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OPEN FILE REPORT SERIES

WEATHERING PROCESSES - P241 EASTERN GOLDFIELDS FIELD TRIP

C.R.M. Butt, H.M. Churchward, M.J. Lintern and K.M. Scott

CRC LEME OPEN FILE REPORT 64

February 1999

(CSIRO Division of Exploration Geoscience, unnumbered report, 1990. Second impression 1999)

CRC LEME is an unincorporated joint venture between The Australian National University, University of Canberra, Australian Geological Survey Organisation and CSIRO Exploration and Mining, established and supported under the Australian Government's Cooperative Research Centres Program.

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Headquarters: CRC LEME c/o CSIRO Exploration and Mining, Private Bag, PO Wembley, Western Australia, 6014

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

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

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

P241: Gold and associated elements in the regolith - dispersion processes and implications for exploration (1987-1991). Leader: Dr C.R.M. Butt.
The project investigated the distribution of ore and indicator elements in the regolith. It included studies of the mineralogical and geochemical characteristics of weathered ore deposits and wall rocks, and the chemical controls on element dispersion and concentration during regolith evolution. This was to increase the effectiveness of geochemical exploration in weathered terrain through improved understanding of weathering processes. It was supported by 26 companies.

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

P240A: Geochemical exploration in complex lateritic environments of the Yilgarn Craton, Western Australia (1991-1993). Leaders: Drs R.E. Smith and R.R. Anand.
The approach of viewing geochemical dispersion within a well-controlled and well-understood regolith-landform and bedrock framework at detailed and district scales continued. In this extension, focus was particularly on areas of transported cover and on more complex lateritic environments typified by the Kalgoorlie regional study. This was supported by 17 companies.

P241A: Gold and associated elements in the regolith - dispersion processes and implications for exploration. Leader: Dr. C.R.M. Butt.
The significance of gold mobilisation under present-day conditions, particularly the important relationship with pedogenic carbonate, was investigated further. In addition, attention was focussed on the recognition of primary lithologies from their weathered equivalents. This project was supported by 14 companies.

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

This report (CRC LEME Open File Report 64) is a Second impression (second printing) of CSIRO, Division of Exploration Geoscience Restricted Report Unnumbered, first issued in 1990, which formed part of the CSIRO/AMIRA Project P241.

Copies of this publication can be obtained from:
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ITINERARY

Sunday 28th October

1.00 pm	Assemble at CSIRO Floreat Park for travel to Southern Cross by coach.
6.00 pm	Briefing: Mt. Hope - Soils and Landforms Dinner and overnight accommodation

Monday 29th October

8.00 am	Departure for the Bounty Gold Mine after breakfast Guides: Max Churchward and Melvyn Lintern
1.00 pm	Departure for Kalgoorlie after lunch
7.00 pm	Arrival Overland Motor Inn, Kalgoorlie for dinner and overnight accommodation

Tuesday 30 October

8.00 am	Briefing: Mt. Percy - geology, geomorphology and geochemistry Panglo - geology, geomorphology, soils and groundwaters
9.30 am	Depart for Mt. Percy.
9.45 am	Mystery Pit, Mt. Percy. Guides: Charles Butt, Paul Sauter (KCGM) and Ravi Anand. Traverse along west and north walls on bench at RL 400 to NE corner
11.00 am	Depart for Panglo.
11.30 am	Panglo. Guides: Melvyn Lintern, David Gray, Ian G. Robertson (Pancon). Demonstration of water sampling techniques. Soil geochemistry and biogeochemistry.
12.30 am	Lunch.
1.00 pm	Depart for Bottle Creek.

Wednesday 31st October

8.00 am	Field visits around Bottle Creek
4.00 pm	P241 only Sponsors return to Kalgoorlie by coach - end of trip P240 Sponsors depart for Leonora for P240 Field Trip

THE BOUNTY GOLD MINE

The Bounty Gold Mine is located approximately 95 km east north-east of Hyden and 115 km east south-east of Southern Cross, in the Forrestania Greenstone Belt, a southern extension of the Southern Cross Greenstone Belt. Gold mineralisation at Mt. Hope is hosted by a steeply dipping, semi-conformable shear system, near the contact of a mafic intrusive and a komatiitic flow sequence. The main area of interest, the Bounty Zone, has been estimated to contain a mineable resource of 1.92 Mt at 7.5 g/t Au. Open pit mining began in late 1988 and was completed recently. Production is now from an underground resource. A map of the soils and of the stops used for this field trip is shown in Figure 1.

Stop No. 1

This is on the "Airport" road, on the crest of a breakaway. The landform, a major factor affecting the pattern and stratigraphy of the regolith, will be discussed.

To the west are long gentle slopes of an upland, mantled by deep lateritic profiles and associated debris. Lateritic gravels and yellow clay sands dominate the soil mantle. The vegetation consists of heath and low scrub of various accacias and casuarinas.

To the east, below a breakaway, erosional terrain represents areas of extensive, though partial stripping of the deep weathered mantle. Surface soils are predominantly calcareous clay. There are sporadic outcrops of country rock including narrow zones of chert, as low ridges. The vegetation in the erosional terrain is eucalypt woodland.

Note there are relics of the lateritic surface arrayed along the valley side, isolated by erosion from the upland. It thus appears that the ancient weathered surface was broadly similar to the present one.

This site shows a juxtaposed relationship of the calcareous clay and the lateritic residuum, due to erosion. Other sites to be visited will show that a superimposed stratigraphic relationship is also possible in this area.

