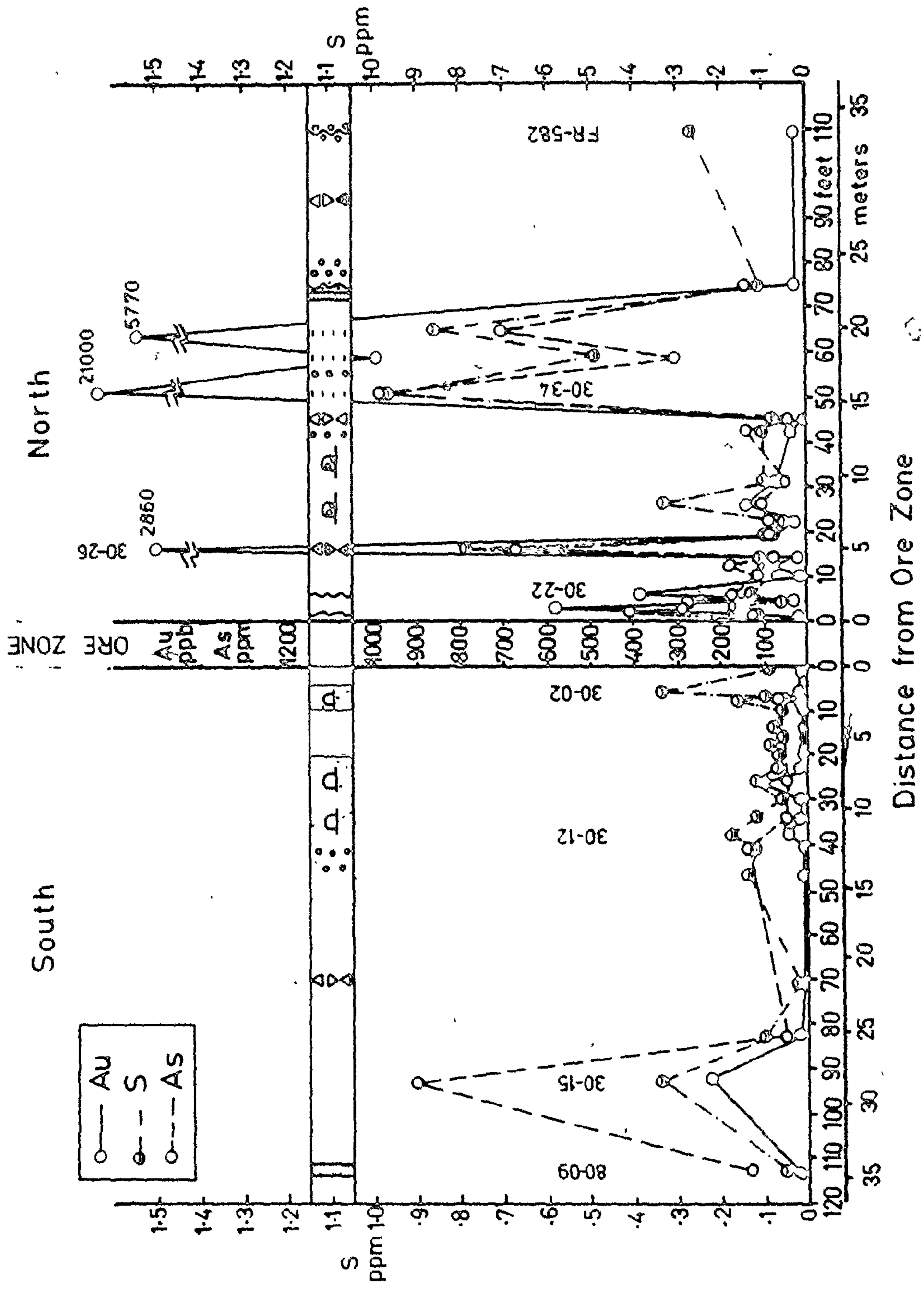

Au
SiO2
CO2
30-11 sample number
30-20
30-22
30-26
2860
FR-576
30-29
30-31
30-34
21000
FR-579
5770
FR-609
CO2 (wt%)
SiO2 (wt%)
30 — 70
25 — 60
20 — 50
15 — 40
10 — 30
5 — 20
0 — 10
Au (ppb)
1000
800
600
400
200
0
0
10
20
30 feet
40
50
60
75
0
5
10 meters
15
20
23
Distance from Ore Zone

FIGURE 5-16. Profiles of Au, S, As and the geology about the main ore zone, 30 Level, Dickenson Mine.


South
North
ORE ZONE
Au ppb
As ppm
S ppm
1·5
1·4
1·3
1·2
1·1
1·0
·9
·8
·7
·6
·5
·4
·3
·2
·1
0
1200
1000
900
800
700
600
500
400
300
200
100
Au
S
As
80-09
30-15
30-12
30-02
30-22
30-26
30-34
FR-582
2860
21000
5770
Distance from Ore Zone
feet
meters
120
110
100
90
80
70
60
50
40
30
20
10
0
35
30
25
20
15
10
5

LEGEND (for Figures 5-16 and 5-17)

□	Mafic flows
□	Andesitic dykes
□	Felsic volcaniclastites
△▽△▽	Flowtop breccia
△▽△▽	Tectonic carbonate breccia
▤	Mafic sediments
∩	Pillows
░	garnets
○	amygdules
〰	shear zone
〰	silicified shear zone
30-15	sample number

FIGURE 5-17. Profiles of Au, SiO_2, CO_2 and the geology about the main ore zone, 30 Level, Dickenson Mine.

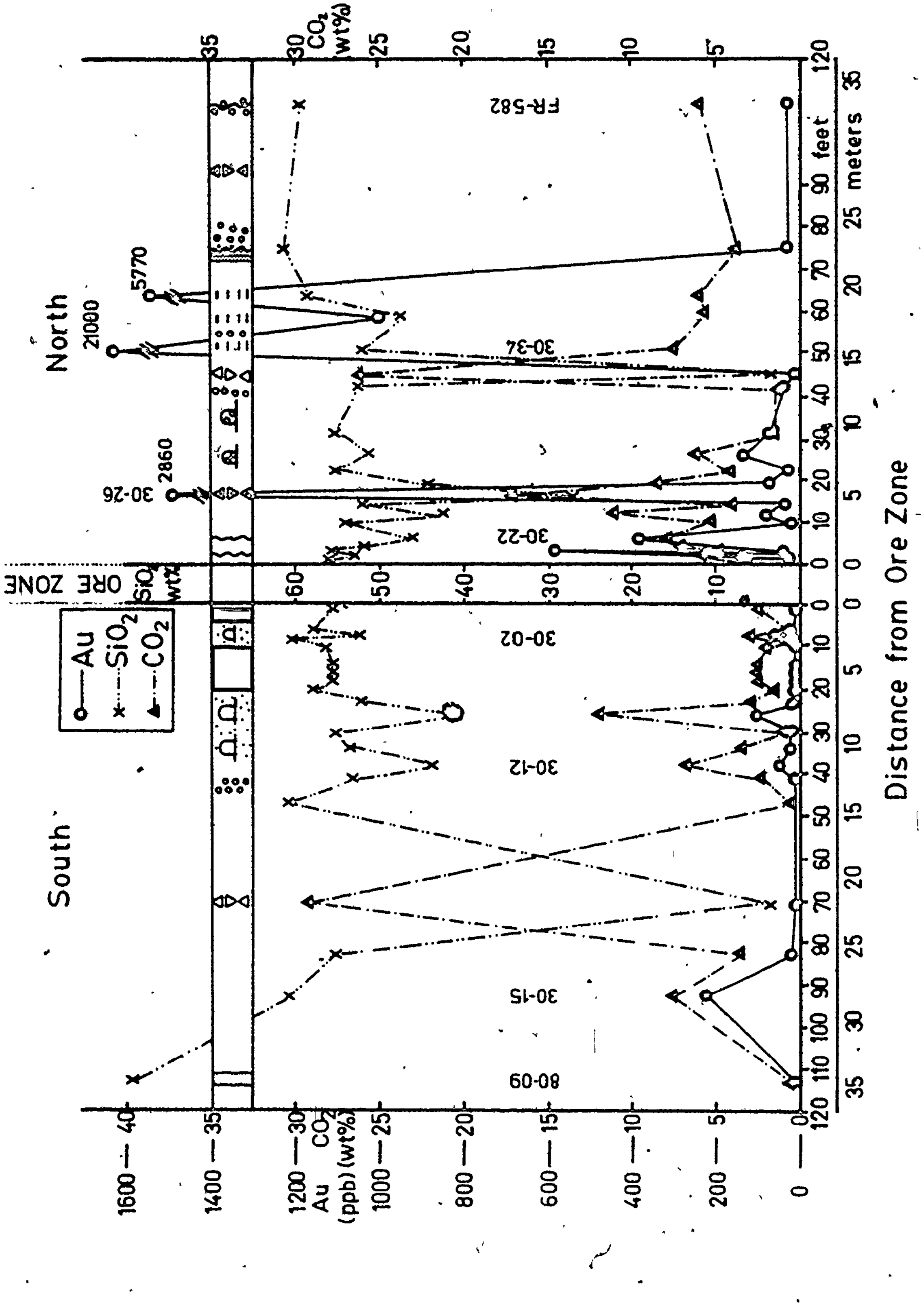

Au
SiO$_2$
CO$_2$
North
South
ORE ZONE
SiO$_2$ wt%
CO$_2$ (wt%)
Au (ppb)
CO$_2$ (wt%)
1600
1400
1200
1000
800
600
400
200
0
40
35
30
25
20
15
10
5
0
60
50
40
30
20
10
2860
21000
5770
30-02
30-12
30-15
80-09
30-22
30-26
30-34
FR-582
120
110
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
120
35
30
25
20
15
10
5
0
5
10
15
20
25
35
feet
meters
Distance from Ore Zone

FIGURE 5-18. Profiles of Au, S and As about the main ore zone in the drilling station, 30 Level, Dickenson Mine.

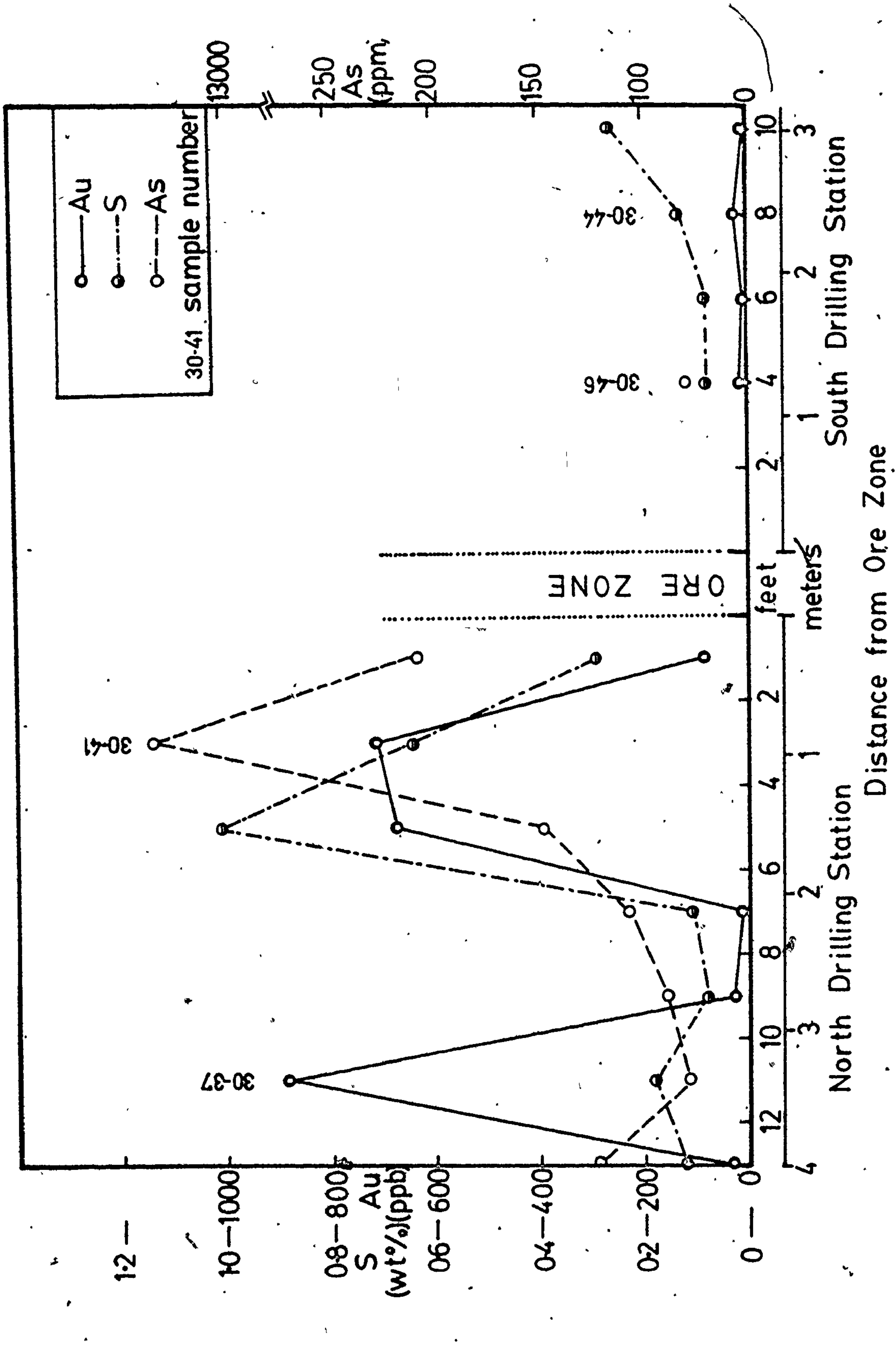
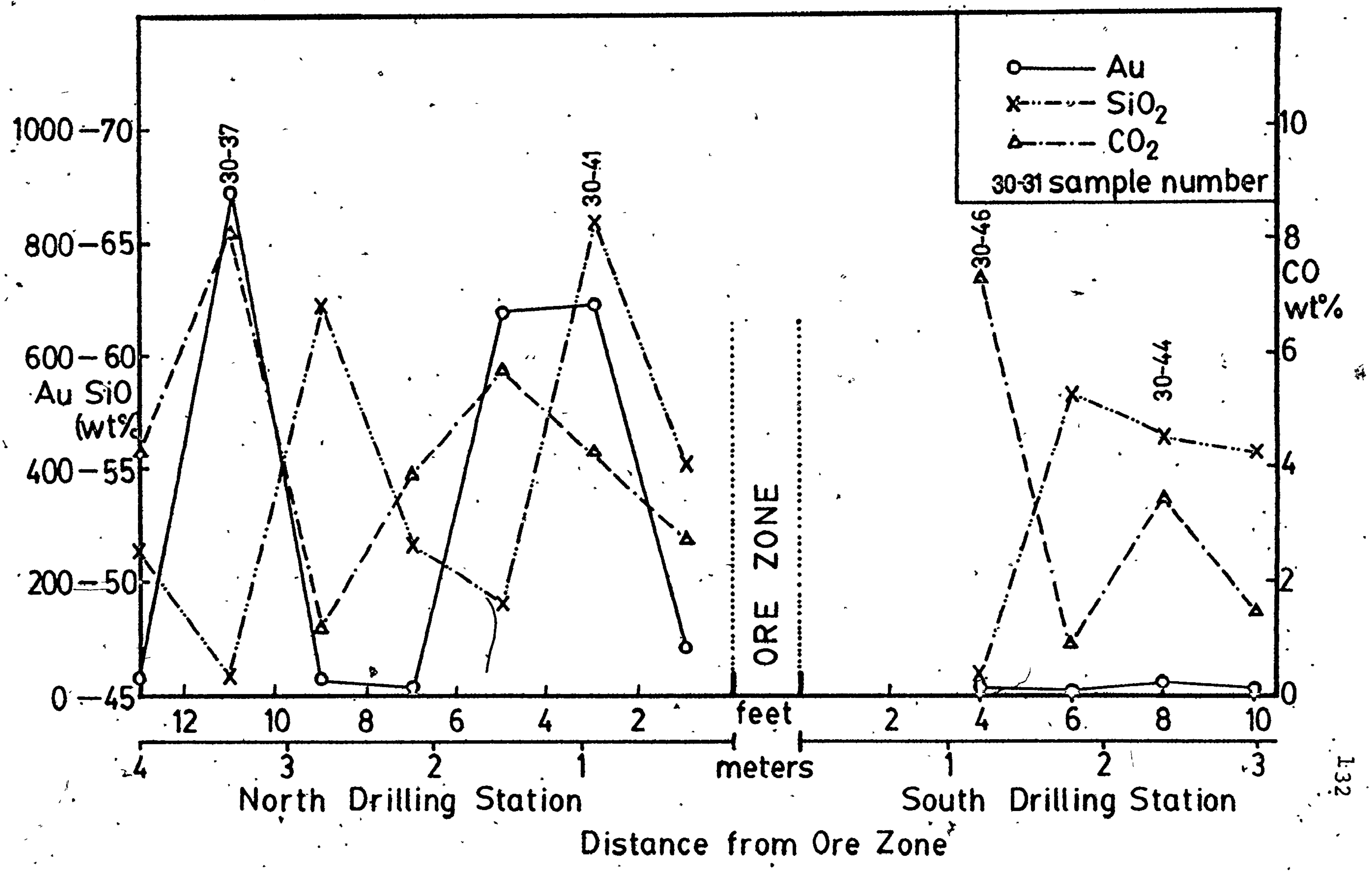

Au
S
As
30-41 sample number
S (wt%)
Au (ppb)
1·2
1·0
0·8
0·6
0·4
0·2
0
1000
800
600
400
200
0
As (ppm)
13000
250
200
150
100
0
30-37
30-41
30-44
30-46
ORE ZONE
feet
meters
4
12
10
8
6
4
2
0
2
4
6
8
10
3
2
1
0
1
2
3
North Drilling Station
South Drilling Station
Distance from Ore Zone

FIGURE 5-19. Profiles of Au, SiO_2 and CO_2 about the main ore zone in the drilling station, 30 Level, Dickenson Mine.


Au
SiO$_2$
CO$_2$
30-31 sample number
30-37
30-41
30-46
30-44
ORE ZONE
1000 – 70
800 – 65
600 – 60
400 – 55
200 – 50
0 – 45
Au SiO
(wt%)
10
8
6
4
2
0
CO
wt%
12
10
8
6
4
2
feet
2
4
6
8
10
4
3
2
1
meters
1
2
3
North Drilling Station
South Drilling Station
Distance from Ore Zone

2) There is a strong positive correlation between Au, As and S, particularly in the north crosscut and drilling station. To a lesser extent these metals are accompanied by high CO_2 values. There is a distinct negative correlation between Au and SiO_2.

3) There is a distinct asymmetry of gold distribution about the ore zone, in that the metal is enriched in the north crosscut by a factor of 5 relative to the south crosscut. In the north drilling station gold values are 20 times greater than in the south drilling station.

5.4.2 Felsic Volcaniclastites

This suite of rocks which is intercalated with the mafic flows and sediments consists essentially of SiO_2 (mean 72.07 wt %), Al_2O_3 (mean 13.53 wt %) and total Fe (mean 7.57 wt %). The bulk chemistry is a reflection of the main mineral constituents, which are quartz, andalusite, micas and iron sulphides. Gold values are low (mean 26 ppb; range 15 to 60 ppb).

It has been suggested to the author that some of these silicic units may be rhyolites. The field characteristics noted in Chapter 5 suggest that these rocks are not flows but rather volcaniclastites. Their chemistry is not that of unaltered silicic volcanics (Tables 5-3(a) and 5-3(b)) in the following respects:

1) Total Fe and MnO are as much as 4 times too high;
2) TiO_2 which ranges from 0.70 to 1.24 wt % (mean 0.98 wt %) is 2 to 3 times higher, while P_2O_5 is 2 to 3 times lower,
3) Ni and Co are 3 to 10 times too high,
4) Cr which ranges from 242 to 1412 ppm (mean 564 ppm) is as much as 100 times higher.

Silicification of an andesitic flow is also an unlikely origin for these units, because such alteration would result in the loss of titanium and iron (Gibson and Watkinson, 1979). The most accomodating hypothesis to explain the field and chemical characteristics of these rocks, is that they have a bimodal source, including both felsic and mafic rocks.

5.4.3 Mafic Sediments

The mafic sediments in the north crosscut differ in some aspects of their chemistry from those in the south crosscut. Some of the more significant comparisons and variations in their mean values are as follows. Both contain similar amounts of SiO_2 (53 to 54 wt %) and Al_2O_3 (8.5 to 10.5 wt %). However the sediments in the south crosscut contain much more total Fe (24 to 11 wt %) and TiO_2 (0.92 to 0.57 wt %), and much less CaO (2.7 to 10.4 wt %), CO_2 (0.6 to 6.4 wt %), S (0.16 to 1.05 wt %), As (0.03 to 0.63 wt %) and Au (4300 to 9300 ppb). These compositional differences are also reflected in the mineralogy, in that the south crosscut sediments are more garnetiferous (almandine) and micaceous (penninite), and contain fewer carbonates and sulphides than those in the north crosscut.

With respect to the enclosing magnesium tholeiites the sediments in the north crosscut contain less SiO_2, Al_2O_3 and TiO_2 and more total Fe, CaO, K_2O, CO_2, As, S and Au. The auriferous sample from the south crosscut is chemically and texturally analogous to the auriferous sediments on the 25 Level.

5.4.4 Ore Zones

There are some significant compositional differences between the ore zones and their host rocks. With respect to the pillowed mafic volcanics, the main gold horizon (30-S580 E. Drift) contains more SiO_2, K_2O, S, As, Zn, Ce, Ba and Au; and less Al_2O_3, total Fe, MgO, CaO, TiO_2 and Zr.

Compared with the felsic volcanics to the immediate north, the "lean iron formation" contains more alkalies, CO_2 S, As, Ce, Ba and Au, and less SiO_2, Al_2O_3, TiO_2, MnO, Cu and Zr.

A comparison of these two ore zones, based upon their mean element abundances indicates that they are chemically similar with the following variations. The main gold horizon contains more SiO_2 (68 to 63 wt %), Cr (304 to 201 ppm), Cu (80 to 40 ppm), Zn (740 to 80 ppm) and Au (6200 to 3100 ppb). It contains less CO_2 (6.0 to 10.0 wt %) and S (0.90 to 1.42 wt %). Both the main ore zone and the "lean iron formation" are quite potassic (2.09 and 2.46 wt % respectively), when compared with all other pre-tectonic units on the 30 Level.

There is one further noteworthy observation. With increasing gold content samples from the main ore zone exhibit a strong enrichment in As, S, Zn, Ce and total Fe; a moderate enrichment in Cr, Ni, V and Ba, and a depletion in MgO and Zr. With increasing gold content samples from the "lean iron formation" exhibit a strong depletion in As, Ni, Zn and Ce, and a strong enrichment in only S.

5.4.5 Intrusives

The dykes on this level are calc-alkalic andesites and basalts. They have undergone little alteration (L.O.I.< 3.0 wt %). Gold values are generally low with a mean value of 2.1 ppb for the andesites and 15.7 ppb for the basalt.

The quartz feldspar porphyry is calc-alkalic and dacitic in composition (Figure 5-1). It has undergone little alteration (L.O.I. < 2.0 wt %) and has a gold value of 17.3 ppb.

A characteristic of not only these 30 Level intrusives but those sampled and analysed from other levels, is that their Na_2O contents are significantly higher than for other igneous rocks in the mine environment, suggesting that they post-date the Na-depletion event.

CHAPTER 6

A DISCUSSION

The orebodies at Dickenson Mine lie along the eastern flank of a volcanic complex consisting mainly of massive to pillowed basaltic komatiites and magnesium tholeiites with lesser amounts of ultrabasic and felsic flows. During periods of volcanic quiescence interflow exhalites and proximal volcaniclastites developed within the volcanic pile. To the immediate east of this complex lies a large basin of mixed clastic and chemical sediments (Fig. 1-4).

6.1 Alteration

Numerous periods of alteration and the high intensity of metamorphism, make it difficult to ascertain the earliest alteration event. The mafic flows are clearly subaqueous with chloritized pillow rims. Spilitization, as described by Hyndman (1972) may have occurred but specific evidence is lacking. The flows have been pervasively leached of alkalies, particularly sodium, and one must conclude that large scale hydrothermal activity (syn ? post ? volcanic) has affected rocks in the mine environment. However, mafic flows with

Na_2O values less than 0.5 wt % are common throughout the volcanic pile suggesting that this hydrothermal activity was regional in scale, and not necessarily confined to mineralized areas.

Carbonates (dolomite, ankerite and siderite), a common phase in most assemblages generally occur in veins (± quartz), which appear to be both syn- and post tectonic. In some locals however, such as the 30 Level auriferous mafic sediments, carbonates occur as fine grained pervasive disseminations and are probably syn-volcanic.

On the 25 Level carbonate alteration locally appears to be stratabound in that it is confined to komatiitic volcaniclastites, which are enclosed by relatively unaltered mafic volcanics, and volatile free (carbonate and water) auriferous sediments. Two periods of alteration are evident; an earlier syn-volcanic phase resulting in the carbonitization of the komatiites and a later phase (pre? syn? tectonic) which produced concordant and distinct mm wide carbonate bands.

Komatiites on the 17 Level have been subjected to an early pervasive carbonitization followed by at least two periods of carbonate veining. It is also noteworthy that what appears to be primary carbonate on this level is quite auriferous (> 1.0 ppm).

Post tectonic shears on all levels, commonly contain opaque oxides and hydrated silicates.

6.2 Metamorphism

Petrographic observation indicates a minimum of two periods of amphibolite grade metamorphism. The first is post mineralization and results in the development of porphyroblasts of Fe-Mg-aluminosilicates, which are commonly poikilitic.

The second event is clearly post tectonic and represented by high temperature cross-cutting veins, derived <u>in situ</u>. A case in point are veins of euhedral andalusite rhombs which grade into earlier formed aggregates of the same mineral. It is also common to observe euhedral, relatively unalterd garnets along fractures, truncating earlier formed garnet poikiloblasts.

6.3 Vein Development

Veins of diverse mineralogy occur both concordant and discordant to stratigraphy. This varied vein composition might be interpreted to suggest several periods of vein development. However, such a conclusion may be too simplistic. At no one local were more than four cross-cutting relationships observed. Also, the composition of veins often closely approximates that of the host rock. For example, in the komatiites the dominant vein mineral assemblage is dolomite-talc ± tremolite. In the magnesium tholeiites, veins generally consist of tremolite-quartz ± Mg carbonate ± actinolite. In the Fe tholeiites and Fe-rich sediments actinolite occurs as the dominant amphibole. In the felsic volcanics veins are dominantly quartz-

-andalusite ± plagioclase with no mafic component. It is also common to observe lithologically controlled veins which are generally subhorizontal and related to the second period of metamorphism. In this case the vein is confined within a specific unit and terminates abruptly at its lithologic contact.

In the author's opinion a good deal of the veining was developed largely *in situ*, in that the veins are merely metamorphic partial melts (sweats) of the enclosing volcanics.

6.4 Mine Structure and Problems of Stratigraphic Correlation

6.4.1 Structure

The main structural element is a dominant northwest trending foliation which dips steeply to the southwest. Lithologic contacts trend in this direction as do the ore zones. Stratigraphic top indicators are uncommon but appear to indicate tops to the south-southwest. Minor fold axes are rare. At the current termination of the E.SC. zone the mineralization is folded about a northwest axial plane, plunging steeply in that direction. Minor folds observed in syngenetic iron formations have fold axes trending to the northwest. Clastic sediments in the vicinity of the No. 1 shaft on the 17 Level exhibit a similar folding style and possible interference patterns.

Surface mapping about the mine, indicates generally northwesterly trending bedding with facing directions to the south, and a second period of folding about northeast trending axial planes (Pirie and Grant, 1978; McGeehan and Hodgson, 1980),

The dominant folding pattern underground however, seems to consist of tight, steeply plunging isoclinal structures, with northwesterly trending axial planes. For the most part the bedding seems to have been transposed in this direction except in low strain areas.

Stratigraphic correlation within the Dickenson Mine has proven difficult mainly because distinctive lithological markers are rare. Two rocks or rock types which have played a significant role in the question of whether the ore zones are conformable with stratigraphy are "chickenfeed" and iron formation.

6.4.2 Chickenfeed

"Chickenfeed" is a much used term in mine nomenclature. From examination of mine plans the author would estimate that approximately 20% of the underground workings at Dickenson have been mapped or logged as"chickenfeed".

The term was first used by Chisholm (1951) to denote a felsic fragmental rock which he classified as a rhyolite tuff, and which graded into an agglomeratic unit. He observed this tuff underground at the New Dickenson Mine where it provided an excellent marker horizon, separating mafic volcanics form Timiskaming-type sediments. The term has since been used to denote altered and carbonatized felsic to intermediate volcanic rocks (reported in Pirie, 1977).

Rocks termed "chickenfeed" have been correlated from level to level in the Dickenson Mine implying that all of these rocks have the same genetic origin. The author mapped and sampled "chickenfeed" from the 17,25 and 30 Levels, and has observed it on a few other levels. On the 17 Level a 90 m wide section of "chickenfeed" is interpreted as heavily sheared and carbonatized komatiitic flows, with well preserved flow top breccia and cherty, carbonate-rich intercalations. On the 25 Level the "chickenfeed" sampled consists of distinct units of ultramafic to basaltic komatiitic volcaniclastites, intercalated with cherty tuffs. On the 30 Level a 50 m wide section of drill core logged as "chickenfeed" was examined and interpreted by the author as a serpentinized basaltic komatiite capped by a flow top breccia. On other levels units mapped as "chickenfeed" are considered to be heavily veined tholeiitic flows.

These observations suggest that "chickenfeed" is not one specific rock type characterized by a distinct mechanism of emplacement, but rather that "chickenfeed" consists mainly of carbonated ultramafic and mafic flows and volcaniclastic rocks for which variable modes of emplacement must apply (i.e. extrusive, erosional, intrusive). Therefore, to correlate "chickenfeed" from level to level, or to use "chickenfeed" as a marker horizon in a stratigraphic sense, has little if any geological validity, and may lead to erroneous stratigraphic correlation.

6.4.3 Iron Formations

Banded iron formations are rare in the mine environment, and the author is aware of only a few localities. On the 15 Level sulphide facies iron formation occurs in the central section of the mine. It trends northeasterly over a short distance and exhibits numerous tight asymmetric folds about northwesterly trending axial planes. On the 22 Level sulphide facies iron formation occurs in the central section of the mine, within a complexly folded package of clastic sediments near the volcanic interface. On the 30 Level sulphide facies iron formation occurs immediatly northwest of the No. 2 shaft and exhibits a distinct northwesterly trend.

Iron formations have however played an important role in arguments against a syngenetic origin for the ore zones at Dickenson, according to Rigg and Helmstaedt (1980), who argue that ore zones cut stratigraphy as defined by iron formation. In their Figure 4, Rigg and Helmstaedt (1980) show iron formation trending northeast, tightly folded about northwest axial planes and commonly faulted off. Since the ore zone in this area trends northwest, it is implied that it cuts stratigraphy. This inferred attitude of the iron formation is based upon interpretation of drill hole data as logged by mine personnel over the past several years, and not an observed truncation of iron formation by an ore zone. Drill logs in this section of the mine occasionally contain a unit (units?) mapped as FeF (iron formation). Occasionally FeF is intersected two or three times along the same hole. The contact between FeF in the core and the enclosing rocks trends northwest. Mine plans do not distinguish between sulphide, oxide, carbonate and silicate facies iron formations, nor do they distinguish between syngenetic iron formation and what are clearly zones of secondary sulphide enrichment. Therefore, it cannot be ascertained from core logs whether rock designated FeF represents the same stratigraphic unit. In fact, one is probably correlating totally different units. Also, it is common to observe the connotation FeF? in drill logs.

The author therefore suggests there is little justification in stratigraphically correlating drill core FeF intersections with tight asymmetric folds, thereby generating a northeasterly trend to bedding in this section. In fact, stratigraphy (as indicated by flow tops, bedding, etc.,) in the areas mapped clearly trends northwesterly. In crosscuts perpendicular to the main ore zones lithologic contacts are abundant and easily observed. Therefore, if the ore zones do in fact cut stratigraphy as has been suggested, then surely somewhere along the great extent of these drifts one clear discordancy ~~would~~ be evident.

6.5 Comparison of the Ore Zones

There are marked chemical differences between the ore zones on Levels 17, 24 and 30, and the auriferous sediments on the 25 Level. At least two different types of mineralization are indicated.

Average compositions of the ore zones are presented in Table 6-1 and they indicate that the auriferous sediments contain significantly less SiO_2, 2.5 times as much total Fe and up to 4 times as much MnO as the main ore zones. They also contain more MgO, TiO_2, Y, Zr, Cr, Co, Cu, V and Au, and less K_2O, As, Rb, Sr, Ce and Ba. Zn and Ni values are highly variable.

Mineralogically and texturally there is also a notable difference. The 25 Level auriferous sediments are fine grained and laminated with rare ovoids. Bedding is accentuated by mm wide opaque bands. The mineralogy and texture on Levels 17, 24 and 30 is much more diverse. Texturally they grade from well banded to fragmental in appearance. A distinct compositional layering is evident by bands consisting of opaques and magnesium-aluminosilicates, opaques and calcium-aluminosilicates and zones of aluminosilicates. In the fragmented portion of the ore zone, dacitic fragments of amphibolite grade are slightly flattened and rimmed by mafic material consisting of biotite-opaques-quartz ± andalusite ± garnets ± tourmaline.

TABLE 6-1: Average Major and Trace Element Values for Ore Zones on Levels 17, 24, 25 and 30.

	1	2	3	4	5	6
			In Weight Percent			
SiO_2	63.07	68.24	67.08	61.14	58.58	55.54
Al_2O_3	10.47	9.29	12.01	10.74	11.01	10.64
Fe_2O_3	7.18	7.42	8.12	7.51	18.54	20.51
MgO	2.08	2.73	1.66	6.28	4.93	5.54
CaO	1.78	2.18	0.23	7.66	0.74	0.78
Na_2O	0.60	0.38	0.21	0.25	<0.20	<0.20
K_2O	2.46	2.09	1.71	1.87	1.09	1.08
TiO_2	0.73	0.59	0.81	0.75	1.10	1.07
MnO	0.04	0.13	0.10	0.20	0.45	0.50
P_2O_5	0.05	0.02	0.03	0.04	0.04	0.04
L.O.I.	10.14	6.04	6.52	3.74	2.30	2.58
CO_2	10.14	6.04	6.20	2.10	1.68	2.10
H_2O	0	0	0.94	1.64	0.62	0.48
S	1.42	0.90	1.03	0.63	0.89	1.29
As	0.94	0.88	0.50	0.67	0.26	0.33
			In ppm			
Ni	229	163	424	158	242	300
Rb	46	42	32	34	<20	<20
Sr	143	81	38	97	49	44
Y	<20	<20	<20	<20	31	30
Zr	38	34	48	49	65	61
Nb	0	0	<20	<20	<20	<20
Cr	201	304	336	213	411	416
Co	41	<40	<40	<40	83	94
Pb	<20	<20	<20	<20	<20	<20
Cu	38	81	115	122	153	164
Zn	81	739	136	231	311	343
Ce	358	299	130	189	81	133
Nd	<20	<20	<20	<20	<20	20
V	244	190	272	231	377	400
La	<20	<20	<20	<20	<20	<20
Ba	120	111	178	91	41	44
			In ppb			
Au	3,070	6,220	6,330	1,400	11,800	21,115

1. 30 Level Lean iron formation (mine terminology).
2. 30 Level Main Au zone.
3. 17 Level Ore zone.
4. 24 Level Main Au zone.
5. 25 Level Sediments with >100 ppb Au.
6. 25 Level Sediments with >1.0 ppm Au.

The ore zones then are pre-metamorphic and of amphibolite grade. A well developed micaceous foliation is parallel to the banding just noted. The banding parallels the trends of the ore zone which in turn are parallel to stratigraphy. Kink bands at 40-45° angles to this foliation are common, and accentuated by the opaques and micas. Porphyroblasts commonly incorporate Au-bearing opaques during growth and are occasionally flattened.

If these ore zones are silicified basalts as has been suggested (see Chapter 7), then the silicification is not pervasive and the mineralization is a multi-stage process. In the enclosing altered volcanics there is no relationship between silicification and Au; in fact if anything, there appears to be an inverse relationship. Furthermore, the stratabound, folded mineralization at the present termination of the E.SC. zone, is mineralogically, texturally and chemically analogous to that of the main ore zones.

CHAPTER 7

ORE GENESIS

"Gold; is where you find it".
—— Anonymous.

7.1 GOLD TRANSPORT AND COMPLEXING

The mode of transport and deposition of gold in hydrothermal ore solutions has been a controversial topic for many years. Several theories have been postulated but basically two are favoured; one is the transport of gold as chloride complexes and the other suggests that gold can be carried as sulphide complexes.

The earliest workers who studied gold solubility include Ogryzlo (1935), Lindner and Gruner (1939), Zviginev and Paulsen (1940), Smith (1944), Krauskopf (1951), Cloke and Kelly (1964) and Anderson and Burnham (1964). Barnes and Czamanske, 1967, proposed sulphide complexing of gold (AuS^-) in near neutral (pH= 6 to 8) solutions up to 250^oC. Helgeson and Garrels (1968) developed a thermodynamic model for hydrothermal gold ore deposits and suggested that gold-quartz veins form from acidic (pH= 2.7 to 3.0), chloride-rich solutions containing from 1.0 to approximately 50 ppb gold.

The gold is transported as chloride complexes ($AuCl_2^-$) with maximum deposition of ore occurring at temperatures between 200 and 250°C. The solubility of gold in high temperature (300-500°C) chloride solutions buffered with respect to pO_2 was examined by Henley (1973). He found that gold solubility increases from 10 ppm at 300°C to 1000 ppm at 510°C, and suggested that for this temperature range the molecular chloride species $Au_2Cl_6(HCl)_2$ is more important than the ionic thio complexes proposed by Seward (1973). Henley's experiments however were carried out in a system buffered with respect to pO_2 by magnetite-hematite. Whether such strongly oxidizing conditions are relevant to actual gold transport is problematical.

The study of the active Broadlands-Ohaki-Waiotayu geothermal field, together with experimental studies in sulphur-rich aqueous systems (Weissberg, 1970; Seward, 1973; Ewers and Keays, 1977) suggests that sulphur complexing of gold may be an important solubility mechanism in many auriferous hydrothermal systems. The complexing of gold with sulphur species over a pH range of 4 to 9.5 and a temperature interval of 100 to 300°C yields high gold solubility due to gold-thio complexes including $AuHS^0$ (acid pH), $Au(HS)_2^-$ (near neutral pH) and $Au_2(HS)_2S^{2-}$ (alkaline solution). Furthermore, arseno-thio and antimino-thio complexes such as $Au(AsS_3)^{2-}$ may also be stable under these conditions. In the case of the Dickenson Mine there can be no doubt that gold transporting solutions also carried high levels of arsenic.

7.2 SUGGESTED ORIGINS FOR THE DICKENSON ORE

7.2.1 The Source Rock

Most models for volcanic hosted gold-sulphide, gold-quartz deposits propose the leaching of gold from the volcanic pile by a variety of geothermal, hydrothermal or metamorphogenic processes with subsequent deposition as exhalites or veins. Recent models proposed by Keays and Davison (1976), Keays (1979) and Keays et al.(1980) suggest that gold is enriched in ultramafic komatiites and leached during talc-carbonate alteration. This suggestion is of interest because of the close spatial relationship between komatiites and gold mineralization on two of the levels examined (Levels 17 and 25). However, tables 7-1 and 7-2 show that the gold values for these rocks are in accordance with and in fact greater than background levels for komatiites from Timmins and Kirkland Lake. An attempt to determine background levels for the Red Lake camp was made by Cowan (1979) and by the author who analyzed several samples from a recent thesis by Cunningham (1979).

TABLE 7-1: Range in Gold Content for Archean Volcanic Rocks in an Unmineralized Environment.

	ppb			
	1 Range	1 Mean	1 n	2
Red Lake				
Pyroxenitic komatiite	0.10-13	5.3	5	
Basaltic komatiite	0.5-15	4.1	7	1.7
High magnesium tholeiite	6.2-279	98	3	2.1
High iron tholeiite	4.3-380	60	8	3.8
Andesite	1.3-6.7	4.2	4	1.4
Acid volcanic	0.9-3.5	2.1	2	
Chert	0.4-10	3.1	8	
Pyroclastic				9.3
+Timmins				
Ultramafic komatiite	0.5-4.5	1.8	13	
Magnesium tholeiite	0.2-5.3	2.6	34	
Kirkland Lake				
*Ultramafic komatiite	1.75	1.75	1	
σUltramafic komatiite flow				
a) Chilled margins		1.6	3	
b) Spinifex zone		2.1	3	
c) Foliated zone		3.3	1	
d) Cumulate zone		3.6	4	
'Kakagi Lake				
Tholeiites	0.3-8.1	2.0	17	

n- Number of samples.
1- Cowan (1979).
2- Five gold analysis by author of samples obtained from Cunningham (1979).
+- Fyon (1980).
*- Tihor and Crocket (1977).
σ- MacRae and Crocket (1977).
'- Kwong and Crocket (1978).

TABLE 7-2: Range in Gold Content for Mafic Volcanics in the Dickenson Mine.

	ppb			Dominant alteration
	Range	Mean	n	
25 Level komatiitic volcaniclastites	0.59-7.1	3.1	7	carbonitization
17 Level komatiitic flow	8.2-43.0	18.0	5	carbonitization
30 Level komatiitic flow	2.7	2.7	1	serpentinization
30 Level basaltic komatiites	34.0-880	230	11	minor carbonitization
30 Level magnesium tholeiites	5.7-580	55	29	

n- Number of samples

It is noteworthy that the gold content of mafic flows from an unmineralized environment in the Red Lake camp is higher than for similar rocks in Timmins, Kirkland Lake and Kakagi Lake (Table 7-1). This would seem to suggest that either the mafic volcanics are anomalously high in background gold or a zone of gold enrichment extends for some distance from the Dickenson Mine area.

The range and mean for basaltic komatiites from the mine environment (Table 7-2) is much greater than background and the magnesium tholeiites exhibit a greater range. Furthermore, the mafic volcanics are much more enriched in gold than the felsic volcanics.

7.2.2 Syngenetic or Epigenetic?

The nature and origin of gold mineralization at the Dickenson Mine is currently under consideration with essentially three schools of thought; (1) Epigenetic (metamorphic dehydration), (2) Epigenetic (hydrothermal, structurally controlled), (3) Syngenetic.

Kerrich (1980) recognizes the presence of auriferous sediments in the Dickenson Mine. The author interprets his ensuing discussion (Kerrich, 1980, p. 137 to 211) as a suggestion that the main ore zones were deposited from metamorphic fluids formed through dehydration reactions at the greenschist-amphibolite transition. The fluid flow is focussed along conduits from which the ore fluid may either discharge into the hydrosphere, crystallize as veins or pond beneath impermeable barriers.

Pirie (1977) described the Dickenson "South C", "North C" and "F" ore zones as exhibiting characteristics of quartz-carbonate veins within carbonatized mafic metavolcanic wallrocks. He described the "East South C" and "I" zones as sulphide layers and laminations with accompanying cherty material. These zones are parallel to the foliation in the enclosing fine grained chloritic and biotitic mafic metavolcanic wallrocks and according to Pirie (1977) have more the appearance of a stratigraphic horizon such as an interflow sedimentary unit rather than a vein system.

In 1978 however, Pirie suggested that the "East South C" and "I" zones were hydrothermally altered mafic metavolcanics rather than sediments. He also mentioned the newly delineated "East South C Footwall Zone" which was described by the mine's geologist at the time (Mr. W. Valiant) as a substantial low grade ore body, in places over 15 m wide, where the gold values are found in the pyrrhotite-pyrite-bearing metavolcanics.

MacGeehan and Hodgson (1980), and Rigg and Helmstaedt (1980), consider the main ore zones to represent major hydrothermal conduits formed during deformation and regional metamorphism. They are of two types: a) carbonate-chert veins formed by open space filling, and b) silicified replacement zones. They also mention the possibility of some folded syngenetic ore at the end of the "East South C" zone.

The presence of syngenetic ore in the Dickenson Mine, represented by the argillaceous sediments on the 25 Level ("East South C Footwall Zone"), was first suggested by Kusmirski and Crocket (1980). Crocket et al. (1980), suggest that the main ore zone on the 30 Level ("East South C") may also represent syngenetic ore.

7.2.3 A Model

The metal-rich mineralized zone on the 25 Level is considered to be an auriferous sediment in which both chemical (exhalative) and clastic components are recognizable. The close association in this zone of Au, As and S has been previously noted (see Section 5.3). This intimate relationship suggests that the exhalative solutions probably contained gold as soluble thio or arsenothio complexes. Such solutions were probably of relatively low temperature and upon interaction with seawater precipitate metals in response to changes in temperature and pH. Precipitation at shallow depths is suggested to account for the high magnetite content. Besides the three ore metals, other major constituents were undoubtedly carried in solution including Fe, Ti, Mn, Cu, Co, Zn and perhaps Si. These auriferous rocks are also enriched in MgO, Ni, and Cr which may suggest some localized leaching of ultramafics.

Finally, the aluminous nature of these rocks indicates a significant detrital component. Similar argillaceous auriferous iron formations have been documented and discussed previously (Fripp 1975, 1976).