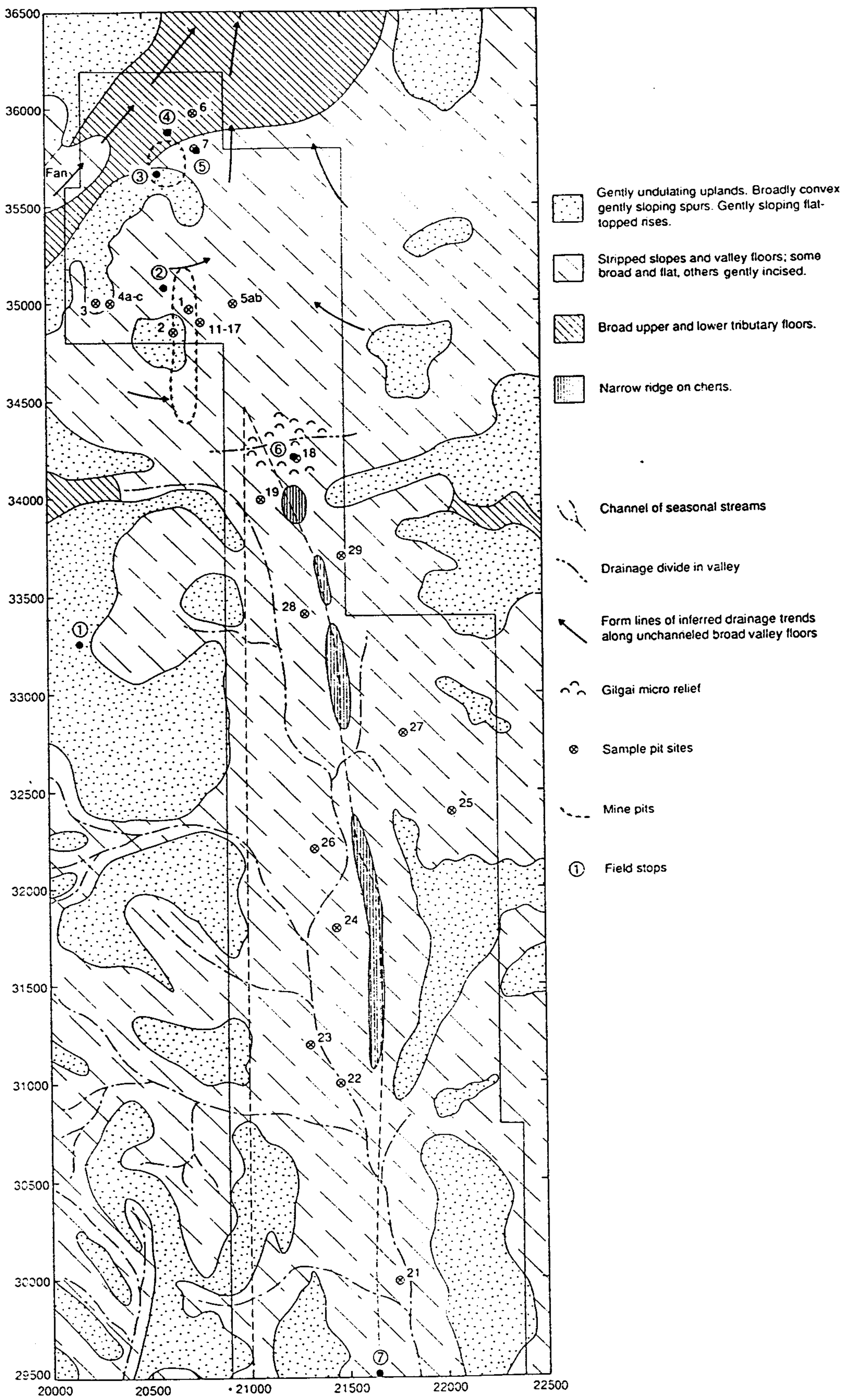
Stop No. 2

West wall of the Hangingwall Pit, viewed from its eastern rim. This is situated in an erosional terrain and the cutting shows calcareous clays overlying non-calcareous clays, the latter merging with weathered country rock at depth. This is a frequently occurring style of regolith stratigraphy for the Eastern Goldfields. Note the concentration of carbonate adjacent to subcrops of country rock.

Stop No. 3

Entrance to the North Bounty Pit. Lateritic duricrust, gravels and sands overlie the greenstone sequence. Nodular, incipiently pisolithic and vermicular structures are present along this face. This laterite is a part of a tongue of deeply weathered regolith extending from the upland to the valley floor.

Figure 1



The geomorphology of the Mt. Hope Area showning Field Stop Sites

Stop No. 4

Northern rim of the North Bounty Pit. Details of the geology of the Forrestania Greenstone Sequence will be introduced by the Mine Geologist, Duncan Buchanan. Note the lateritic materials which dominate the southern part of the pit. These extend northward, dipping beneath calcareous clays that dominate the soils overlying the northern part of the pit. The regolith stratigraphy in the northern part of the pit is:-

0-75 cm	Calcareous clays
75-250 cm	Brown, non-calcareous clays
>250 cm	Vermicular and nodular lateritic residuum, which merges at depth to the underlying lithologies.

As the lateritic residuum continues as a substrate towards the northern extremity of the pit, it changes to a more plastic, mottled clay. This site shows a superimposed relationship of the two main elements of the regolith stratigraphy.