The main ore zones require a somewhat different interpretation. They are interpreted as felsic volcaniclastic rocks mineralized by auriferous chemical precipitates of exhalative volcanic origin. Usually they are enclosed by subaqueous mafic volcanics which are commonly pillowed. These ore zones are pre-metamorphic and parallel the local stratigraphy, which in turn is parallel to a well developed foliation (see Section 6.5). In the one exception to this rule, folded mineralization has an axial plane parallel this dominant foliation. To date the author is not aware of any evidence proving these ore zones to be epigenetic.

The asymmetric profiles about the 30 Level ore zone indicate an extreme difference in profile background gold content on the north side of the ore zone as compared to the south, a phenomena uncharacteristic of ore deposition from focussed fluid flow or fracture filling. Remembering that tops face south, such a feature is readily explained in a volcanogenic model, in that one would expect more communication between ore solutions and underlying volcanics. The period of volcanic hiatus as implied by the small width of these ore zones was short, and as such they would soon be overlain by subsequent flows.

These ore zones are definitely not cherts in the classic sense, for they are much too aluminous. In fact the felsic component appears to pre-date the ore-bearing solutions, and probably represents a volcaniclastic horizon. Precipitation of metals (Au, As, S, Fe, Zn) from exhalites or brines occurred under deeper water conditions to account for the high percentage of sulphides. Of special significance are recent analyses by M. Lavigne Jr. (pers. comm.), on several samples of sulphide facies banded iron formations from the Dickenson Mine. They contain approximately 9-10 wt % Al_2O_3 which indicates to the author that felsic volcanism, or at least detritus from a felsic source, was definitely synchronous with exhalative activity.

7.2.4 A Conclusion regarding Ore Genesis

The author concludes, that the evidence presented to date regarding the formation of the "East South C" and "East South C Footwall" ore zones at the Dickenson Mine, is much more easily accomodated in an hypothesis, that these ore zones are synvolcanic/syngenetic deposits.

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APPENDIX A

Major and Trace Element Composition for all Samples

Sample Number	25-16	25-15	25-03D	25-03C	25-03A	25-03B
			In weight %			
SiO_2	49.86	58.39	16.31	20.42	67.54	24.31
Al_2O_3	11.62	12.90	1.97	4.42	15.81	2.72
Fe_2O_3	12.86	12.77	6.83	17.43	6.09	10.85
MgO	9.27	6.92	19.16	18.18	5.32	20.22
CaO	10.60	5.32	27.22	19.56	1.80	21.09
Na_2O	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
K_2O	0.86	0.39	0.22	<0.20	1.23	<0.20
TiO_2	0.91	1.08	0.09	0.28	1.34	0.16
MnO	0.21	0.18	0.29	0.64	0.10	0.42
P_2O_5	0.02	0.02	N.D.	0.01	0.01	N.D.
L.O.I.	3.56	1.85	27.84	18.85	1.58	20.13
CO_2	3.56	0.46	27.44	17.25	0.33	19.29
H_2O	N.D.	1.39	0.40	1.60	1.25	0.84
S	0.11	0.07	0.02	0.06	0.35	0.02
Total	99.89	99.89	99.96	99.87	101.22	99.92
			In ppm			
Ni	93	108	537	1547	1611	563
Rb	23	< 20	< 20	N.D.	38	< 20
Sr	111	78	180	117	48	95
Y	27	27	< 20	< 20	< 20	< 20
Zr	71	84	51	37	49	41
Nb	< 20	< 20	< 20	< 20	< 20	< 20
Cr	334	451	2800	3570	6569	4845
Co	43	46	< 40	107	115	40
Pb	< 20	< 20	< 20	< 20	< 20	< 20
Cu	131	109	26	81	131	39
Zn	104	88	52	89	48	49
As	54	50	50	247	407	50
Ce				N.A.		
Nd				N.A.		
V				N.A.		
La				N.A.		
Ba				N.A.		
			In ppb			
Au	10.75	10.09	2.18	6.95	5.78	1.71

Sample Number	80-17	25-01A	25-01B	25-02A	25-02B	80-13
			In weight %			
SiO_2	76.27	29.67	48.99	29.84	21.61	67.34
Al_2O_3	10.63	5.88	6.75	13.88	11.01	10.02
Fe_2O_3	4.68	8.20	6.30	12.50	11.39	13.97
MgO	4.01	13.90	10.12	14.38	15.71	2.46
CaO	1.91	23.48	15.99	19.42	22.16	0.91
Na_2O	0.24	<0.20	<0.20	<0.20	<0.20	0.31
K_2O	0.40	<0.20	N.D.	<0.20	<0.20	1.47
TiO_2	0.78	0.51	0.63	0.50	0.42	1.10
MnO	0.05	0.33	0.21	0.43	0.49	0.27
P_2O_5	0.03	0.01	0.02	0.01	N.D.	0.05
L.O.I.	1.67	17.74	10.74	10.43	16.52	1.97
CO_2	1.31	17.74	10.74	9.70	15.53	1.32
H_2O	0.36	N.D.	N.D.	0.73	0.94	0.65
S	0.27	0.20	0.13	0.03	0.02	0.12
Total	100.95	99.93	99.93	101.47	99.83	100.02
			In ppm			
Ni	782	597	300	484	303	222
Rb	20	<20	N.D.	N.D.	< 20	24
Sr	26	58	51	82	101	75
Y	<20	<20	< 20	< 20	< 20	< 20
Zr	40	43	40	42	44	52
Nb	N.D.	< 20	< 20	< 20	< 20	N.D.
Cr	3399	836	1095	218	140	214
Co	50	< 40	< 40	40	42	56
Pb	< 20	< 20	< 20	< 20	< 20	< 20
Cu	141	95	59	45	< 20	111
Zn	35	31	31	48	45	94
As	118	97	< 50	< 50	< 50	345
Ce	N.D.			N.A.		< 20
Nd	< 20			N.A.		< 20
V	301			N.A.		278
La	N.D.			N.A.		< 20
Ba	93			N.A.		240
			In ppb			
Au	17.7	4.66	3.83	1.77	0.59	13.04

Sample Number	25-06	25-05	25-04	25-07	25-12	25-08
			In weight %			
SiO_2	63.71	69.62	66.42	59.15	59.75	55.34
Al_2O_3	11.67	12.56	12.18	12.03	11.69	10.42
Fe_2O_3	16.21	10.61	12.88	16.54	17.62	21.67
MgO	3.03	1.87	3.14	4.84	4.56	4.86
CaO	0.52	0.57	0.63	0.76	0.41	0.52
Na_2O	<0.20	<0.22	<0.20	<0.20	<0.20	<0.20
K_2O	1.61	1.44	1.00	1.60	1.65	1.01
TiO_2	1.23	1.17	1.14	1.16	1.16	1.11
MnO	0.41	0.24	0.29	0.28	0.48	0.64
P_2O_5	0.02	0.03	0.02	0.02	N.D.	0.02
L.O.I.	1.37	1.51	1.93	1.91	1.79	2.69
CO_2	0.81	0.78	0.82	1.55	0.82	2.30
H_2O	0.56	0.73	1.11	0.36	0.97	0.39
S	0.10	0.12	0.20	1.22	0.54	1.29
Total	99.91	100.00	99.92	99.85	99.89	99.91
			In ppm			
Ni	123	143	107	299	98	267
Rb	28	30	25	<20	34	<20
Sr	77	101	59	53	75	52
Y	27	34	31	36	49	35
Zr	74	104	75	65	72	58
Nb	<20	<20	<20	<20	<20	<20
Cr	385	331	298	472	585	473
Co	73	<40	49	99	82	106
Pb	<20	<20	<20	N.D.	<20	<20
Cu	127	133	143	241	127	157
Zn	125	73	195	642	277	303
As	297	448	882	3583	2472	3556
Ce				N.A.		
Nd				N.A.		
V				N.A.		
La				N.A.		
Ba				N.A.		
			In ppb			
Au	17.6	9.46	96.5	4500	150	920

Sample Number	25-09	80-16	25-14	25-13	25-10	25-11
			In weight %			
SiO_2	54.07	51.51	57.65	62.58	47.44	62.22
Al_2O_3	10.17	10.10	10.49	12.41	10.80	12.20
Fe_2O_3	21.37	23.43	19.56	14.89	9.21	15.48
MgO	6.77	6.18	5.03	4.05	13.93	4.08
CaO	1.04	0.99	0.61	0.66	10.81	0.83
Na_2O	<0.20	<0.20	<0.20	<0.20	1.67	<0.20
K_2O	0.88	0.75	1.14	1.70	1.59	1.28
TiO_2	1.01	1.08	1.01	1.11	0.89	1.25
MnO	0.53	0.46	0.60	0.37	0.17	0.31
P_2O_5	0.03	0.08	0.04	0.04	0.59	0.04
L.O.I.	2.57	3.28	2.44	1.47	2.67	2.06
CO_2	1.82	3.28	1.56	0.34	2.44	0.35
H_2O	0.75	N.D.	0.88	1.13	0.23	1.71
S	1.11	1.71	1.11	0.36	0.24	0.14
Total	99.89	100.01	99.88	99.86	100.92	99.92
			In ppm			
Ni	345	416	174	162	256	137
Rb	<20	<20	<20	27	40	20
Sr	48	28	41	63	1324	67
Y	24	22	35	25	40	<20
Zr	60	67	56	66	83	72
Nb	<20	N.D.	<20	<20	<20	<20
Cr	443	256	437	450	308	430
Co	104	80	80	69	<40	64
Pb	<20	N.D.	<20	<20	20	<20
Cu	157	111	155	139	59	148
Zn	406	174	189	347	110	90
As	3610	4386	2126	2331	50	295
Ce	N.A.	133		N.A.		
Nd	N.A.	20		N.A.		
V	N.A.	400		N.A.		
La	N.A.	<20		N.A.		
Ba	N.A.	44		N.A.		
			In ppb			
Au	8150	90600	1350	295	14.41	9.70

Sample Number	240-B1	240-B2	80-15	80-14
		In weight %		
SiO_2	66.02	56.26	59.20	60.72
Al_2O_3	10.37	11.10	9.88	9.63
Fe_2O_3	6.98	8.03	18.09	18.92
MgO	4.91	7.65	5.52	4.91
CaO	5.71	9.60	3.74	1.08
Na_2O	0.23	0.26	0.24	<0.20
K_2O	1.67	2.07	<0.20	<0.20
TiO_2	0.67	0.82	1.01	1.10
MnO	0.13	0.26	0.43	0.42
P_2O_5	0.03	0.05	0.05	0.07
L.O.I.	4.13	3.34	1.52	2.64
CO_2	2.00	2.19	1.49	2.64
H_2O	2.13	1.15	0.03	n.d.
S	0.80	0.46	0.19	0.43
Total	102.72	100.18	99.90	100.01
		In ppm		
Ni	155	161	284	314
Rb	33	35	< 20	< 20
Sr	93	101	38	21
Y	< 20	< 20	< 20	21
Zr	45	53	51	65
Nb	< 20	N.D.	N.D.	N.D.
Cr	197	228	240	281
Co	< 40	< 40	61	79
Pb	N.D.	< 20	< 20	< 20
Cu	113	131	101	149
Zn	369	92	113	266
As	10637	2759	327	892
Ce	288	89	< 20	29
Nd	< 20	< 20	< 20	< 20
V	209	252	311	353
La	< 20	< 20	< 20	< 20
Ba	58	123	37	37
		In ppb		
Au	2400	425	31.8	115

Sample Number	17-12	17-11	17-10	17-09	17-08	17-07A
			In weight %			
SiO_2	51.00	55.54	47.17	58.07	65.47	60.65
Al_2O_3	11.73	8.55	7.35	10.92	9.72	12.55
Fe_2O_3	18.40	17.34	23.20	18.11	14.63	15.85
MgO	10.83	3.98	6.41	7.17	5.01	5.56
CaO	0.43	0.26	0.31	0.49	0.35	0.28
Na_2O	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
K_2O	1.50	1.48	0.27	<0.20	<0.20	0.22
TiO_2	0.96	0.63	0.52	0.89	0.74	0.56
MnO	0.29	0.31	0.43	0.38	0.35	0.61
P_2O_5	0.03	0.01	0.01	0.01	0.01	N.D.
L.O.I.	3.91	8.89	10.17	3.10	3.23	2.92
CO_2	1.66	8.89	10.17	1.60	1.94	1.62
H_2O	2.25	N.D.	N.D.	1.50	1.29	1.30
S	0.75	2.97	4.07	0.62	0.28	0.48
Total	99.85	100.01	99.94	99.79	99.86	99.93
			In ppm			
Ni	133	164	282	222	842	3719
Rb	36	35	< 20	< 20	< 20	< 20
Sr	72	41	34	41	< 20	34
Y	< 20	23	< 20	< 20	< 20	N.D.
Zr	63	41	40	55	42	40
Nb	< 20	< 20	< 20	< 20	N.D.	N.D.
Cr	542	483	376	597	332	681
Co	140	101	155	93	132	517
Pb	< 20	< 20	< 20	< 20	< 20	< 20
Cu	175	129	177	153	130	122
Zn	588	620	199	244	1157	681
As	154	587	263	322	719	2627
Ce			N.A.			
Nd			N.A.			
V			N.A.			
La			N.A.			
Ba			N.A.			
			In ppb			
Au	8.53	69	845	14.89	29	16.7

Sample Number	17-07B	17-06	17-05	17-04	17-03	17-02
In weight %						
SiO_2	70.48	71.69	60.79	59.46	61.79	65.55
Al_2O_3	11.65	9.56	11.16	11.51	10.07	9.39
Fe_2O_3	10.31	11.02	16.92	17.24	14.52	13.76
MgO	3.45	3.92	5.38	6.38	4.36	3.90
CaO	0.33	0.29	0.38	0.51	0.43	0.44
Na_2O	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
K_2O	0.50	N.D.	< 0.20	< 0.20	0.63	0.87
TiO_2	0.85	0.67	0.90	0.92	0.68	0.64
MnO	0.24	0.25	0.26	0.30	0.19	0.21
P_2O_5	0.02	0.01	0.02	0.02	0.02	0.01
L.O.I.	1.99	2.37	3.44	3.16	5.36	3.76
CO_2	0.82	0.72	1.04	0.73	5.36	3.14
H_2O	1.17	1.65	2.04	2.43	N.D.	0.62
S	0.09	0.15	0.65	0.37	1.86	1.36
Total	99.94	99.95	99.91	99.88	99.93	99.90
In ppm						
Ni	251	150	171	166	131	125
Rb	< 20	N.D.	N.D.	< 20	< 20	23
Sr	36	< 20	< 20	34	35	38
Y	< 20	< 20	< 20	< 20	24	< 20
Zr	67	58	58	51	51	53
Nb	< 20	< 20	< 20	< 20	< 20	< 20
Cr	411	358	619	470	289	264
Co	63	47	93	84	81	88
Pb	< 20	< 20	< 20	< 20	< 20	< 20
Cu	34	250	121	92	126	136
Zn	108	< 20	< 20	80	99	84
As	258	208	78	124	209	99
Ce	N.A.					
Nd	N.A.					
V	N.A.					
La	N.A.					
Ba	N.A.					
In ppb						
Au	4.09	9.63	11.96	11.77	60	34.4

Sample Number	17-01	17-25	170-A	170-B	17-13	17-14
In weight %						
SiO_2	64.13	73.16	60.11	67.96	54.14	66.08
Al_2O_3	12.97	13.27	10.96	11.81	8.05	13.48
Fe_2O_3	14.08	7.00	10.14	7.23	14.75	11.14
MgO	3.86	0.94	2.17	1.87	8.44	3.37
CaO	0.41	0.37	0.17	0.16	7.33	1.52
Na_2O	<0.20	<0.20	0.31	0.24	<0.20	<0.20
K_2O	<0.20	0.33	2.58	2.21	<0.20	<0.20
TiO_2	0.96	0.91	0.63	0.85	0.52	0.93
MnO	0.26	0.09	0.14	0.08	0.35	0.26
P_2O_5	0.03	N.D.	0.02	0.04	0.02	0.03
L.O.I.	2.67	2.47	10.70	6.38	5.84	2.58
CO_2	0.74	1.53	10.70	6.38	5.84	2.58
H_2O	1.93	0.94	N.D.	N.D.	N.D.	1.15
S	0.40	0.77	1.43	0.90	0.45	0.42
Total	99.83	99.89	99.99	100.01	99.91	99.92
In ppm						
Ni	671	854	198	219	180	1226
Rb	N.D.	<20	41	39	N.D.	N.D.
Sr	23	30	43	41	69	35
Y	<20	<20	<20	25	<20	<20
Zr	59	70	<20	58	50	69
Nb	<20	<20	N.D.	N.D.	<20	<20
Cr	432	585	248	174	265	479
Co	83	<40	43	<40	54	108
Pb	<20	N.D.	N.D.	<20	<20	<20
Cu	133	103	119	123	114	134
Zn	58	44	216	147	77	45
As	632	6110	7063	3042	149	1111
Ce	N.A.		166	94	N.A.	
Nd	N.A.		<20	24	N.A.	
V	N.A.		235	309	N.A.	
La	N.A.		<20	<20	N.A.	
Ba	N.A.		143	213	N.A.	
In ppb						
Au	5.63	4500	1100	13350	30.8	53

Sample Number	17-15	17-16	17-17	17-18	17-19	17-20
	In weight %					
SiO_2	62.20	59.01	68.59	38.55	29.76	59.16
Al_2O_3	12.44	15.02	7.78	24.10	2.27	6.96
Fe_2O_3	15.29	13.25	9.21	11.57	8.62	5.59
MgO	5.37	5.43	3.50	9.91	12.32	7.75
CaO	0.49	2.20	2.69	8.20	22.80	10.18
Na_2O	<0.20	<0.20	<0.20	0.95	<0.20	<0.20
K_2O	0.35	0.71	0.63	1.01	0.25	1.16
TiO_2	0.88	0.64	0.25	0.82	0.14	0.55
MnO	0.23	0.39	0.19	0.36	0.56	0.26
P_2O_5	0.03	N.D.	N.D.	0.04	N.D.	N.D.
L.O.I.	2.65	2.54	5.54	4.30	23.08	8.02
CO_2	0.92	1.27	5.54	0.99	23.08	7.97
H_2O	1.73	1.27	N.D.	3.31	N.D.	0.05
S	0.82	0.38	1.21	0.13	0.08	0.13
Total	100.76	99.87	99.80	100.00	99.91	99.84
	In ppm					
Ni	141	2858	1850	1169	909	1802
Rb	<20	<20	<20	27	<20	54
Sr	36	90	119	324	73	77
Y	<20	<20	<20	27	<20	<20
Zr	63	54	54	93	40	48
Nb	<20	<20	<20	<20	<20	N.D.
Cr	585	627	292	1183	3776	5044
Co	72	471	324	86	45	81
Pb	<20	<20	<20	21	<20	<20
Cu	122	101	75	110	39	80
Zn	62	480	66	66	48	254
As	90	3173	2253	575	446	889
Ce	N.A.					
Nd	N.A.					
V	N.A.					
La	N.A.					
Ba	N.A.					
	In ppb					
Au	51	82	2150	185	42.8	26.4

Sample Number	17-21	17-22	17-23	17-24	17-26	17-27
	In weight %					
SiO_2	37.39	28.00	35.75	35.13	15.88	7.08
Al_2O_3	3.08	2.90	4.09	4.32	3.90	1.86
Fe_2O_3	13.37	18.61	18.90	17.91	21.16	5.82
MgO	13.67	15.96	16.69	22.24	17.24	19.45
CaO	13.40	10.76	5.87	3.18	14.47	32.06
Na_2O	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
K_2O	0.29	<0.20	0.28	<0.20	<0.20	0.69
TiO_2	0.17	0.19	0.32	0.35	0.30	0.09
MnO	0.49	0.97	0.48	0.42	0.58	0.38
P_2O_5	N.D.	N.D.	N.D.	N.D.	N.D.	0.01
L.O.I.	18.05	22.37	17.52	16.23	25.67	32.76
CO_2	17.57	22.31	16.85	14.42	24.92	32.66
H_2O	0.48	0.06	0.67	1.81	0.75	0.10
S	0.04	0.02	0.03	0.03	0.04	0.03
Total	99.98	99.81	99.96	99.86	99.96	99.93
	In ppm					
Ni	1301	1407	2078	2047	2108	1132
Rb	<20	<20	<20	<20	25	<20
Sr	78	58	47	52	124	219
Y	<20	<20	<20	<20	<20	<20
Zr	41	40	40	40	40	60
Nb	<20	N.D.	<20	<20	<20	<20
Cr	5075	4304	6294	3321	4061	2677
Co	68	128	141	151	160	59
Pb	<20	<20	<20	<20	<20	<20
Cu	<20	21	23	53	72	117
Zn	62	79	244	125	106	64
As	428	312	268	640	298	651
Ce	N.A.					
Nd	N.A.					
V	N.A.					
La	N.A.					
Ba	N.A.					
	In ppb					
Au	9.96	4.89	8.20	22.5	18.5	1200

Sample Number	30-33	77FR-575	30-01	30-02	30-03	30-04
		In weight %				
SiO_2	56.00	56.20	58.02	51.81	60.60	56.60
Al_2O_3	15.84	15.98	12.58	11.29	12.38	15.90
Fe_2O_3	7.67	5.82	11.93	11.65	9.71	7.34
MgO	3.85	4.52	6.92	8.87	7.13	3.71
CaO	7.18	6.67	7.27	12.14	7.12	6.99
Na_2O	3.25	3.21	<0.20	<0.20	<0.20	2.54
K_2O	2.30	2.29	0.47	<0.20	<0.20	2.33
TiO_2	1.14	1.06	0.84	0.74	0.83	1.10
MnO	0.12	0.13	0.23	0.28	0.21	0.12
P_2O_5	0.35	0.33	0.01	0.02	0.01	0.32
L.O.I.	2.50	2.71	1.23	2.88	1.56	2.03
CO_2	2.50	2.71	0.75	2.88	0.84	2.00
H_2O	N.D.	N.D.	0.48	N.D.	0.72	0.03
S	0.09	0.12	0.32	0.10	0.16	0.06
Total	100.29	99.04	99.83	99.79	99.72	99.03
		In ppm				
Ni	39	15	200	108	129	40
Rb	51	50	< 20	< 20	< 20	61
Sr	713	603	80	90	69	674
Y	20	25	< 20	< 20	< 20	< 20
Zr	198	208	71	59	67	202
Nb	23	< 20	< 20	< 20	< 20	< 20
Cr	72	80	658	685	708	77
Co	< 40	< 40	59	< 40	< 40	< 40
Pb	22	23	< 20	< 20	< 20	20
Cu	22	43	129	73	102	23
Zn	114	117	83	81	67	104
As	< 50	< 50	136	50	66	< 50
Ce	N.A.	108			N.A.	
Nd	N.A.	41			N.A.	
V	N.A.	109			N.A.	
La	N.A.	42			N.A.	
Ba	N.A.	743			N.A.	
		In ppb				
Au	2.29	N.A.	19.5	59	8.48	3.21

Sample Number	77FR-541	30-05	30-06	30-07	30-08	30-09
			In weight %			
SiO_2	56.16	55.47	55.84	55.92	57.82	52.33
Al_2O_3	15.80	15.83	15.82	15.89	16.11	12.77
Fe_2O_3	5.80	7.38	7.39	7.46	7.53	10.50
MgO	5.55	3.65	3.70	3.70	3.37	8.01
CaO	6.43	6.89	6.90	6.92	6.68	10.59
Na_2O	3.09	3.31	3.25	3.13	2.29	0.25
K_2O	2.49	2.34	2.27	2.33	2.52	1.18
TiO_2	1.07	1.10	1.12	1.12	1.10	0.93
MnO	0.11	0.12	0.11	0.11	0.12	0.23
P_2O_5	0.31	0.34	0.34	0.34	0.32	0.05
L.O.I.	2.55	2.37	2.37	2.21	1.57	3.08
CO_2	2.55	2.37	2.37	2.21	1.57	3.08
H_2O	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
S	0.06	0.08	0.06	0.09	0.07	0.07
Total	99.42	98.88	99.18	99.23	99.49	99.99
			In ppm			
Ni	15	39	33	33	36	98
Rb	55	54	53	51	66	30
Sr	607	722	698	707	739	165
Y	24	< 20	< 20	21	22	< 20
Zr	208	189	187	201	201	97
Nb	< 20	< 20	20	< 20	20	< 20
Cr	78	65	82	67	64	305
Co	< 40	< 40	< 40	< 40	< 40	< 40
Pb	21	< 20	20	21	20	< 20
Cu	34	< 20	< 20	< 20	20	145
Zn	114	114	115	116	98	82
As	< 50	< 50	< 50	< 50	< 50	< 50
Ce	110			N.A.		
Nd	44			N.A.		
V	108			N.A.		
La	60			N.A.		
Ba	779			N.A.		
			In ppb			
Au	N.A.	1.75	1.11	1.95	2.42	11.6

Sample Number	77FR-542	30-10	30-11	30-12	77FR-543	30-13
			In weight %			
SiO_2	41.27	55.29	53.78	43.73	53.70	60.90
Al_2O_3	9.31	13.26	12.12	11.53	14.63	11.72
Fe_2O_3	9.17	12.40	9.92	11.10	7.24	15.33
MgO	10.05	7.42	7.70	9.54	8.21	4.75
CaO	16.29	8.15	11.15	15.63	11.50	3.60
Na_2O	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
K_2O	0.33	< 0.20	0.41	0.21	0.21	0.38
TiO_2	0.60	0.97	0.93	0.79	0.91	1.03
MnO	0.32	0.20	0.21	0.31	0.22	0.30
P_2O_5	N.D.	0.02	0.02	0.03	N.D.	0.02
L.O.I.	12.17	2.01	3.51	6.87	2.50	1.75
CO_2	12.17	1.06	3.51	6.87	2.50	0.65
H_2O	N.D.	0.95	N.D.	N.D.	N.D.	1.10
S	0.11	0.06	0.11	0.18	0.11	0.14
Total	99.63	99.78	99.87	99.22	99.24	99.93
			In ppm			
Ni	97	131	114	87	73	99
Rb	< 20	< 20	< 20	< 20	< 20	< 20
Sr	85	85	102	99	77	67
Y	23	< 20	< 20	< 20	20	32
Zr	49	73	72	64	61	68
Nb	< 20	< 20	< 20	< 20	< 20	< 20
Cr	227	375	477	282	360	453
Co	46	52	< 40	< 40	42	62
Pb	< 20	< 20	< 20	< 20	< 20	< 20
Cu	32	112	122	132	46	117
Zn	80	82	58	75	67	81
As	50	< 50	51	< 50	< 50	133
Ce	< 20		N.A.		< 20	N.A.
Nd	< 20		N.A.		< 20	N.A.
V	201		N.A.		274	N.A.
La	< 20		N.A.		< 20	N.A.
Ba	< 20		N.A.		< 20	N.A.
			In ppb			
Au	102	13.95	14.79	56	18.9	17.3

Sample Number	30-14	77FR-546	30-15	80-09	77FR-549	80-08
			In weight %			
SiO_2	13.52	55.03	60.74	79.74	61.27	69.37
Al_2O_3	2.52	13.56	6.04	15.43	14.30	13.96
Fe_2O_3	9.37	6.13	6.27	2.17	7.03	3.24
MgO	14.21	9.06	5.86	0.48	6.98	2.22
CaO	29.54	11.30	10.89	0.36	7.72	5.67
Na_2O	< 0.20	< 0.20	< 0.20	0.35	< 0.20	1.56
K_2O	< 0.20	0.21	0.94	< 0.20	0.25	1.45
TiO_2	0.16	0.92	0.39	1.19	1.02	0.44
MnO	0.48	0.23	~~0.23~~	0.05	0.20	0.05
P_2O_5	0.01	N.D.	N.D.	0.06	N.D.	0.08
L.O.I.	29.94	4.42	8.13	1.45	1.41	1.97
CO_2	29.25	3.65	7.79	0.58	1.04	1.73
H_2O	0.69	0.77	0.34	0.87	0.37	0.12
S	0.02	0.10	0.32	0.05	0.12	0.02
Total	99.77	100.97	99.89	101.34	100.31	100.03
			In ppm			
Ni	101	96	50	57	61	24
Rb	< 20	< 20	25	< 20	< 20	51
Sr	93	81	94	66	80	458
Y	< 20	25	< 20	< 20	27	< 20
Zr	44	67	64	73	74	177
Nb	< 20	< 20	< 20	N.D.	< 20	< 20
Cr	89	335	129	275	405	35
Co	< 40	< 40	< 40	< 40	45	< 40
Pb	< 20	< 20	< 20	N.D.	< 20	< 20
Cu	75	33	36	149	137	< 20
Zn	56	55	1296	21	84	54
As	< 50	51	886	132	108	< 50
Ce	N.A.	< 20	N.A.	< 20	< 20	40
Nd	N.A.	< 20	N.A.	21	< 20	< 20
V	N.A.	264	N.A.	273	293	50
La	N.A.	20	N.A.	< 20	< 20	27
Ba	N.A.	< 20	N.A.	80	< 20	400
			In ppb			
Au	14.6	25	221	25.7	25	17.3

Sample Number	30-16	30-17	30-47	77FR-554	80-07C	80-07F
			In weight %			
SiO_2	74.23	57.39	77.04	46.80	55.44	66.28
Al_2O_3	18.78	13.51	15.12	6.82	9.21	10.23
Fe_2O_3	1.91	4.39	3.98	7.01	25.05	14.72
MgO	1.07	7.40	0.82	8.73	5.02	3.27
CaO	0.95	8.67	0.60	14.68	0.83	1.66
Na_2O	< 0.20	1.53	0.20	< 0.20	< 0.20	< 0.20
K_2O	0.21	1.68	0.26	0.90	< 0.20	0.34
TiO_2	1.24	0.68	0.95	0.42	1.00	1.09
MnO	0.04	0.10	0.11	0.46	0.48	0.32
P_2O_5	0.02	0.30	0.01	N.D.	0.05	0.04
L.O.I.	1.45	3.03	0.92	13.78	2.63	1.80
CO_2	0.37	3.03	0.30	13.78	0.76	0.53
H_2O	1.08	N.D.	0.62	N.D.	1.87	1.27
S	0.04	1.31	0.08	0.30	0.11	0.12
Total	99.96	99.99	99.90	99.90	99.82	99.87
			In ppm			
Ni	82	89	57	132	150	90
Rb	< 20	32	< 20	22	< 20	< 20
Sr	37	840	49	85	22	79
Y	< 20	< 20	< 20	< 20	< 20	< 20
Zr	86	133	71	35	43	64
Nb	< 20	< 20	< 20	N.D.	N.D.	N.D.
Cr	1412	157	621	169	270	255
Co	< 40	< 40	< 40	< 40	85	49
Pb	< 20	21	N.D.	< 20	< 20	< 20
Cu	170	35	112	45	108	120
Zn	27	57	35	59	141	87
As	245	N.D.	96	< 50	< 50	< 50
Ce	N.A.		< 20	< 20	< 20	< 20
Nd	N.A.		< 20	< 20	< 20	21
V	N.A.		238	177	354	322
La	N.A.		< 20	< 20	< 20	< 20
Ba	N.A.		47	45	35	91
			In ppb			
Au	18.9	15.7	15	2850	23.6	60.4

Sample Number	77FR-559	77FR-605†	77FR-606†	77FR-562	77FR-607†
			In weight %		
SiO_2	57.82	58.90	75.40	54.12	71.90
Al_2O_3	11.57	10.50	14.20	9.44	11.50
Fe_2O_3	15.88	13.80	5.40	25.84	8.70
MgO	5.92	4.53	0.92	5.33	1.83
CaO	5.51	5.20	0.23	1.52	0.87
Na_2O	< 0.20	< 0.20	N.D.	< 0.20	N.D.
K_2O	0.42	< 0.20	0.39	0.57	0.28
TiO_2	0.87	0.70	0.88	0.85	0.77
MnO	0.24	0.46	0.16	0.41	0.25
P_2O_5	N.D.	0.07	0.05	N.D.	0.04
L.O.I.	1.48	5.70	2.60	1.52	2.70
CO_2	1.08	3.30	0.60	0.38	0.40
H_2O	0.40	2.40	2.00	1.14	2.3
S	0.16	0.20	0.16	0.22	0.18
Total	99.89	100.06	100.39	99.86	99.02
			In ppm		
Ni	144	N.A.	N.A.	195	N.A.
Rb	< 20	N.D.	N.D.	< 20	< 20
Sr	69	N.A	N.A.	54	N.A.
Y	33	N.A.	N.A.	36	N.A.
Zr	62	N.A.	N.A.	63	N.A.
Nb	N.D.	N.A.	N.A.	N.D.	N.A.
Cr	344	N.A.	N.A.	326	N.A.
Co	87	N.A.	N.A.	149	N.A.
Pb	< 20	N.A.	N.A.	< 20	N.A.
Cu	49	N.A.	N.A.	69	N.A.
Zn	86	60	30	127	40
As	229	N.A.	N.A.	465	N.A.
Ce	24	N.A.	N.A.	21	N.A.
Nd	< 20	N.A.	N.A.	< 20	N.A.
V	298	N.A.	N.A.	341	N.A.
La	< 20	N.A.	N.A.	< 20	N.A.
Ba	21	N.A.	N.A.	35	N.A.
			In ppb		
Au	42.4	17	60	12900	32

Sample Number	77FR-608†	77FR-565	80-05	80-03	30-18
		In weight %			
SiO_2	52.98	49.41	65.40	73.97	56.35
Al_2O_3	12.28	10.29	9.88	12.83	11.87
Fe_2O_3	16.55	29.32	16.93	7.70	9.58
MgO	5.54	6.02	2.88	1.53	6.93
CaO	8.59	0.65	0.74	0.47	7.87
Na_2O	0.25	<0.20	<0.20	<0.20	<0.20
K_2O	0.94	0.39	<0.20	<0.20	2.59
TiO_2	0.82	1.03	1.02	1.12	1.00
MnO	0.25	0.24	0.40	0.19	0.21
P_2O_5	0.07	N.D.	0.06	0.06	0.02
L.O.I.	3.0	2.55	2.30	1.76	3.35
CO_2	3.0	0.40	0.79	1.23	3.35
H_2O	N.D.	2.15	1.51	0.53	N.D.
S	0.62	0.09	0.16	0.15	0.12
Total	101.90	100.00	99.78	99.80	99.90
		In ppm			
Ni	123	185	95	111	82
Rb	31	<20	<20	<20	67
Sr	111	69	57	56	158
Y	31	33	<20	<20	<20
Zr	57	66	35	35	86
Nb	N.D.	<20	N.D.	<20	<20
Cr	105	403	272	242	283
Co	<40	175	51	<40	<40
Pb	<20	<20	<20	<20	<20
Cu	29	31	138	130	134
Zn	215	158	103	54	64
As	58	83	63	163	125
Ce	N.A.	25	<20	<20	N.A.
Nd	N.A.	<20	<20	<20	N.A.
V	N.A.	370	331	270	N.A.
La	N.A.	<20	<20	<20	N.A.
Ba	N.A.	39	38	48	N.A.
		In ppb			
Au	7000	5.63	22.8	16.1	19

Sample Number	30-19	30-20	30-21	30-22	30-32	30-23
			In weight %			
SiO_2	53.05	56.37	51.95	46.25	46.79	54.23
Al_2O_3	11.43	10.35	9.86	10.49	9.40	11.96
Fe_2O_3	7.95	8.27	9.08	9.00	12.02	7.25
MgO	7.58	7.14	7.50	8.96	9.04	7.35
CaO	11.55	10.84	12.56	15.60	13.21	11.14
Na_2O	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
K_2O	1.20	0.91	0.78	0.44	0.99	1.48
TiO_2	0.86	0.76	0.73	0.73	0.83	0.85
MnO	0.19	0.22	0.23	0.24	0.31	0.16
P_2O_5	0.01	0.01	0.01	0.02	0.02	0.01
L.O.I.	5.84	4.83	7.09	7.98	7.13	5.35
CO_2	5.84	4.83	7.09	7.98	7.13	5.35
H_2O	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
S	0.17	0.17	0.06	0.13	0.13	0.09
Total	99.87	99.90	99.88	99.86	99.88	99.88
			In ppm			
Ni	113	87	164	103	72	82
Rb	28	26	<20	<20	26	37
Sr	138	127	117	136	112	164
Y	<20	<20	<20	<20	<20	<20
Zr	84	84	73	73	74	85
Nb	<20	<20	<20	<20	<20	<20
Cr	309	335	255	255	278	372
Co	<40	<40	<40	<40	<40	<40
Pb	<20	<20	<20	<20	<20	<20
Cu	116	130	135	117	101	106
Zn	78	257	<50	82	73	60
As	414	285	268	171	101	112
Ce			N.A.			
Nd			N.A.			
V			N.A.			
La			N.A.			
Ba			N.A.			
			In ppb			
Au	145	580	34.3	380	54	18.8

Sample Number	30-24	30-25	30-26	30-27	77FR-576	30-28
			In weight %			
SiO_2	42.48	52.47	27.09	44.63	55.35	51.71
Al_2O_3	9.04	12.39	5.93	9.76	13.04	9.82
Fe_2O_3	10.61	9.53	14.16	10.08	6.58	10.80
MgO	8.65	7.60	11.31	9.47	7.64	7.57
CaO	15.89	11.90	21.96	15.45	10.71	10.34
Na_2O	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
K_2O	1.09	0.72	0.50	0.92	0.82	2.15
TiO_2	0.68	0.86	0.43	0.71	0.83	0.78
MnO	0.23	0.16	0.40	0.22	0.17	0.22
P_2O_5	0.02	0.01	0.03	0.02	N.D.	0.01
L.O.I.	11.09	4.11	17.18	8.54	4.19	6.17
CO_2	11.09	4.11	17.18	8.54	4.19	6.17
H_2O	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
S	0.10	0.11	0.79	0.10	0.05	0.33
Total						
			In ppm			
Ni	102	73	80	75	57	79
Rb	24	<20	<20	<20	23	58
Sr	169	125	125	145	123	142
Y	<20	<20	<20	<20	<20	<20
Zr	71	75	53	72	66	74
Nb	<20	<20	<20	<20	<20	<20
Cr	225	305	172	269	232	304
Co	<40	<40	42	<40	<40	41
Pb	<20	<20	<20	<20	<20	<20
Cu	112	111	115	131	45	128
Zn	72	68	97	72	68	70
As	178	80	1752	93	83	102
Ce			N.A.		<20	N.A.
Nd			N.A.		<20	N.A.
V			N.A.		244	N.A.
La			N.A.		<20	N.A.
Ba			N.A.		34	N.A.
			In ppb			
Au	77	26.7	2850	74	25.2	140

Sample Number	30-29	30-30	30-31	77FR-578	30-34	30-35
			In weight %			
SiO_2	55.23	52.92	13.67	55.81	52.41	47.79
Al_2O_3	13.51	14.34	2.02	12.05	7.48	9.12
Fe_2O_3	10.45	11.31	11.41	5.60	11.19	13.82
MgO	7.81	8.01	14.93	7.84	6.41	8.14
CaO	9.64	9.97	31.12	11.28	9.94	12.01
Na_2O	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
K_2O	0.68	0.69	<0.20	0.80	1.52	1.57
TiO_2	0.95	1.01	0.13	0.72	0.50	0.75
MnO	0.15	0.20	0.33	0.14	0.18	0.27
P_2O_5	0.02	0.02	0.01	N.D.	N.D.	0.02
L.O.I.	1.37	1.35	26.21	5.54	7.17	5.92
CO_2	1.37	1.35	26.10	5.47	7.17	5.92
H_2O	N.D.	N.D.	0.11	0.07	N.D.	N.D.
S	0.10	0.10	0.08	0.06	1.43	0.49
Total	99.92	99.93	99.91	99.85	99.90	99.93
			In ppm			
Ni	83	102	60	55	101	89
Rb	<20	<20	<20	23	36	34
Sr	89	97	148	112	114	115
Y	23	24	<20	<20	<20	<20
Zr	77	74	48	55	49	65
Nb	<20	<20	<20	<20	<20	<20
Cr	470	409	72	245	370	351
Co	<40	<40	<40	<40	<40	56
Pb	<20	<20	<20	<20	N.D.	<20
Cu	113	120	30	46	127	126
Zn	80	90	136	60	96	135
As	52	140	46	57	17894	309
Ce		N.A.		<20		N.A.
Nd		N.A.		<20		N.A.
V		N.A.		207		N.A.
La		N.A.		<20		N.A.
Ba		N.A.		<20		N.A.
			In ppb			
Au	75	39	82	N.A.	21000	1000

Sample Number	77FR-579	77FR-609†	77FR-582	77FR-585	77FR-587
			In weight %		
SiO_2	58.93	61.68	59.25	53.90	62.45
Al_2O_3	8.75	12.86	10.23	14.54	12.86
Fe_2O_3	7.29	13.04	5.24	9.20	7.55
MgO	6.99	2.85	6.35	8.88	7.31
CaO	9.18	1.46	9.83	10.07	7.79
Na_2O	< 0.20	0.63	< 0.20	< 0.20	< 0.20
K_2O	0.48	0.95	1.11	< 0.20	< 0.20
TiO_2	0.47	0.81	0.61	0.88	0.81
MnO	0.35	0.27	0.16	0.29	0.21
P_2O_5	N.D.	0.03	N.D.	N.D.	N.D.
L.O.I.	5.98	5.40	6.84	2.12	2.09
CO_2	5.98	3.70	6.79	2.12	1.75
H_2O	N.D.	1.70	0.05	N.D.	0.34
S	1.22	0.11	0.26	0.12	0.10
Total	99.84	100.01	99.88	100.00	101.17
			In ppm		
Ni	60	81	45	71	57
Rb	< 20	32	40	< 20	< 20
Sr	64	77	151	99	74
Y	22	< 20	< 20	24	< 20
Zr	41	52	47	63	44
Nb	< 20	N.D.	< 20	N.D.	< 20
Cr	150	257	200	304	237
Co	< 40	69	< 40	51	< 40
Pb	< 20	< 20	< 20	< 20	< 20
Cu	45	105	45	43	42
Zn	90	72	45	110	73
As	2055	140	< 50	56	< 50
Ce	< 50	N.A.	< 20	< 20	< 20
Nd	< 20	N.A.	< 20	< 20	< 20
V	237	N.A.	214	306	234
La	< 20	N.A.	< 20	< 20	< 20
Ba	< 20	N.A.	127	N.D.	N.D.
			In ppb		
Au	5800	23	24.4	5.68	11.48

Sample Number	77FR-591	77FR-610†	77FR-594	77FR-599†
		In weight %		
SiO_2	54.62	40.21	61.93	41.04
Al_2O_3	13.63	5.44	12.83	4.79
Fe_2O_3	10.47	10.52	6.51	10.52
MgO	8.44	7.98	6.80	7.29
CaO	9.70	16.19	7.56	15.67
Na_2O	< 0.20	0.45	< 0.20	< 0.20
K_2O	0.29	< 0.20	0.29	0.57
TiO_2	0.86	0.30	0.84	0.27
MnO	0.21	0.45	0.28	0.44
P_2O_5	N.D.	0.02	N.D.	0.01
L.O.I.	2.99	19.30	2.75	19.60
CO_2	2.89	19.30	2.51	19.60
H_2O	0.10	N.D.	0.24	N.D.
S	0.08	0.26	0.12	0.14
Total	101.31	101.13	100.92	100.41
		In ppm		
Ni	86	77	79	82
Rb	< 20	< 20	< 20	< 20
Sr	78	82	77	91
Y	23	20	25	< 20
Zr	63	40	64	40
Nb	< 20	N.D.	N.D.	N.D.
Cr	281	44	276	318
Co	50	< 40	47	63
Pb	< 20	< 20	< 20	< 20
Cu	43	58	45	123
Zn	73	46	65	116
As	59	84	69	732
Ce	< 20	N.A.	< 20	N.A.
Nd	< 20	N.A.	< 20	N.A.
V	274	N.A.	253	N.A.
La	< 20	N.A.	< 20	N.A.
Ba	< 20	N.A.	< 20	N.A.
		In ppb		
Au	130	12	10.14	105

0

Sample Number	30-46	30-45	30-44	30-43	30-42	30-41
			In weight %			
SiO_2	45.80	58.15	56.43	55.60	55.19	65.81
Al_2O_3	10.93	13.17	11.91	12.21	10.81	10.52
Fe_2O_3	10.91	11.57	10.53	13.14	13.87	5.76
MgO	9.54	6.90	7.46	7.75	6.80	3.82
CaO	14.04	6.77	8.23	7.31	7.13	5.51
Na_2O	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
K_2O	0.20	0.30	0.38	<0.20	1.90	1.50
TiO_2	0.73	0.90	0.83	0.83	0.77	0.62
MnO	0.32	0.22	0.23	0.30	0.33	0.15
P_2O_5	0.01	0.01	0.01	0.02	0.01	N.D.
L.O.I.	7.33	1.85	3.84	2.40	2.78	4.26
CO_2	7.33	0.92	3.45	1.49	2.78	4.26
H_2O	N.D.	0.93	0.39	0.91	N.D.	N.D.
S	0.08	0.08	0.13	0.26	0.29	0.64
Total	99.90	99.92	99.98	99.82	99.90	99.82
			In ppm			
Ni	108	99	74	195	136	272
Rb	<20	<20	<20	<20	50	35
Sr	100	82	79	72	106	117
Y	<20	<20	<20	<20	<20	<20
Zr	60	70	67	54	62	64
Nb	<20	<20	<20	<20	<20	<20
Cr	518	770	645	728	533	400
Co	<40	<40	<40	59	56	<40
Pb	<20	<20	<20	<20	<20	N.D.
Cu	97	73	137	148	117	125
Zn	87	98	80	79	92	44
As	77	<50	<50	<50	208	13034
Ce			N.A.			
Nd			N.A.			
V			N.A.			
La			N.A.			
Ba			N.A.			
			In ppb			
Au	16.9	7.32	21.5	14.01	85	710