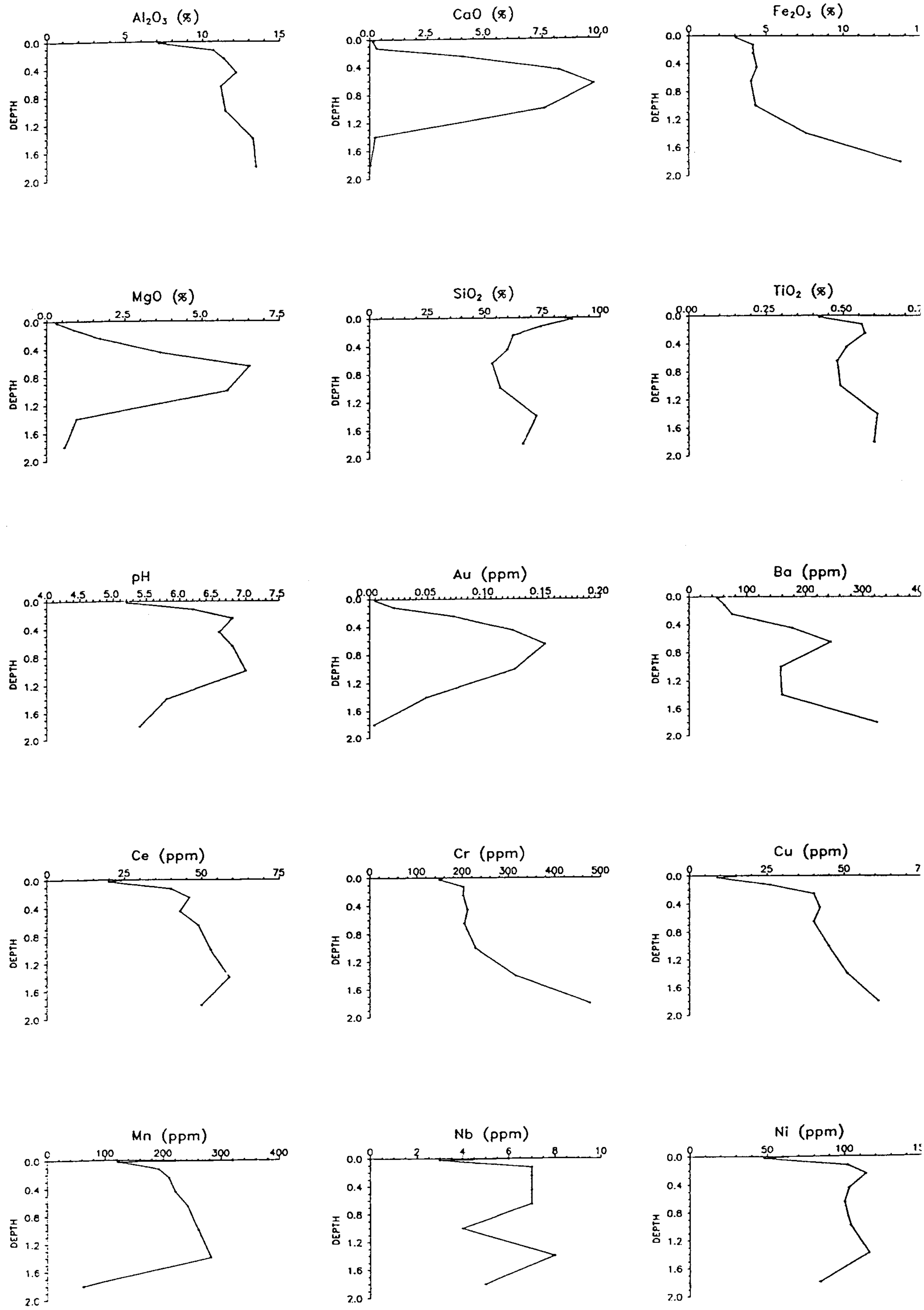
Stop No. 5

This shows the floor of a broad north-trending valley. The vegetation is a eucalypt woodland. The soil profile (Figure 2) shows the following features :

0 - 10 cm	A brown, sandy loam which is firm and brittle, tends to powder and is structureless to platy.
10 - 15 cm	A brown sandy light clay with some blocky structures developed.
15-20 cm	Soft carbonate pockets appear at about 15cm. The carbonate content increases with depth to 20 cm.
20 - 30 cm	A light brown friable light clay with friable carbonate throughout and a pH of 8.0.
30-40 cm	A brown, medium clay, without visible carbonate, appears as pockets in the carbonate-rich soil at about 30 cm. These have a pH of 8.5.
40 - 50 cm	A brown medium clay with larger pockets of soft carbonate, with a pH of 8.5. The carbonate content gradually decreases with depth.