Sample Number	30-40	30-39	30-38	30-37	30-36
			In weight %		
SiO_2	49.01	51.66	62.02	45.95	51.46
Al_2O_3	8.60	11.94	13.08	10.61	12.52
Fe_2O_3	16.04	10.04	9.19	9.98	10.27
MgO	8.24	8.32	5.65	9.23	8.40
CaO	8.23	11.26	6.98	13.85	10.93
Na_2O	<0.20	<0.20	<0.20	<0.20	<0.20
K_2O	1.98	1.63	0.50	0.96	0.88
TiO_2	0.65	0.81	0.84	0.71	0.80
MnO	0.30	0.22	0.19	0.24	0.23
P_2O_5	0.01	0.02	0.02	0.01	0.02
L.O.I.	5.77	3.90	1.39	8.17	4.21
CO_2	5.77	3.90	1.15	8.17	4.21
H_2O	N.D.	N.D.	0.24	N.D.	N.D.
S	1.08	0.11	0.08	0.18	0.12
Total	99.92	99.92	99.95	99.90	99.85
			In ppm		
Ni	131	98	74	90	92
Rb	56	39	<20	22	<20
Sr	134	146	90	134	119
Y	<20	<20	<20	26	<20
Zr	55	76	71	76	74
Nb	<20	<20	<20	<20	<20
Cr	645	717	763	545	595
Co	61	44	<40	<40	<40
Pb	<20	<20	<20	<20	<20
Cu	132	105	99	89	127
Zn	113	71	69	77	77
As	148	107	89	78	121
Ce	N.A.	<20	N.A.		
Nd	N.A.	<20	N.A.		
V	N.A.	242	N.A.		
La	N.A.	<20	N.A.		
Ba	N.A.	44	N.A.		
			In ppb		
Au	675	18.7	25.1	880	30.2

Sample Number	800-01	80-01A	80-02	80-11	80-12A	80-12B
			In weight %			
SiO_2	63.42	63.19	62.59	66.80	67.65	70.27
Al_2O_3	10.27	10.07	11.07	8.60	9.45	9.82
Fe_2O_3	7.60	6.60	7.33	5.08	9.29	7.87
MgO	1.67	2.74	1.82	4.54	1.78	1.86
CaO	1.21	2.69	1.44	5.61	0.50	0.44
Na_2O	0.47	0.76	0.56	0.24	0.44	0.45
K_2O	2.72	1.92	2.73	1.19	2.46	2.61
TiO_2	0.74	0.72	0.71	0.51	0.62	0.65
MnO	0.04	0.05	0.04	0.17	0.11	0.12
P_2O_5	0.03	0.08	0.03	0.02	0.02	0.02
L.O.I.	10.29	9.83	10.30	6.63	6.49	5.01
CO_2	10.29	9.83	10.30	6.63	6.49	5.01
H_2O	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
S	1.53	1.33	1.39	0.61	1.19	0.89
Total	100.47	100.72	101.60	100.59	101.08	100.97
			In ppm			
Ni	128	136	424	137	194	158
Rb	41	43	54	29	47	51
Sr	99	180	160	89	78	76
Y	< 20	< 20	< 20	< 20	< 20	< 20
Zr	43	27	43	40	29	34
Nb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cr	198	199	207	266	326	321
Co	< 40	< 40	54	< 40	40	< 40
Pb	< 20	< 20	N.D.	< 20	N.D.	N.D.
Cu	< 20	46	53	85	114	44
Zn	58	62	123	75	1383	759
As	4800	7398	15946	5946	10785	9644
Ce	182	281	610	207	369	322
Nd	< 20	20	< 20	< 20	< 20	< 20
V	290	208	235	144	215	211
La	< 20	< 20	< 20	< 20	< 20	< 20
Ba	145	93	123	95	128	110
			In ppb			
Au	3300	3150	2750	3400	8750	6500

N.D.- None Determined

N.A.- Not Analyzed

† - from Cowan (1979)

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APPENDIX B

Analytical Errors

Analytical Errors

The two major sources of error during the x-ray fluorescence analysis of major and trace elements are precision and accuracy. These factors were examined with the results presented here.

Precision

The precision of an analysis is judged by running an individual sample several times over the course of the analysis and then examining the variability of each element.

Table B-1 illustrates the range in major element values for sample 30-46. Tables B-2, B-3 and B-4 illustrate the range in trace element values for three whole rock samples.

Elements with high concentrations commonly show precision within 5%. It is only at concentrations of less than 20 ppm that the variation for some elements (Rb, Y, Nb, Pb, Ce, Nd) is significant. This phenomenon is a function of the sensitivity of the spectrometer. That is, at low concentrations peak count rates can be difficult to distinguish from background or noise.

Accuracy

The accuracy of an analysis is judged by running standards as unknowns and then comparing these determined values to the recommended values of Abbey (1977).

Table B-5 illustrates the determined and recommended major element values for several standards. Tables B-6 and B-7 illustrate the determined and recommended trace element values for several standards. All elements were generally accurate to within 5%; the exception being those present at below background levels.

Homogeneity

Sample homogeneity or lack there of, was a further concern. As such, two to four pressed discs were made from individual whole rock powders and analysed consecutively. The range in major element values for sample 25-11 are illustrated in Table B-8. The range in trace element values for three samples are listed in Tables B-9, B-10 and B-11. Once again the only significant variability occurs for those elements whose concentrations are at the lower limit of detection of the spectrometer. As such, one can conclude, that the major and trace element compositions presented in Appendix A, are truly representative of the bulk composition of the individual samples.

TABLE B-1. Range in Major Element Values for Sample 30-46.

Element								Mean
SiO_2	48.63	47.86	47.56	47.83	47.61	47.53	48.17	47.88
Al_2O_3	11.63	11.50	11.51	11.57	11.45	11.46	11.67	11.54
Fe_2O_3	11.59	11.46	11.45	11.45	11.41	11.44	11.68	11.50
MgO	10.13	9.99	9.90	9.89	9.82	9.85	9.98	9.94
CaO	14.91	14.84	14.78	14.82	14.70	14.75	15.06	14.84
Na_2O	0.07	0.06	0.07	0.09	0.06	0.08	0.09	0.07
K_2O	0.21	0.21	0.21	0.21	0.21	0.21	0.22	0.21
TiO_2	0.77	0.76	0.76	0.76	0.76	0.75	0.77	0.76
MnO	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
P_2O_5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

TABLE B-2. Range in Trace Element Values for Sample 30-46.

						Mean
S	805	836	798	829	854	824.4
Ni	107.7	109.8	110.5	106.6	109.7	107.9
Rb	1	3	1	4	2	2.2
Sr	94	98	100	105	101	99.6
Y	7	8	14	18	15	12.4
Zr	56	61	63	59	62	60.2
Nb	3	7	6	7	12	7
Cr	536	540	515	484	513	517.6
Co	45	40	39	31	31	37.2
Pb	12	10	12	11	9	10.8
Cu	98	102	90	100	97	97.4
Zn	92	87	84	88	86	87.4
As	79	64	82	84	76	77

TABLE B-3. Range in Trace Element Values for Sample 30-33.

					Mean
S	943	919	931	969	940.5
Ni	37.2	40.0	38.5	35.8	37.9
Rb	56	52	51	48	51.8
Sr	726	735	713	714	722
Y	20	15	20	19	18.5
Zr	193	200	198	198	197.3
Nb	16	16	23	19	18.5
Cr	68	72	72	74	71.5
Co	14	15	0	15	11
Pb	20	23	22	18	20.8
Cu	25	24	22	22	23.3
Zn	124	118	114	115	117.8
As	11	13	7	4	8.8

TABLE B-4. Range in Trace Elements Values for Sample 30-39.

			Mean
Ce	14	13	13.5
Nd	11	11	11
V	238	245	241.5
La	10	11	10.5
Ba	47	41	44

TABLE B-5. Standard Values - Comparison between Determined Major Elements and those Recommended by Abbey (1977).

Element	BR determined	BR recommended	JG-1 determined	JG-1 recommended	GSP-1 determined	GSP-1 recommended	NIM-G determined	NIM-G recommended
SiO_2	39.66	38.39	71.69	72.36	68.65	67.31	74.76	75.72
Al_2O_3	10.07	10.25	13.50	14.20	15.56	15.19	12.22	12.09
Fe_2O_3	8.05	12.21	2.66	1.99	4.05	4.08	2.19	1.88
MgO	13.01	13.35	1.56	0.76	1.17	0.96	0.10	0.04
CaO	13.70	13.87	2.16	2.17	2.04	2.02	0.85	0.78
Na_2O	3.55	3.07	3.26	3.39	2.79	2.80	3.58	3.30
K_2O	1.49	1.41	4.57	3.96	5.71	5.53	5.15	5.00
TiO_2	2.42	2.61	0.42	0.27	0.66	0.66	0.12	0.09
MnO	0.18	0.20	0.08	0.06	0.04	0.04	0.03	0.02
P_2O_5	1.63	1.05	0.09	0.09	0.27	0.28	0.02	0.02

Element	JB-1 determined	JB-1 recommended	NIM-L determined	NIM-L recommended	BCR-1 determined	BCR-1 recommended	AGV-1 determined	AGV-1 recommended
SiO_2	52.40	52.62	52.57	52.45	55.84	54.85	60.94	59.72
Al_2O_3	14.34	14.62	13.58	13.59	12.97	13.68	16.30	17.22
Fe_2O_3	9.57	8.38	10.85	9.82	13.45	13.52	7.59	6.65
MgO	7.58	7.76	0.29	0.28	2.56	3.49	1.24	1.55
CaO	9.71	9.35	3.07	3.24	7.30	6.98	5.38	5.00
Na_2O	2.77	2.79	7.40	8.30	3.11	3.29	3.92	4.31
K_2O	1.49	1.42	5.64	5.46	1.69	1.68	2.74	2.93
TiO_2	1.38	1.34	0.53	0.49	2.20	2.22	1.16	1.05
MnO	0.16	0.15	0.90	0.76	0.18	0.19	0.12	0.10
P_2O_5	0.25	0.26	0.01	0.06	0.38	0.33	0.45	0.50

TABLE B-6. Standard Values - Comparison between Determined and Recommended Trace Element Values.

Element	NIM-D		SY-1		JB-1		BCR-1		SY-3		W-1	
	determined	recommended	determined	recommended	determined	recom mended	determined	recommended	determined	recommended	determined	recommended
Cr	2900	2900	86	?	401	400	21	16	9	8	95	120
	2959		81		403		17		10		89	
Co	210	210	19	?	30	39	44	37	12	12	45	50
	210		21		27		39		10		48	
Pb	8	?	495	495	12	12	13	15	120	130	14	8
	10		495		15		19		132		9	
Cu	12	10	25	?	53	56	19	19	13	17	110	110
	12		21		60		24		13		110	
Zn	93	91	233	?	74	84	131	120	215	250	84	86
	95		237		84		140		235		89	

Element	W-1		BCR-1		GSP-1		AGV-1		SY-3	
	determined	recommended	determined	recommended	determined	recommended	determined	recommended	determined	recommended
Ce	30	23?	45	54	388	390?	63	63?	2050	2000?
	24		51		382		63		2130	
Nd	26	15	30	29	141	190?	41	39?	500	500?
	19		27		132		38		500	
V	223	240	416	410	79	49	141	125	37	51
	221		418		66		137		34	
La	25	12?	21	25	201	200?	36	45?	1331	1400?
	29		25		200		57		1224	
Ba	259	160	604	680	1277	1300	1122	1200	446	440
	253		604		1398		1154		440	

TABLE B-7. Standard Values - Comparison between Determined and Recommended Trace Element Values.

Element	NIM-G		GSP-1		NIM-S		BCR-1		W-1	
	deter-mined	recom-mended	deter-mined	recom-mended	deter-mined	recom-mended	deter-mined	recom-mended	deter-mined	recom-mended
	388		259		535		44		22	
Rb	340	330	253	250	541	550	42	47	24	21
	345		259		541		36		23	
	10		254		66		326		188	
Sr	13	10	237	230	72	64	346	330	198	190
	21		257		73		328		202	
	160		32		15		30		18	
Y	193	125	30	32	12	3?	41	37?	19	25
	136		28		2		33		27	
	270		517		14		196		95	
Zr	270	290	540	500	63	45?	181	185	107	105
	297		510		19		208		100	
	36		29		0		12		1	
Nb	35	52	28	29	12	3.5?	18	14	11	9.5?
	35		30		1		15		1	

Element	MRG-1		NIM-P		NIM-D		BCR-1		NIM-N	
	deter-mined	recom-mended	deter-mined	recom-mended	deter-mined	recom-mended	deter-mined	recom-mended	deter-mined	recom-mended
	187.3		556.5		2147.5		20.3		109.5	
Ni	195.6	200	537.5	560	2102.5	2100	2.2	13	91.5	120
	180.7		571		2119.9		32.3		95	
	0.05		0.02		0.02		0.05		0.02	
S		0.06		0.02?		0.02?		0.04?		0.01?
	0.06		0.03		0.02		0.04		0.02	

Element	AS-1		AS-2		AS-3		AS-4	
	99		155		295		3000	
As		100		150		300		3000
	97		150		302		3000	

TABLE B-8: Range in Major Element Values for Sample 25-11.

Element					Mean
SiO_2	64.20	64.15	64.78	64.29	64.36
Al_2O_3	12.54	12.58	12.71	12.66	12.62
Fe_2O_3	15.94	15.94	16.16	15.98	16.01
MgO	4.15	4.27	4.27	4.19	4.22
CaO	0.87	0.87	0.87	0.89	0.86
Na_2O	0.11	0.10	0.09	0.10	0.10
TiO_2	1.28	1.28	1.30	1.29	1.29
MnO	0.32	0.32	0.33	0.32	0.32
P_2O_5	0.04	0.05	0.04	0.04	0.04

TABLE B-9. Range in Trace Element Values for Samples FR-578 and 800-01.

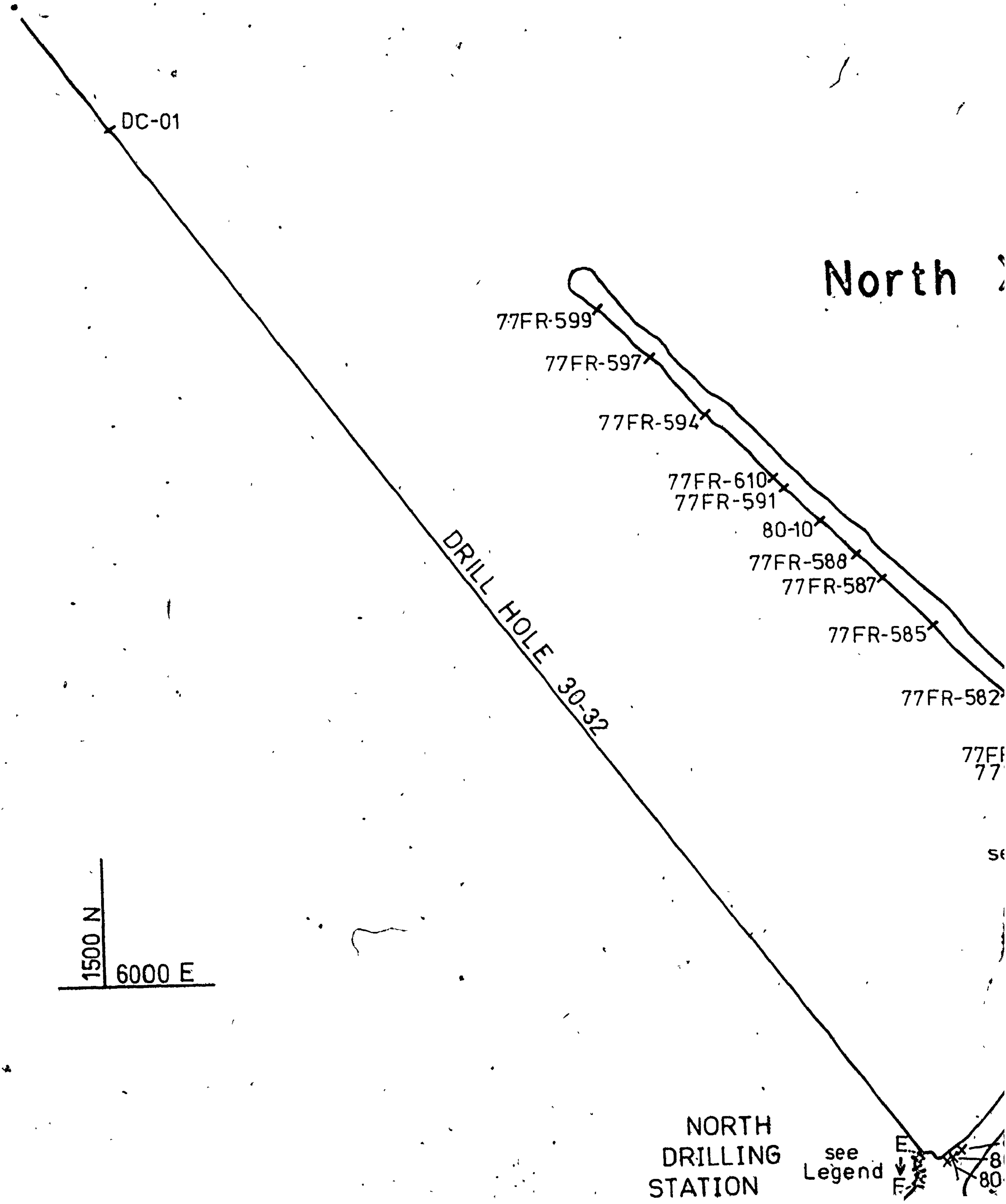
	FR-578			Mean	800-01			Mean
S	639	654	609	634	17305	17128	16935	17122.7
Ni	52.1	59.7	53.9	55.2	128.9	130.0	125.2	128
Rb	23	23	22	22.7	41	40	41	40.7
Sr	111	112	113	112	99	98	100	99
Y	15	13	14	14	15	17	17	16.3
Zr	57	55	54	55.3	43	42	43	42.7
Nb	2	1	2	1.7				
Cr	252	251	231	244.7				
Co	21	25	23	23				
Pb	17	17	15	16.3				
Zn	64	57	59	60				
As	67	48	55	56.7				

TABLE B-10. Range in Trace Element Values for Sample 25-11.

					Mean
S	1402	1379	1399	1372	1388
Ni	134.2	135.5	136.9	141.7	137.1
Rb	22	24	21	13	20
Sr	72	60	67	68	66.8
Y	24	9	16	17	16.5
Zr	75	69	73	70	71.8
Nb	13	14	3	15	8.8
Cr	415	429	417	460	430.3
Co	63	58	64	71	64
Pb	8	11	8	12	9.8
Cu	147	146	151	147	147.8
Zn	85	92	92	90	89.8
As	307	299	293	280	294.8

TABLE B-11. Range in Trace Element Values for Sample 800-01.

				Mean
Ce	188	178	180	182
Nd	15	16	15	15.3
V	284	292	293	289.7
La	8	1	8	5.7
Ba	153	131	153	145.7

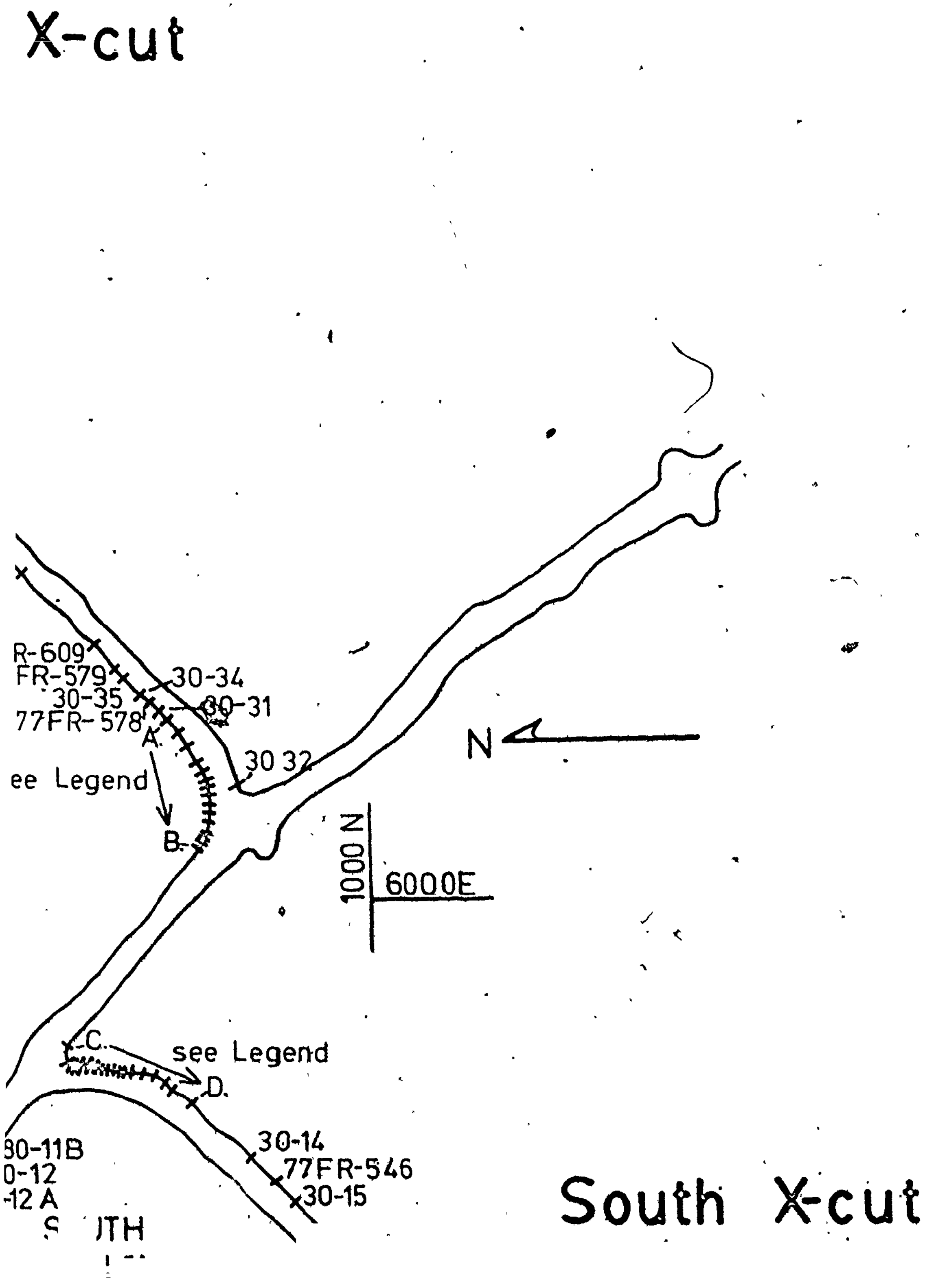

DC-01
North
77FR-599
77FR-597
77FR-594
77FR-610
77FR-591
80-10
77FR-588
77FR-587
77FR-585
77FR-582
DRILL HOLE 30-32
1500 N
6000 E
NORTH
DRILLING
STATION
see
Legend
E
F