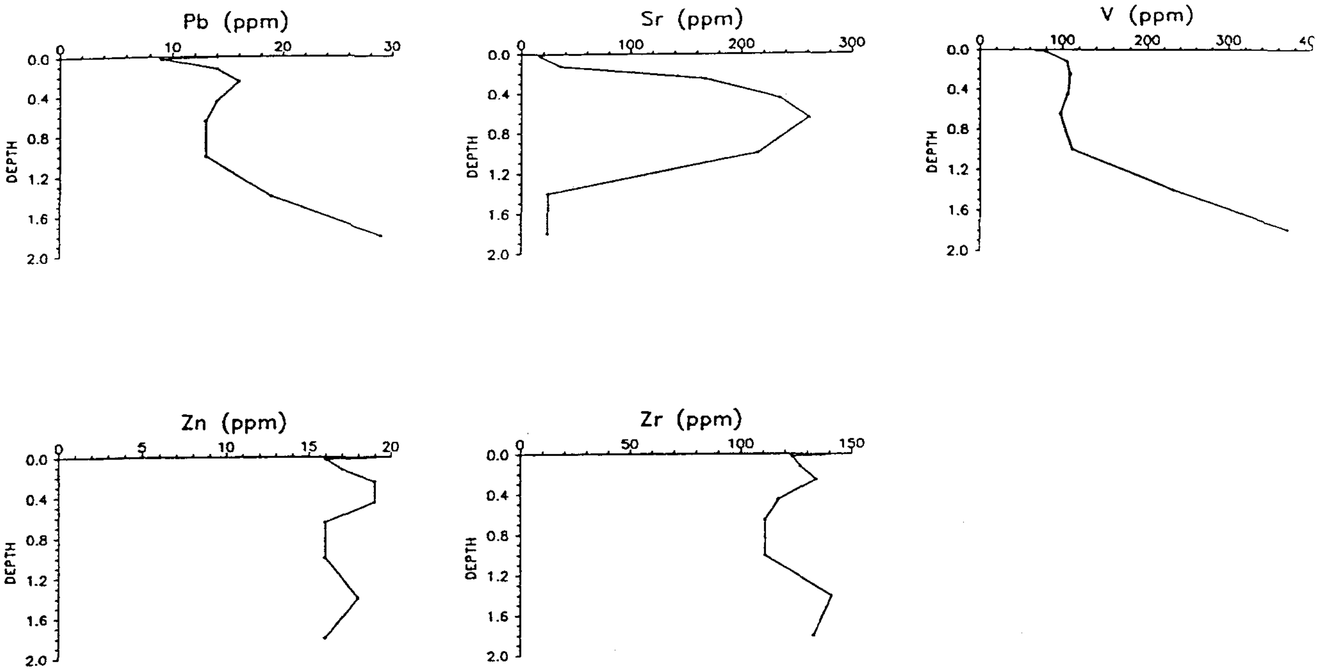
The principal minerals are quartz, kaolinite, dolomite and calcite. There is some hematite and goethite. Quartz is most abundant near the surface and decreases markedly in the clay-rich horizon. Calcite is restricted to the upper part of the profile. Dolomite increases in concentration beneath the calcite and is most abundant at about 1 m depth but continues as pockets to nearly 2 m.

Figure 2



Distribution of elements in profile at Stop No. 5.

Figure 2 (cont)



Silicon is the dominant element within the sandy horizon at the surface. All other elements analysed are depleted here although, immediately at the surface, Ce, Cu, Mn (especially), Nb, Ni, Pb, Zn and Zr are partly enriched. Calcium, Mg and Sr follow the distributions of calcite and dolomite. These elements progressively increase to a maximum at about 1 m depth then decrease further down the profile. Iron and Al concentrations steadily increase with depth and are associated with the development of hematite/goethite and kaolinite, respectively.

There is a strong association between the concentration of Au and that of the alkaline earth elements throughout the profile. The position of the gold maximum is coincident with the alkaline earth maxima. The highest Au concentration is 0.15 ppm.

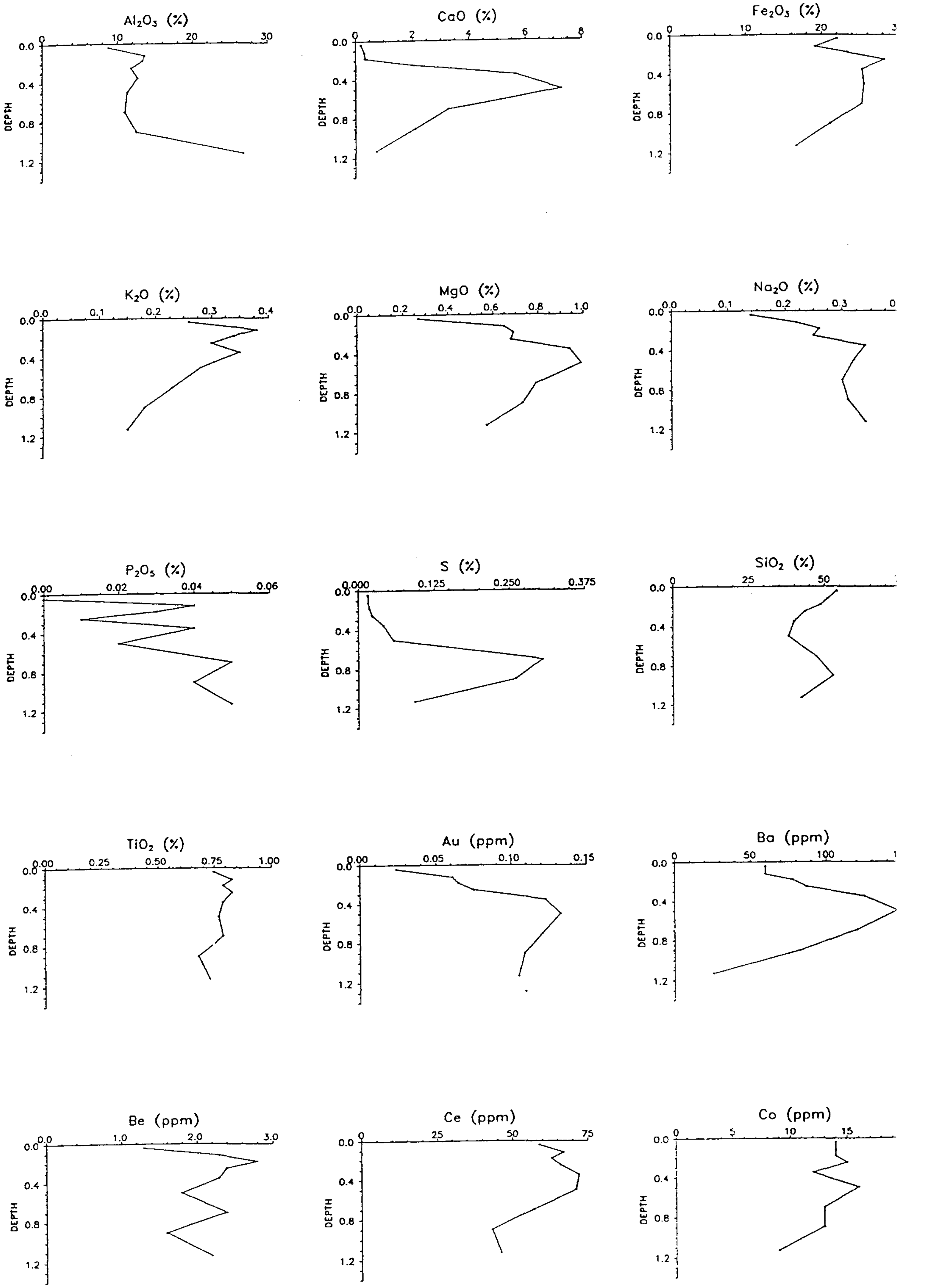
Barium, Cr, Cu, Pb and V distributions closely follow that of Fe, suggesting these elements may be adsorbed onto secondary Fe minerals, although some Ba appears to be associated with the distributions of the alkaline earth elements. Titanium, Nb, Ni, Zn and Zr are similarly distributed but show a distinct zone of depletion corresponding with the occurrence of carbonate. The Mn distribution does not follow any particular mineral phase but concentrations are highest both in the carbonate horizons and at the surface.