2 OF 1

M
Sample Loca
Dick

L

-30



A.→B.

sample numbers i

A 30-30
77FR-577
30-29
30-28
77FR-576
30-27
30-26
30-25
30-24
30-23
30-22
30-21
30-20
30-19
B. 30-18

E.→F.

sample numbers

E. 30-36
30-37
30-38
30-39
30-40
30-41
F. 30-42

Map 1
Sample Locations, 30 Level
Dickenson Mine

LEGEND

-30-47 sample number

A. ⟶ B.

sample numbers in order:

A. 30-30
77FR-577
30-29
30-28
77FR-576
30-27
30-26
30-25
30-24
30-23
30-22
30-21
30-20
30-19
B. 30-18

E. ⟶ F.

sample numbers in order:

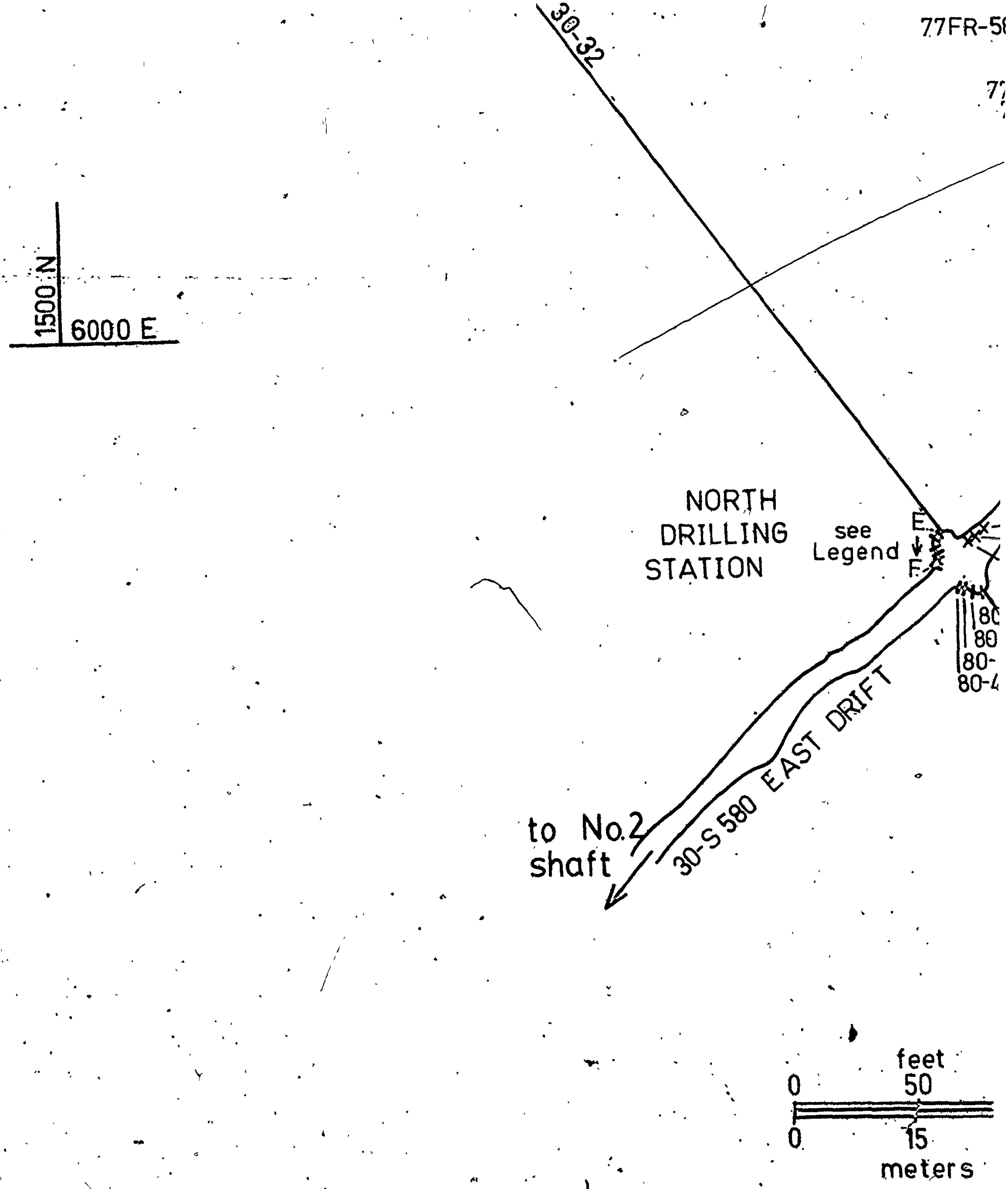
E. 30-36
30-37
30-38
30-39
30-40
30-41
F. 30-42

C. ⟶ D.

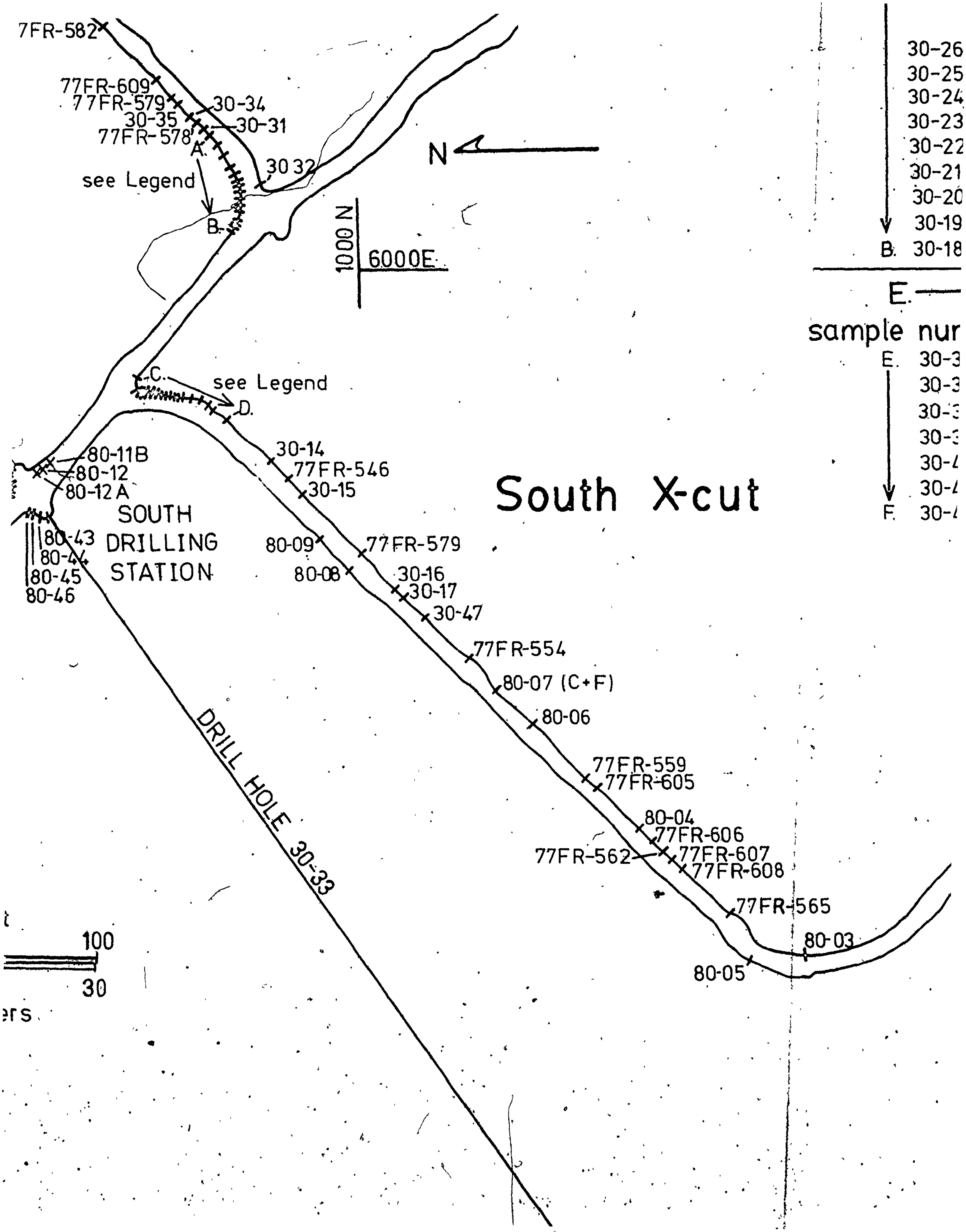
sample numbers in order:

C. 30-33
77FR-575
30-01
30-02
30-03
30-04
77FR-541
30-05
30-06
30-07
30-08
30-09
77FR-542
30-10
30-11
30-12
77FR-543
D. 30-13

cut


77FR-5
77
30-32
1500 N
6000 E
NORTH DRILLING STATION
see Legend
E
F
80
80
80-
80-4
30-S 580 EAST DRIFT
to No.2 shaft
feet
0
50
0
15
meters

4 OF


7FR-582
77FR-609
77FR-579
30-34
30-35
30-31
77FR-578
A.
30 32
see Legend
B.
N
1000 N
6000E
30-26
30-25
30-24
30-23
30-22
30-21
30-20
30-19
B. 30-18
E.
sample nur
E. 30-3
30-3
30-3
30-3
30-4
30-4
F. 30-4
C.
see Legend
D.
80-11B
80-12
80-12 A
SOUTH
DRILLING
STATION
80-43
80-44
80-45
80-46
30-14
77FR-546
30-15
South X-cut
80-09
77FR-579
80-08
30-16
30-17
30-47
77FR-554
80-07 (C+F)
80-06
77FR-559
77FR-605
80-04
77FR-606
77FR-562
77FR-607
77FR-608
77FR-565
80-03
80-05
DRILL HOLE 30-33
100
30
ers

30-26
30-25
30-24
30-23
30-22
30-21
30-20
30-19
B. 30-18

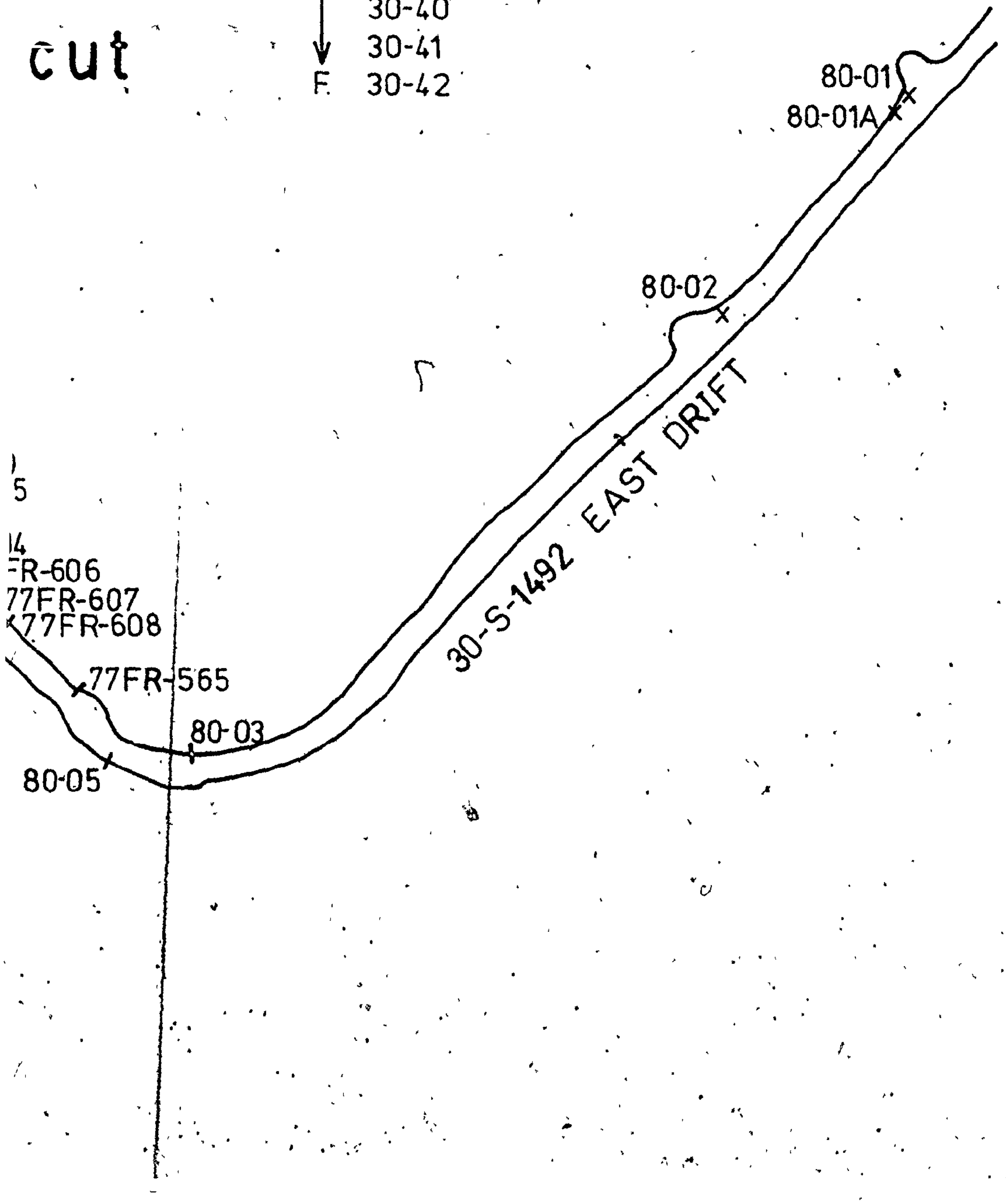
E ⟶ F

sample numbers in order:

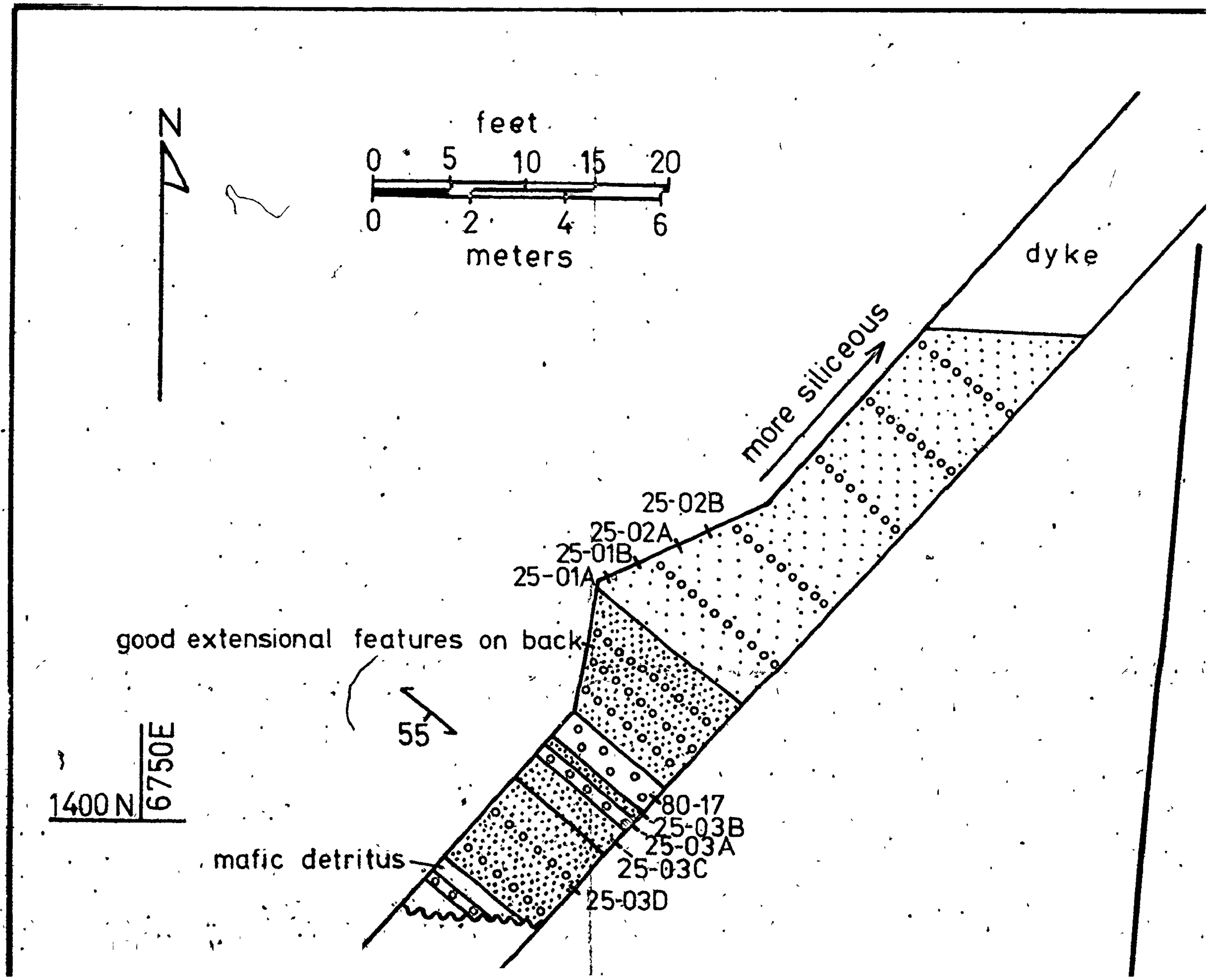
E. 30-36
30-37
30-38
30-39
30-40
30-41
F. 30-42

541
30-05
30-06
30-07
30-08
30-09
77FR-542
30-10
30-11
30-12
77FR-543
D. 30-13

cut

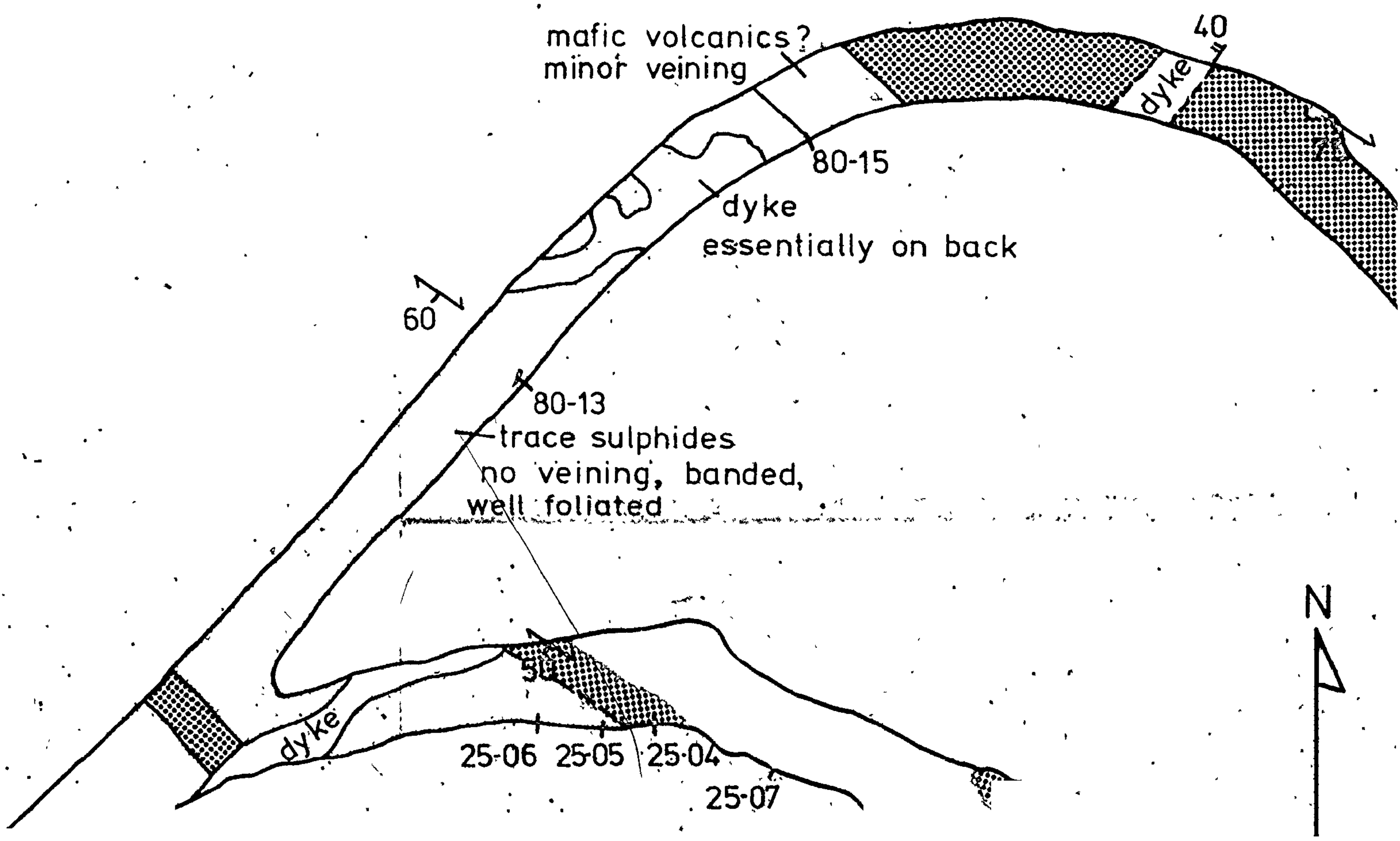


1 of 1


N
feet
0 5 10 15 20
0 2 4 6
meters
dyke
more siliceous
25-02B
25-02A
25-01B
25-01A
good extensional features on back
55
1400 N
6750E
80-17
25-03B
25-03A
25-03C
25-03D
mafic detritus