Stop 6

This is on the floor of a valley and is the general location of a divide between an incised system draining to the south and a poorly defined drainage trending northward, across a broad valley floor. The vegetation is eucalypt woodland. The soil pit is immediately east of some gilgai micro-relief, characterised by a complex of sink holes. The low mounds or puffs, often a feature of this micro-relief, are not well developed at this location. The main features of the profile (Figure 3) are as follows:-

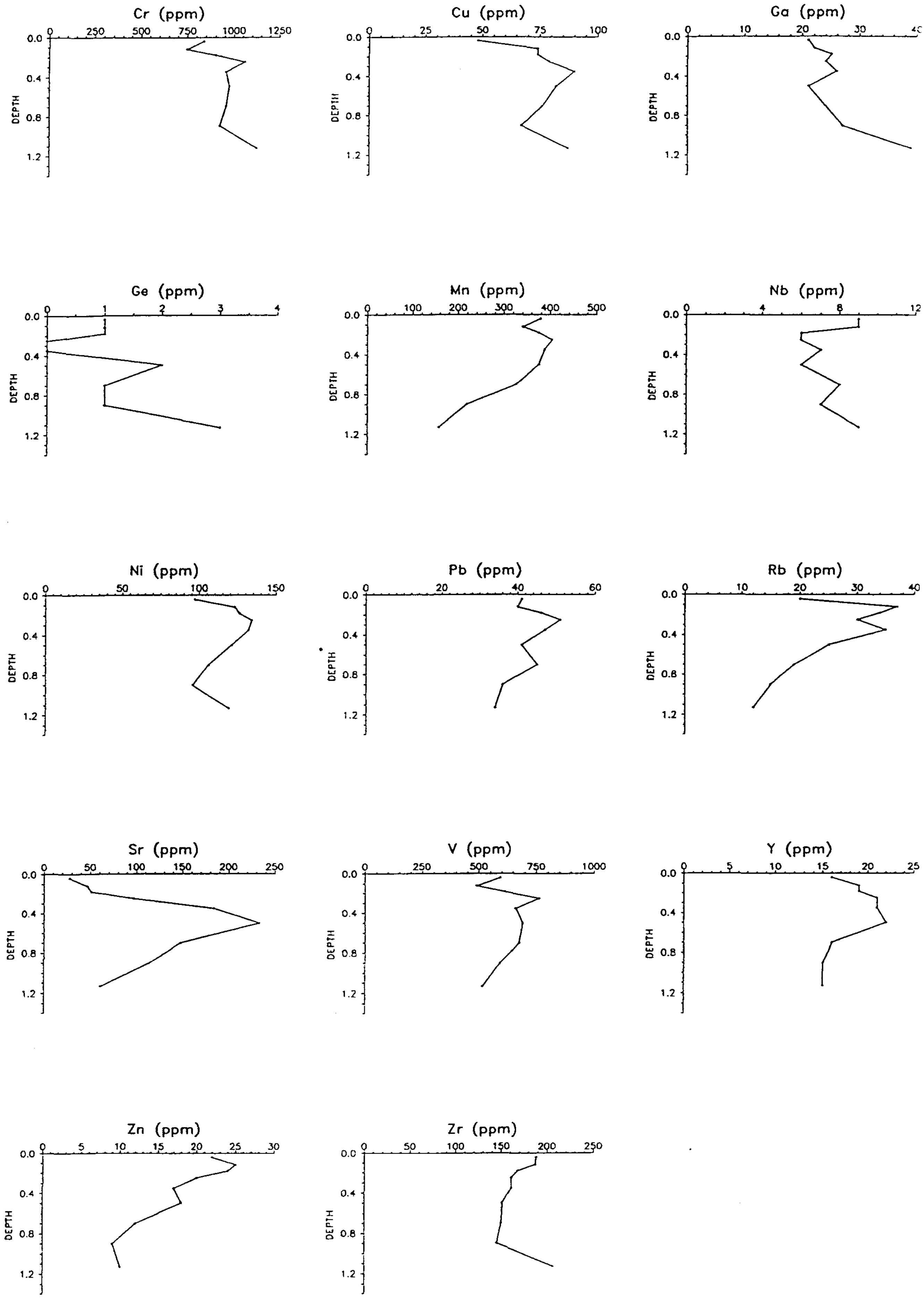
0 - 10 cm	A reddish-brown, light clay, which is very friable and has a well-defined, granular structure; the pH is 6.0.
10-20 cm	As above but with soft carbonate at about 15 cm.
20 - 40 cm	A light brown to light reddish-brown friable soil with a well-developed, fine (1.5 cm) blocky structure, containing soft carbonate throughout. The pH of the soil is 8.0. There is little change to 40 cm.
40 - 60 cm	Here pockets of brown to reddish brown clay, which have no visible carbonate, appear in the soil. The soft carbonate is more clearly restricted to coarse pockets. It gradually decreases with depth but there are still a few pockets at 125 cm. The soil pH is 8.5.