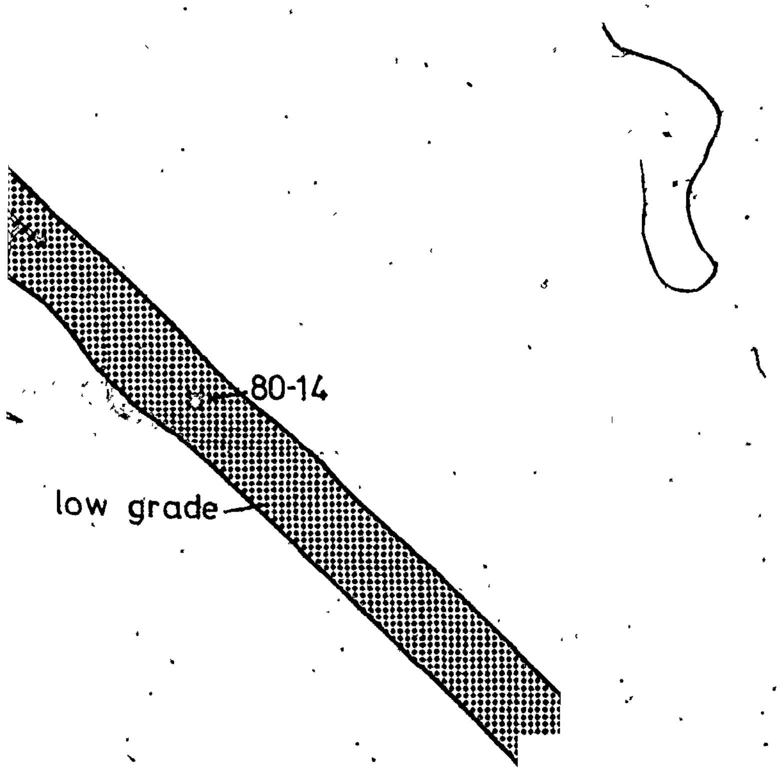
2 OF 1

Map 2
Sample Locations and Gec
25 Level
Dickenson Mine



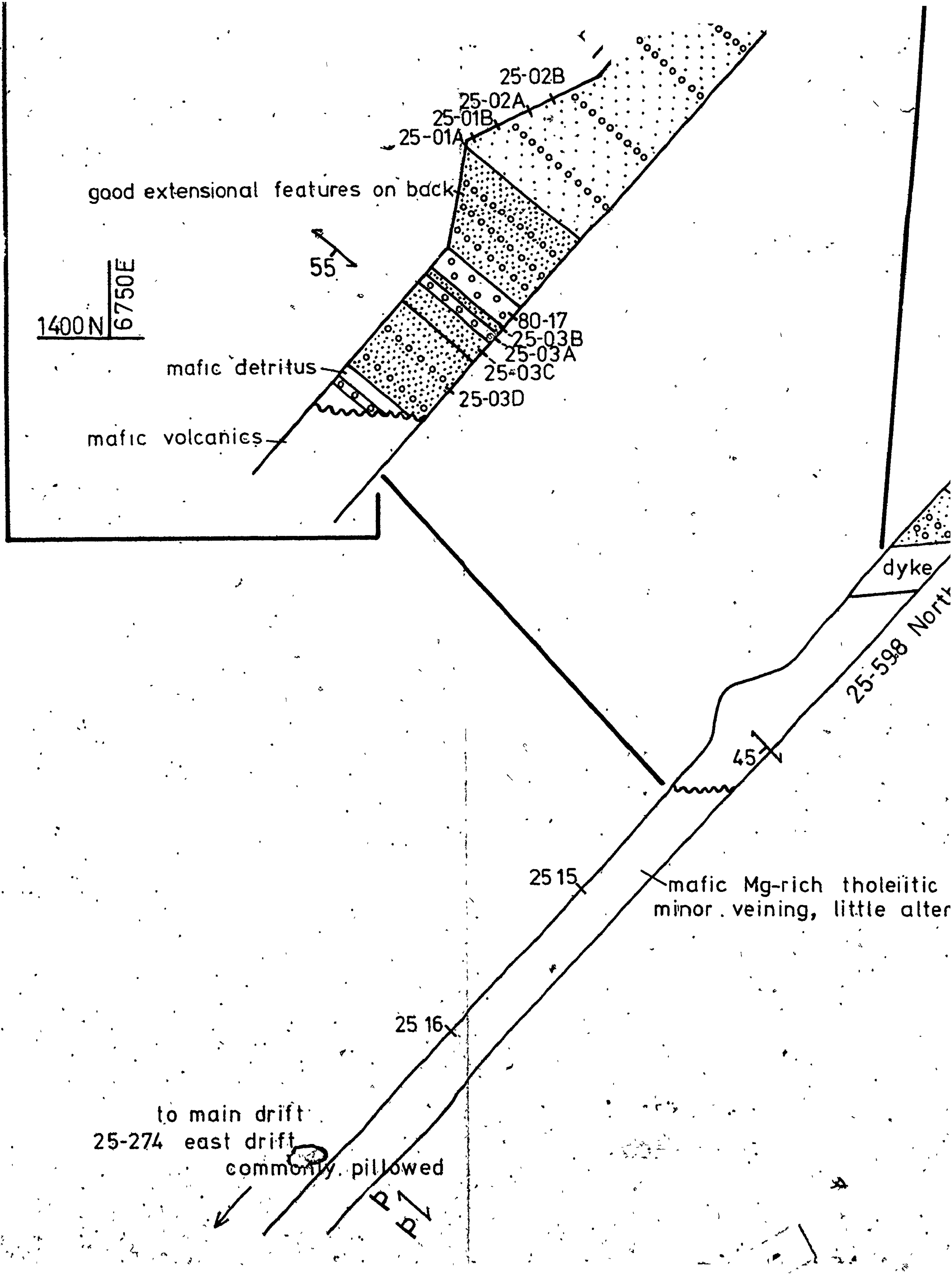
|3 OF 1|

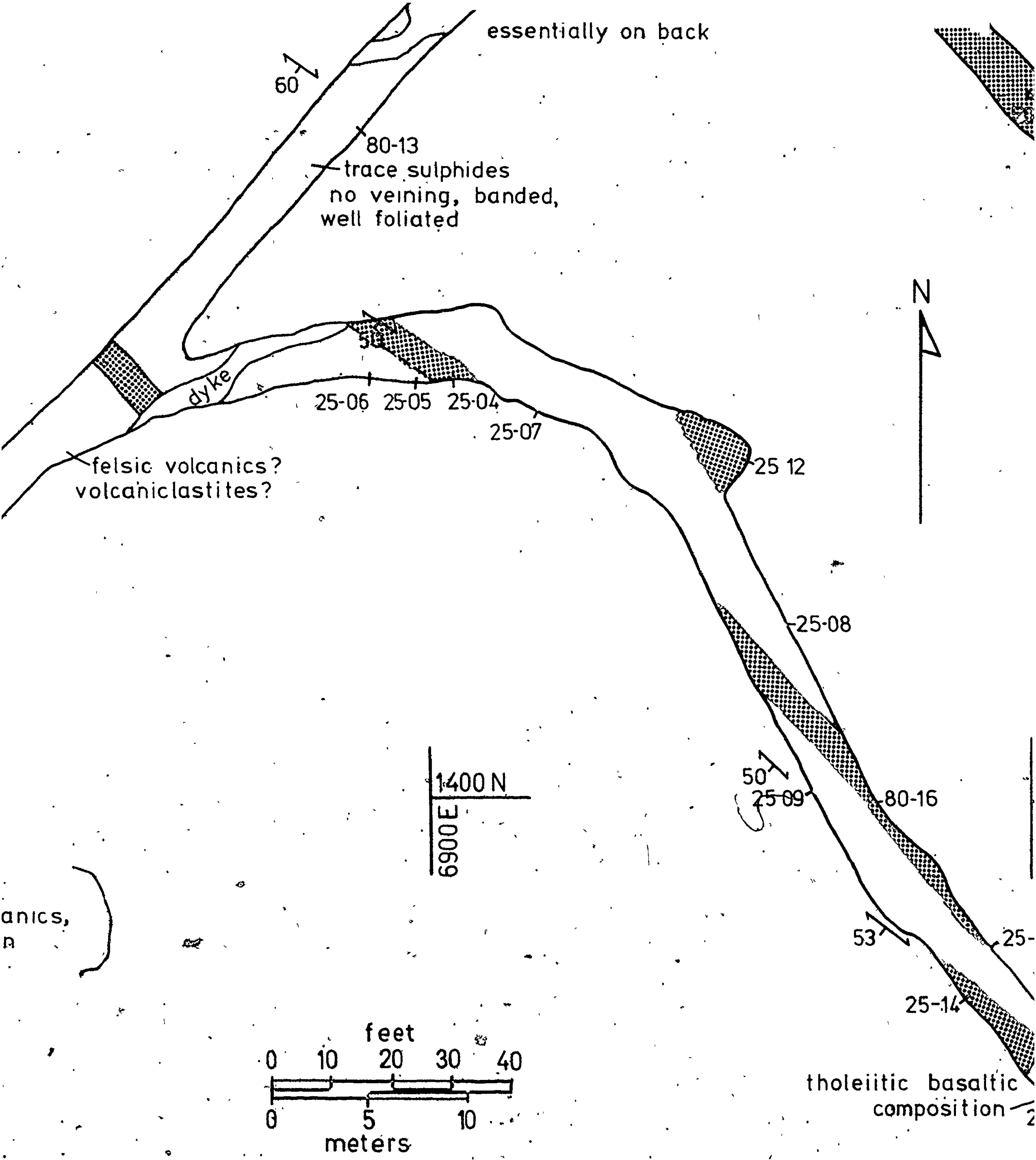
gy



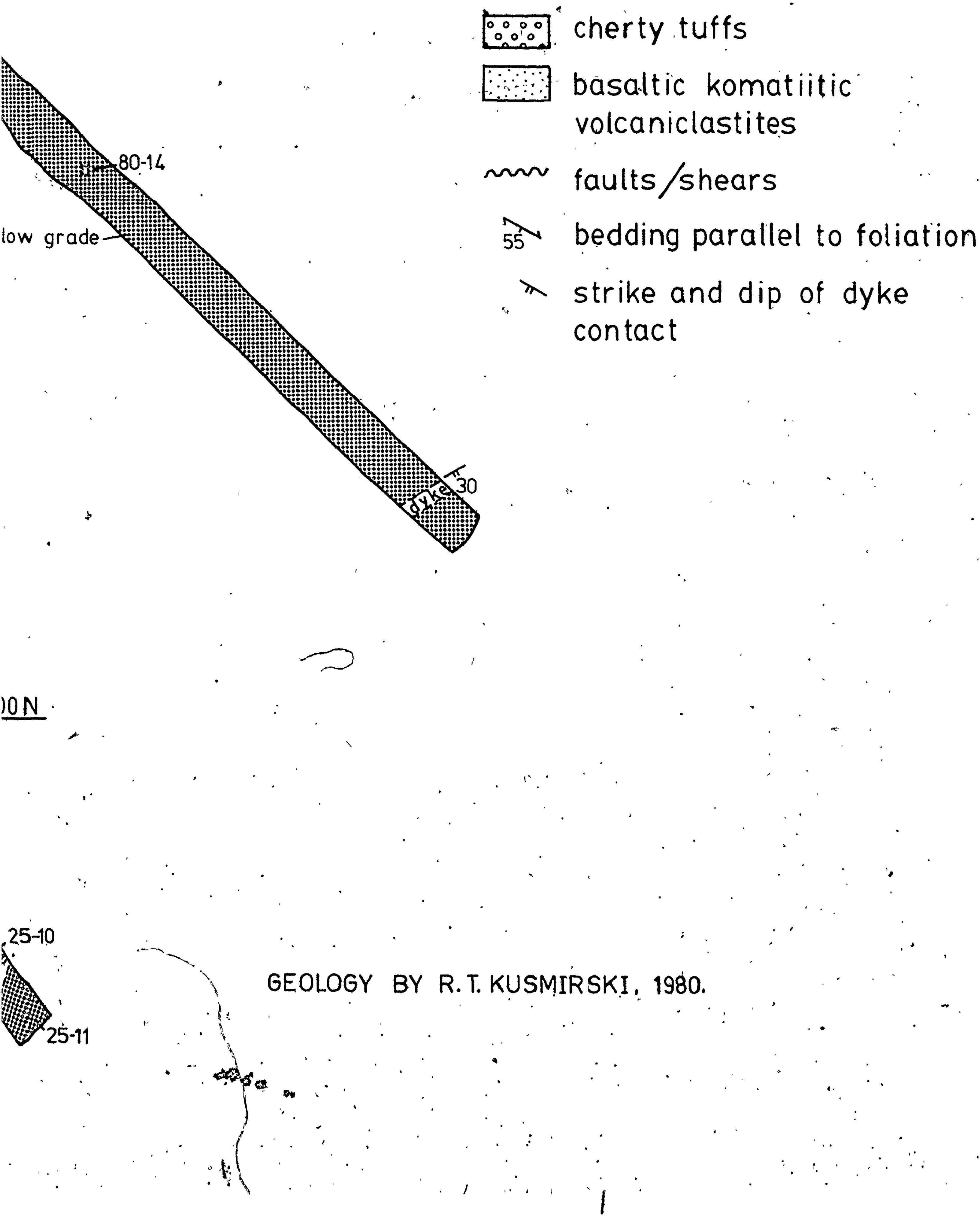
L E G E N D

▭	auriferous sediments
▩	non-auriferous sediments 100—300 ppb
▭	felsic volcaniclastites
░	ultramafic to pyroxenitic komatiitic volcaniclastite
○	cherty tuffs
⬚	basaltic komatiitic volcaniclastites
∿	faults/shears
55	bedding parallel to foliati
⊤	strike and dip of dyke contact


25-02B
25-02A
25-01B
25-01A
good extensional features on back
55
1400 N
6750E
80-17
25-03B
25-03A
25-03C
25-03D
mafic detritus
mafic volcanics
dyke
25-598 Nort
45
25 15
mafic Mg-rich tholeiitic
minor veining, little alter
25 16
to main drift
25-274 east drift
commonly pillowed
P
P


essentially on back
60
80-13
trace sulphides
no veining, banded,
well foliated
N
53
dyke
25-06
25-05
25-04
25-07
felsic volcanics?
volcaniclastites?
25 12
25-08
1400 N
6900 E
50
25-09
80-16
anics,
n
53
25-
25-14
tholeiitic basaltic
composition
feet
0
10
20
30
40
0
5
10
meters

/5 of /



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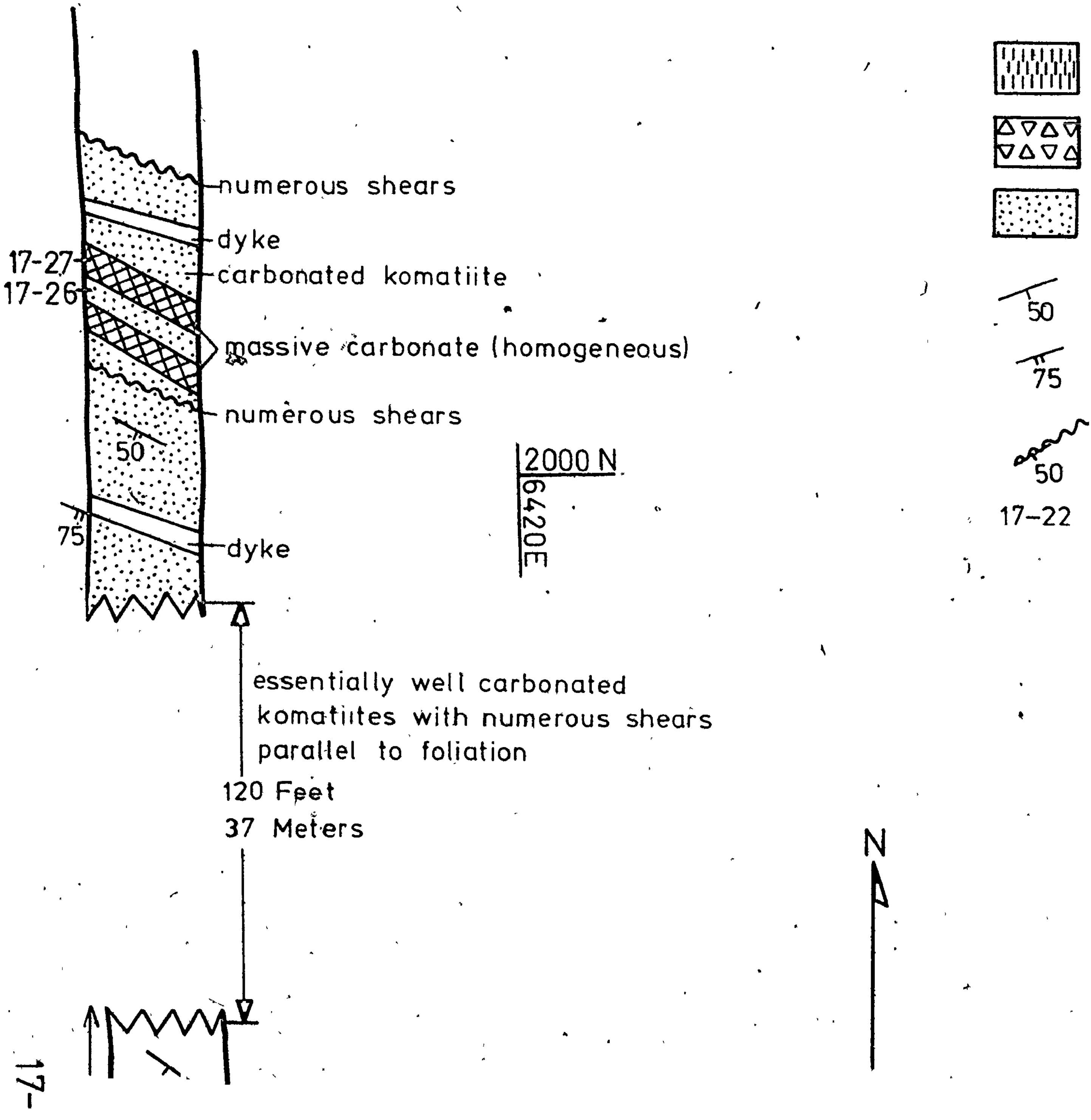
1 OF 1

Map 3
Sample Locations and G
17 Level, Dickenson Mine



2 OF 1

Map 3

ocations and Geology
Dickenson Mine

LEGEND

▥ Peraluminous sediment

▽△ Flowtop breccia

⬚ Carbonated komatiitic flow

50 foliation

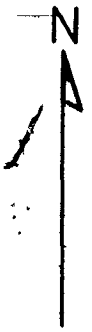
75 strike and dip of dyke contact

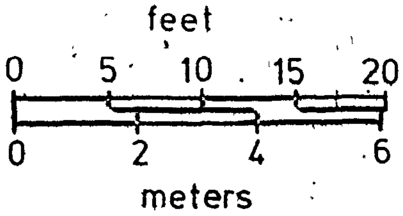
50 strike and dip of fault/shear

17–22 sample number

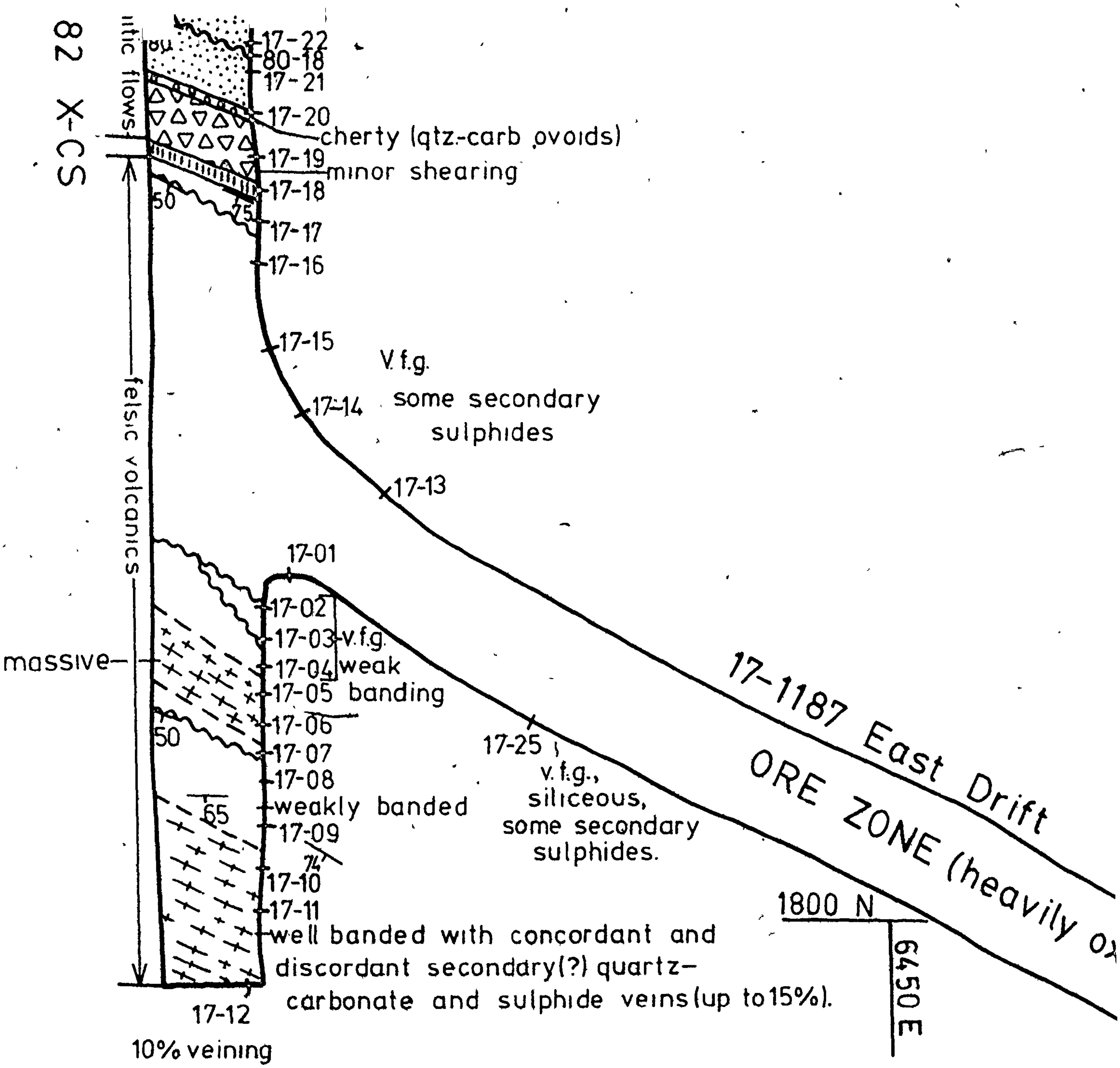
ieous)