Figure 3



Distribution of elements in profile at Stop No. 6.

Figure 3 (cont)



The presence of some ironstone gravel and lithic fragments, which reach 40 cm, suggest that the upper parts of the soil profile could have developed in a transported material.

The principal minerals in this profile are quartz, hematite, goethite, calcite and kaolinite. Other minerals that are present include dolomite, anatase, rutile and talc. Quartz concentrations are highest near the surface and are probably associated with detrital quartz. Hematite and goethite occur throughout the profile, decreasing towards the base, and are probably associated with the gravels. Calcite increases from the surface to peak near the middle of the profile before decreasing. Dolomite appears in the lower part of the profile, and below this kaolinite increases markedly. Kaolinite is the chief mineral present beneath the gravels and continues to at least 14 m depth.

Silicon decreases from the surface downwards, then increases in concentration and appears to be diluted by carbonate. Calcium, magnesium and strontium increase from the surface downwards, peak at about 0.5 m, and then decrease. They are strongly associated with the ocurrence of carbonate minerals. Iron concentrations increase markedly from the surface before decreasing gradually and are probably related to the distribution of hematite and goethite. The Al concentration is relatively constant from the surface to about 0.9 m and then increases markedly. It is strongly related to kaolinite distributions.

There is an association between Au and the alkaline earth elements although some high Au concentrations persist below the carbonate horizon. Gold concentrations peak at 0.13 ppm at a depth of 0.5 m.

Chromium, Cu, Mn, Ni, Pb, V and Y show some association with the distribution of Fe although Cr, Cu and Ni increase at the base of the profile with Al. These elements may be adsorbed onto secondary iron oxides and clay minerals. There are the expected strong associations between Ga and Al, Rb and K, and Ba and Ca.

Stop 7

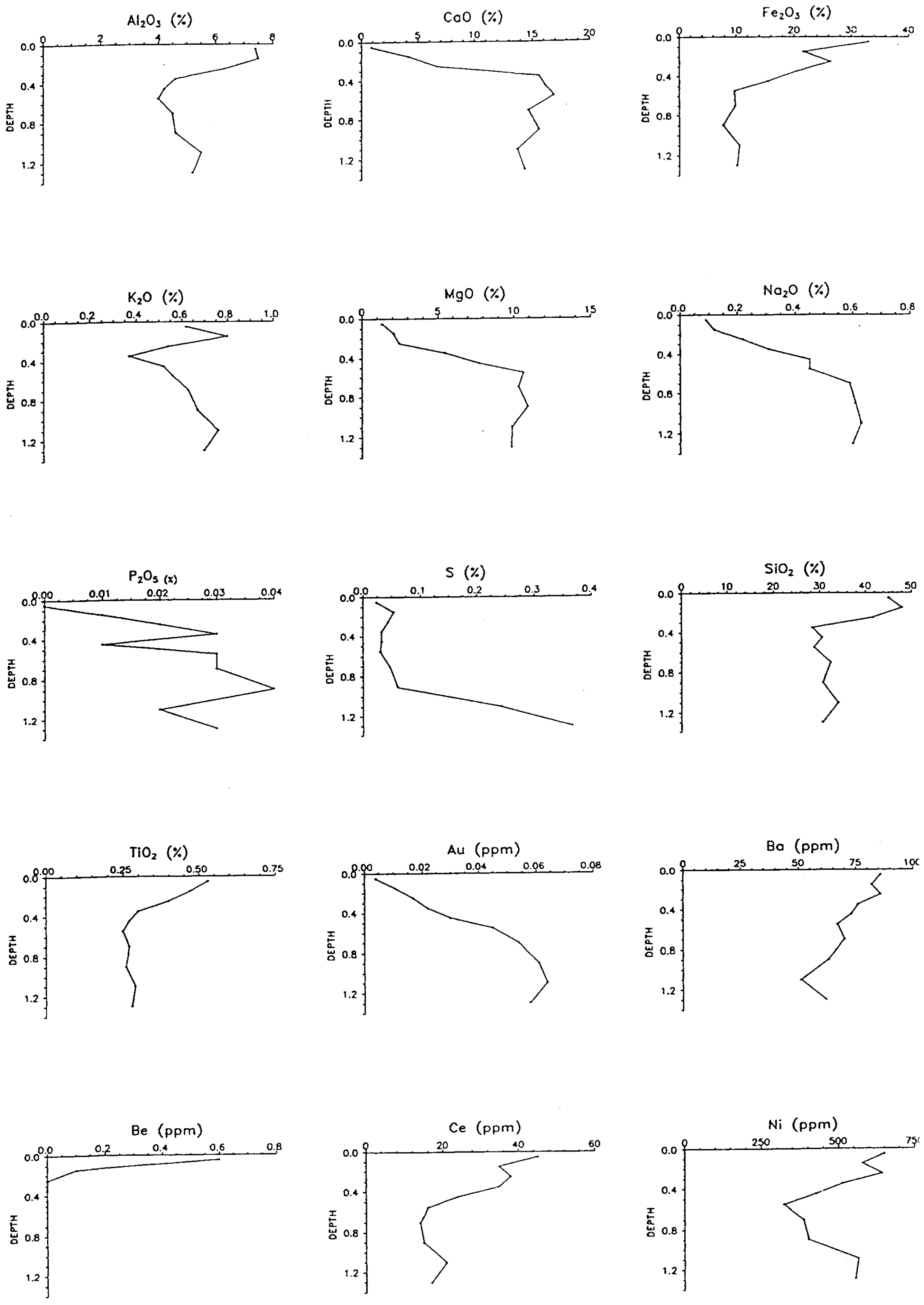
This is on the long, very gentle lower slope. The vegetation is eucalypt woodland.

The soil profile (Figure 4) reveals:-

0 - 20 cm A very friable, powdery, brown light clay. Carbonate permeates the whole soil mass. Some hard carbonate nodules appear at about 15 cm.

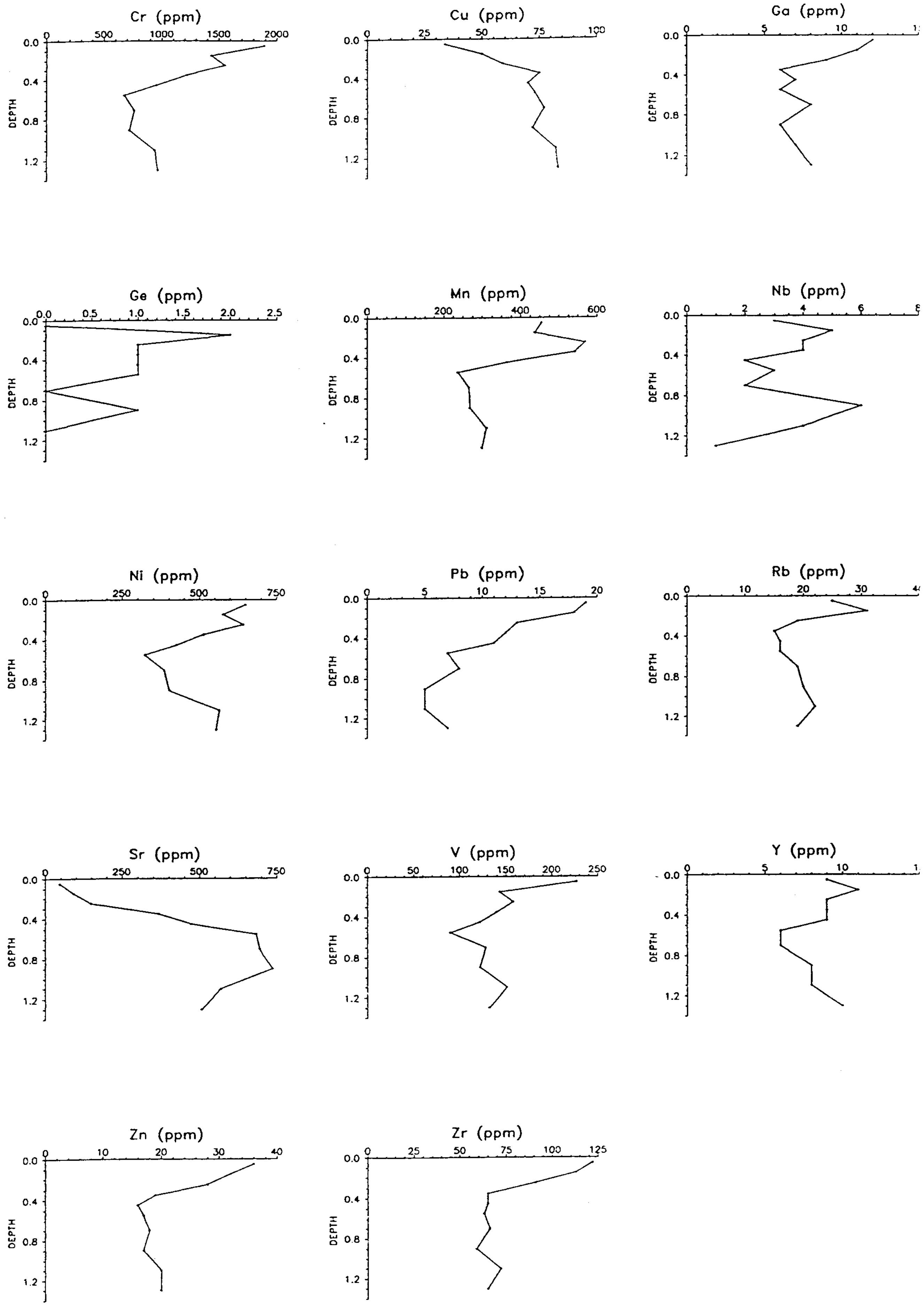
20 - 30 cm Moderate amounts of hard, coarse carbonate pisoliths are set in a brown, very friable, powdery, light clay, with carbonate throughout.

Figure 4



Distribution of elements in profile at Stop No. 7.

Figure 4 (cont)



This material continues to 40 cm, at which depth the soil becomes a friable, but not powdery, pale brown, light clay with soft carbonate throughout; large amounts of hard, coarse carbonate pisoliths are present. By 60 cm a brown clay, that has no visual carbonate, appears. Soft carbonate is restricted to large pockets which decrease with depth beyond 100 cm.