shears



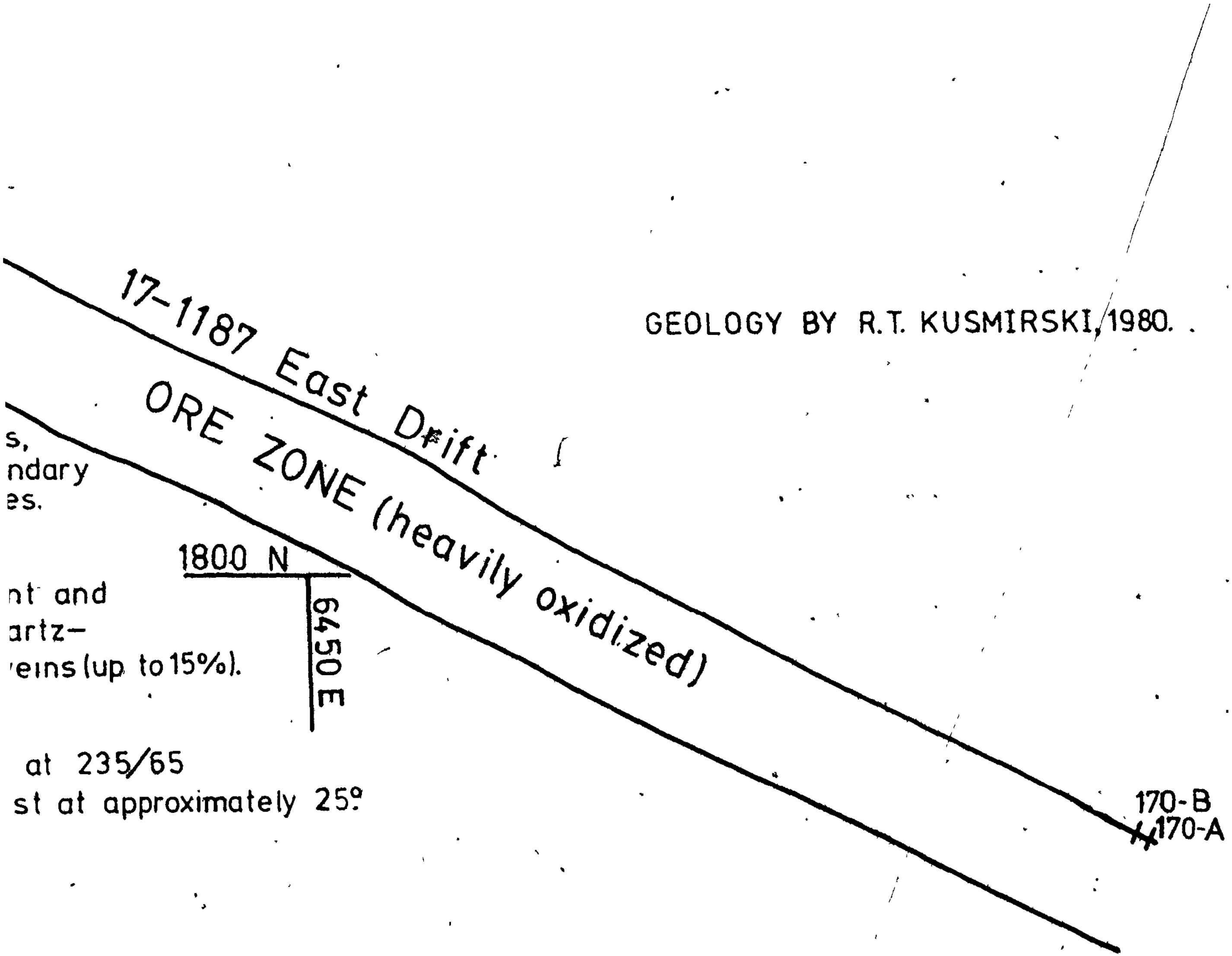


82 X-CS



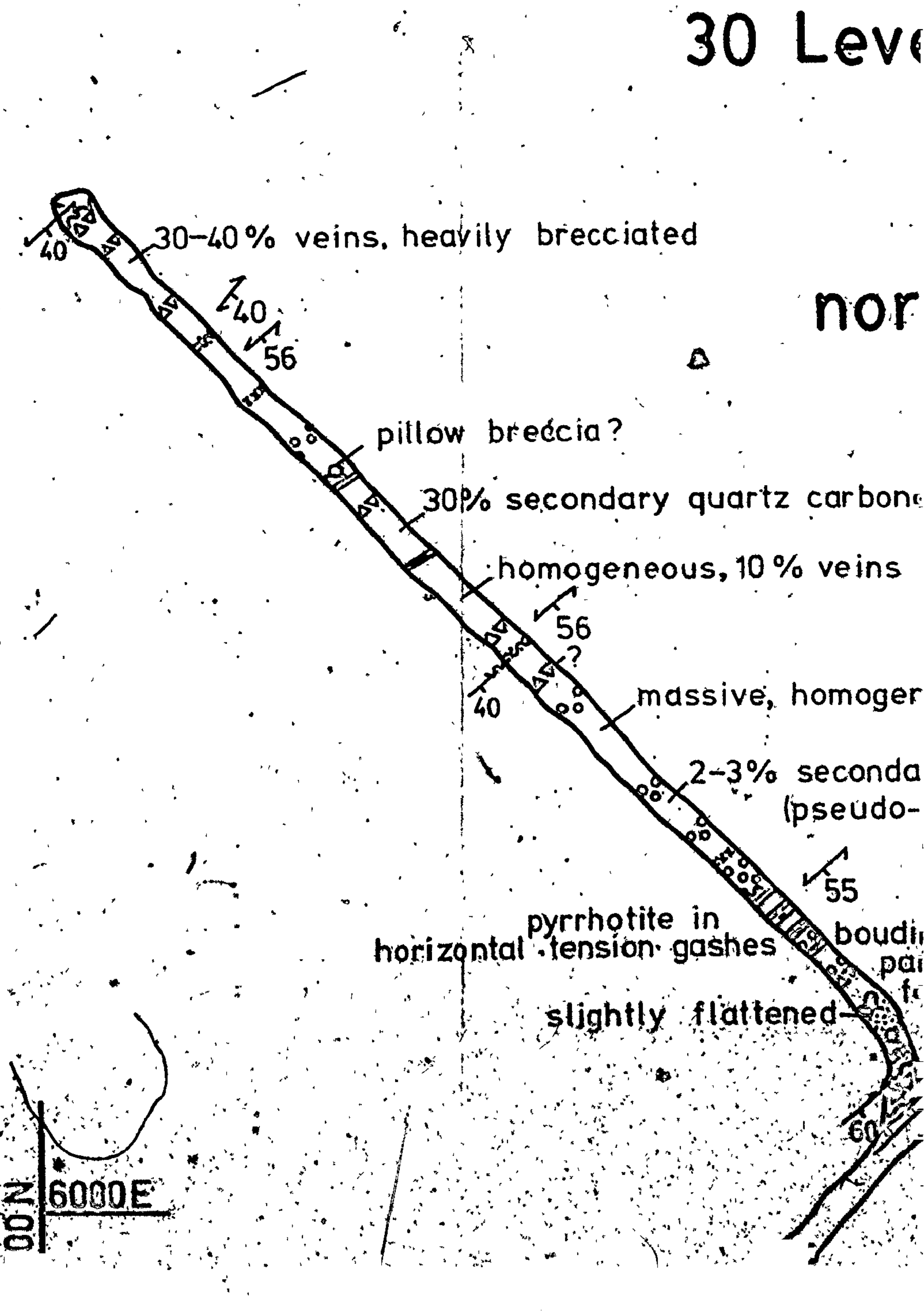
dominant joint planes at 235/65
and sub-horizontal east at approximately 25°

3 OF 1


17-1187 East Drift
ORE ZONE (heavily oxidized)
GEOLOGY BY R.T. KUSMIRSKI, 1980.
s,
ndary
es.
1800 N
6450 E
nt and
artz–
veins (up to 15%).
at 235/65
st at approximately 25°
170-B
170-A

4 OF 4

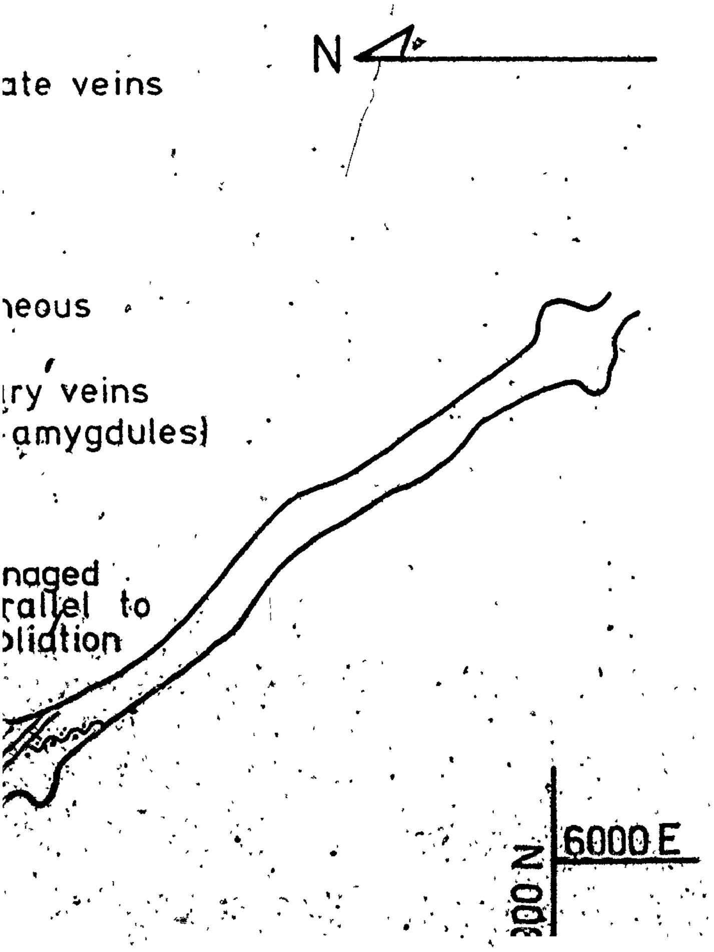
[1 OF]


30 Leve
nor
30–40 % veins, heavily brecciated
40
40
56
pillow breccia?
30% secondary quartz carbon
homogeneous, 10 % veins
56
?
40
massive, homoger
2–3% seconda
(pseudo-
55
pyrrhotite in
horizontal tension gashes
boudi
pa
f
slightly flattened
60
00 N
6000E

21

Map 4
Geology
l, Dickenson Mine

th x-cut



LEGEND

- ☐ Mafic flows
- ☐ Felsic volcaniclast
- ☐ Dykes (Basaltic t
- Andesitic compos
- ▨ Flowtop breccia
- ▨ Tectonic carbonat
- ▤ Mafic sediments
- ∩ ∩ Pillows
- ░ Garnets
- ○ Amygdules
- xxxxxx well defined flow
- 〰 shear zone
- 〰 silicified shear z

3OF

LEGEND

☐ Mafic flows

☐ Felsic volcaniclastites

☐ Dykes (Basaltic to Andesitic composition)

▽△ Flowtop breccia

▽△ Tectonic carbonate breccia

▤ Mafic sediments

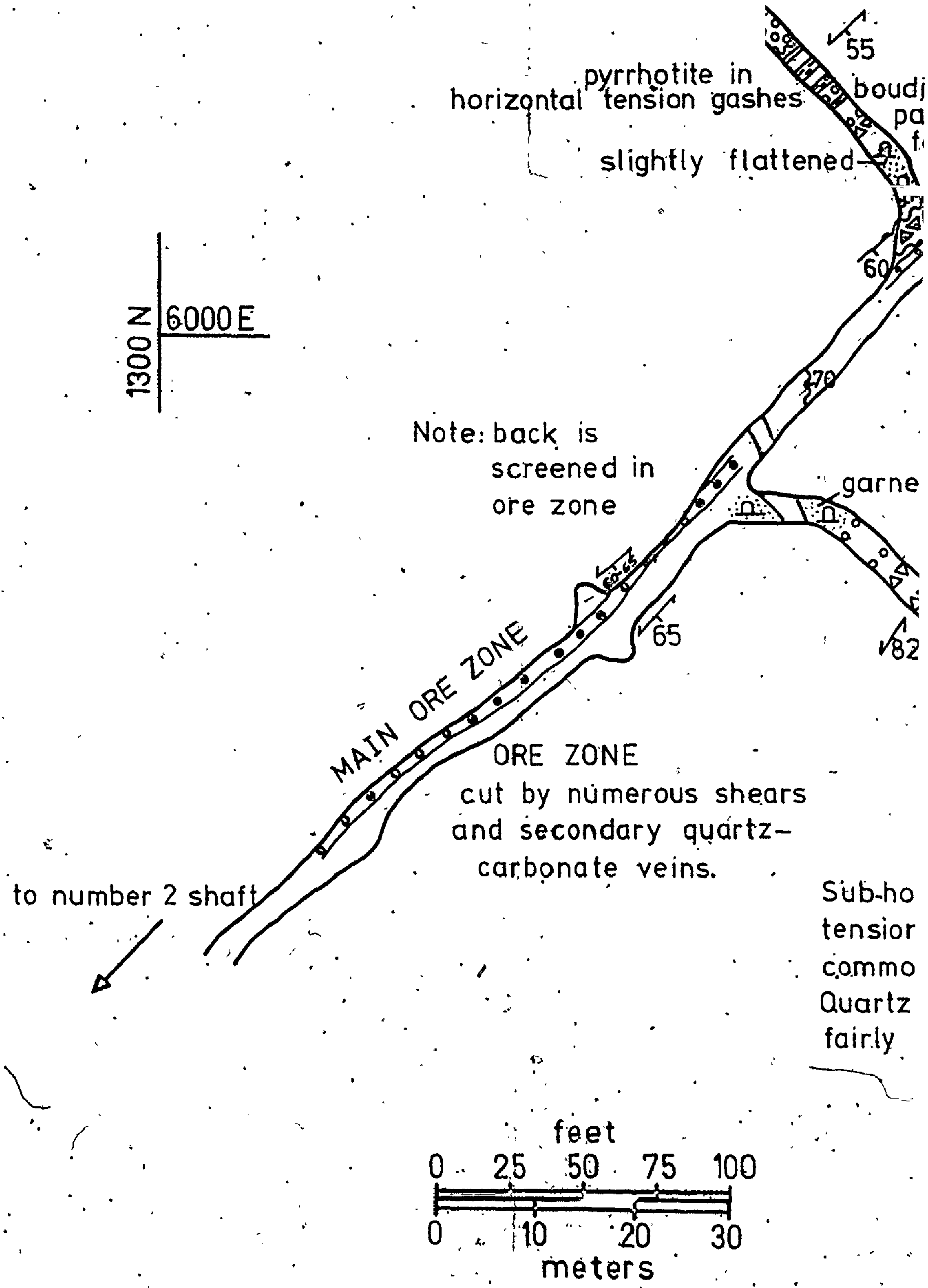
∩ Pillows

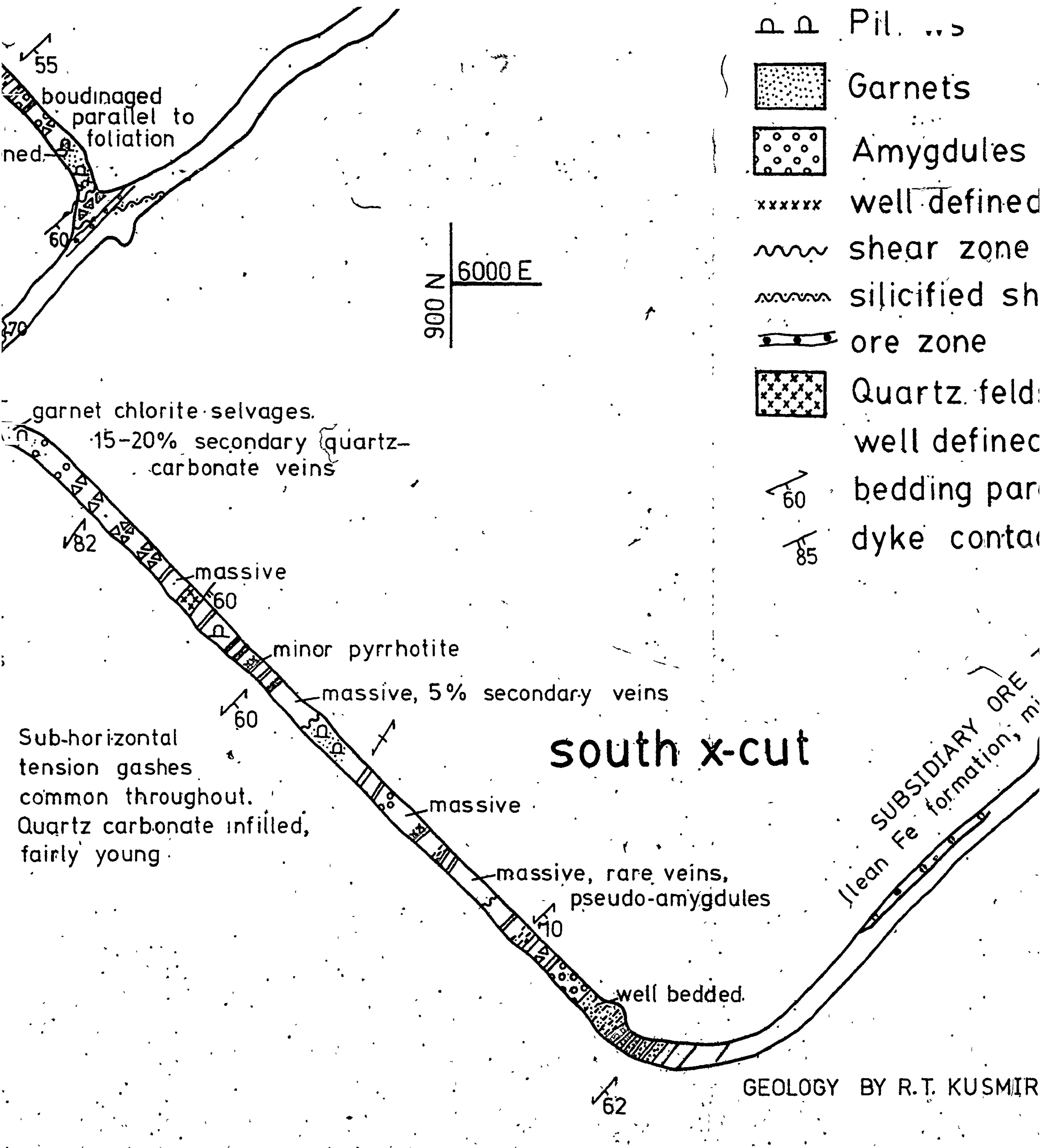
⁘ Garnets

○ Amygdules

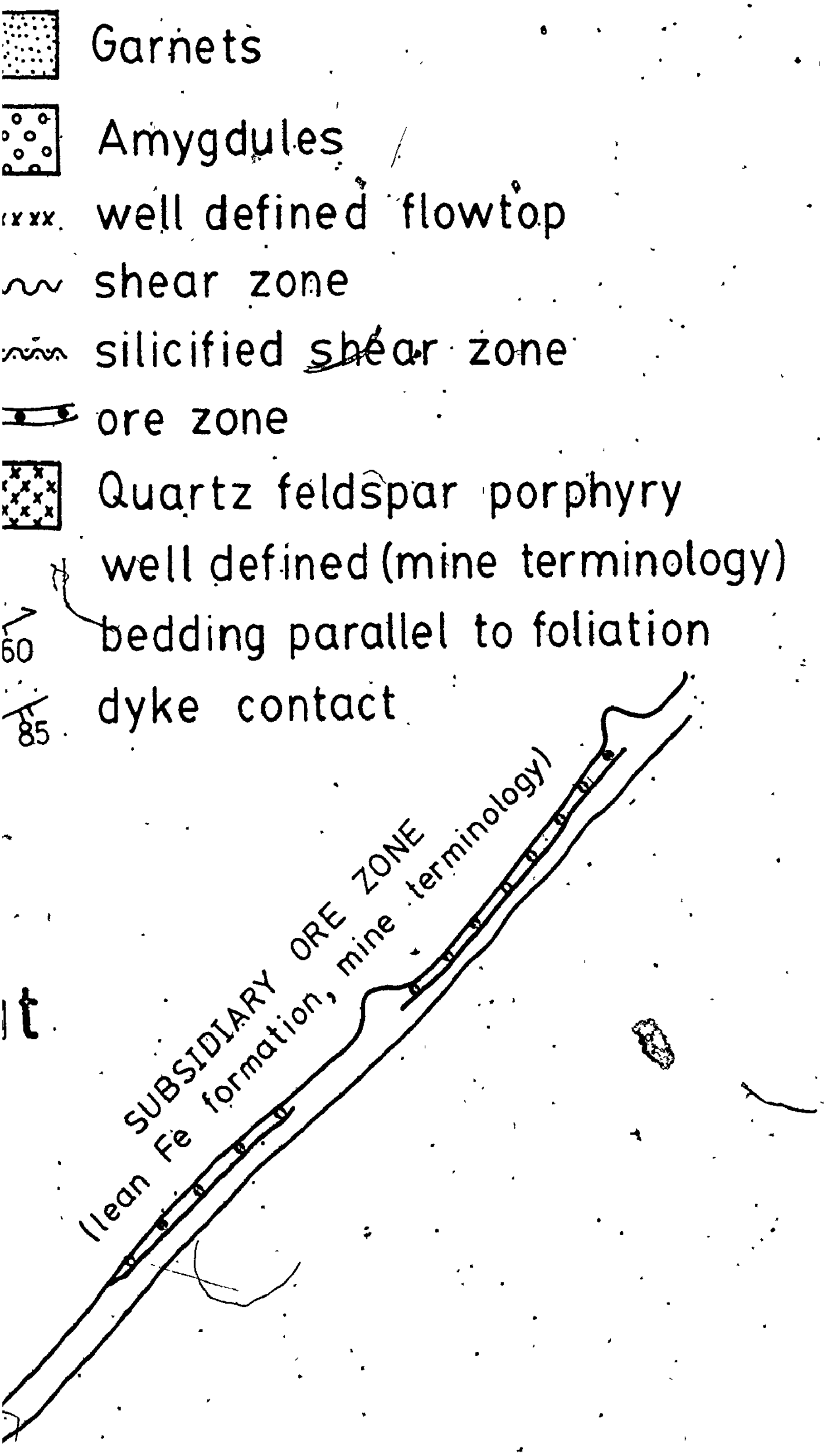
xxxx well defined flowtop

〰 shear zone


pyrrhotite in horizontal tension gashes
boudi
pa
f
slightly flattened
55
60
70
1300 N
6000 E
Note: back is screened in ore zone
garne
60-65
65
82
MAIN ORE ZONE
ORE ZONE cut by numerous shears and secondary quartz-carbonate veins.
to number 2 shaft
Sub-ho
tensior
commo
Quartz
fairly
feet
0 25 50 75 100
0 10 20 30
meters


Pil
Garnets
Amygdules
well defined
shear zone
silicified sh
ore zone
Quartz feld
well definec
bedding par
dyke conta
60
85
55
boudinaged parallel to foliation
ned
60
70
6000 E
900 N
garnet chlorite selvages.
15-20% secondary quartz-carbonate veins
82
massive
60
minor pyrrhotite
massive, 5% secondary veins
60
Sub-horizontal tension gashes common throughout. Quartz carbonate infilled, fairly young
south x-cut
massive
massive, rare veins, pseudo-amygdules
10
well bedded.
62
SUBSIDIARY ORE
(lean Fe formation, m
GEOLOGY BY R.T. KUSMIR

5 - 1



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