The principal minerals are quartz, dolomite, hematite, calcite, feldspar and talc. There is some kaolinite and anatase. Quartz concentrations are greatest in the surface and near-surface material and are relatively constant below this. Calcite is present near the surface and increases in concentration to about 0.3 m before decreasing sharply below this. As the calcite decreases, the dolomite increases in concentration. Below 0.3 m, large amounts of dolomite are present throughout the profile. Some of the dolomite occurrs as concretionary nodules. Hematite and feldspar concentrations are greatest at the surface and gradually decrease down the profile. They are probably associated with ferruginous fragments, which are generally coated with carbonate.

Some of the major (and minor) elements are associated with distinct mineral phases within the profile. These are Ca, Mg and Sr with calcite and dolomite, Fe (and Cr, Ce, Mn, Pb, and V) with hematite, Si with quartz and kaolinite, and K (and Rb) with feldspar, calcite and dolomite. There is little kaolinite in the profile.

Gold is closely related to the alkaline earth element concentrations, peaking in concentration (0.06 ppm) near the base of the profile.

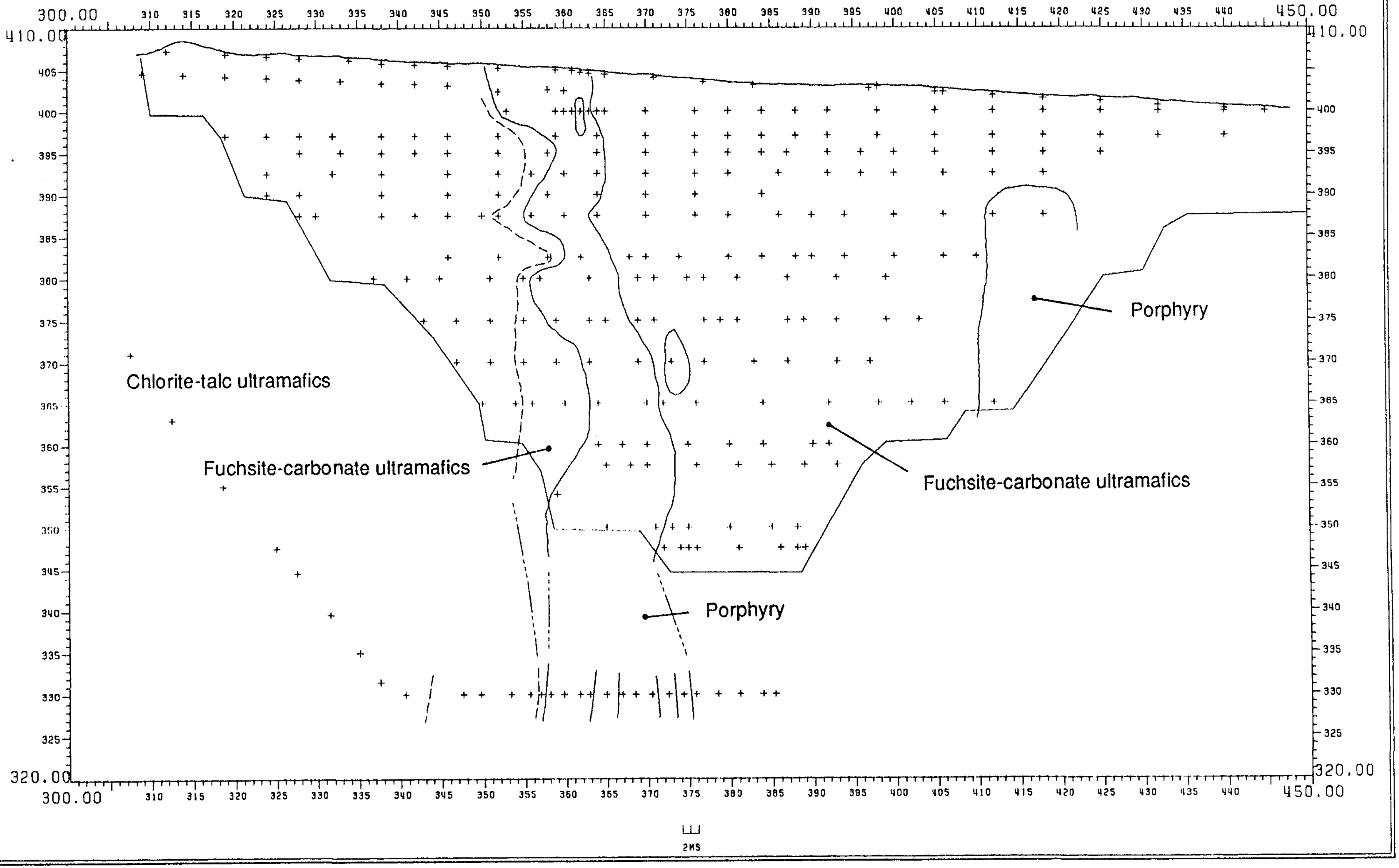
THE MT. PERCY GOLD MINE

The Mystery Zone of the Mt. Percy Mine was selected for a substantial study within the CSIRO/AMIRA Weathering Processes Project (P241) because it offered the opportunity to study the vertical and lateral distribution of a range of elements in the regolith developed over gold mineralization and its wallrocks at a site with an almost complete lateritic regolith. Two sections across the mineralised zone, 15850N and 15900N, have been studied, selected on the basis of features evident from percussion and diamond drilling. Most of the samples used in the study were duplicates of those used for grade control and were collected by ripping and, deeper in the regolith, by drilling. Percussion drill samples, diamond drill core and a few special "grab" samples were also used. The samples selected for the study on section 15850N are shown on Figure 5; these include a diamond drilled core through the mineralised zone, projected to RL 330.

Geological Setting.

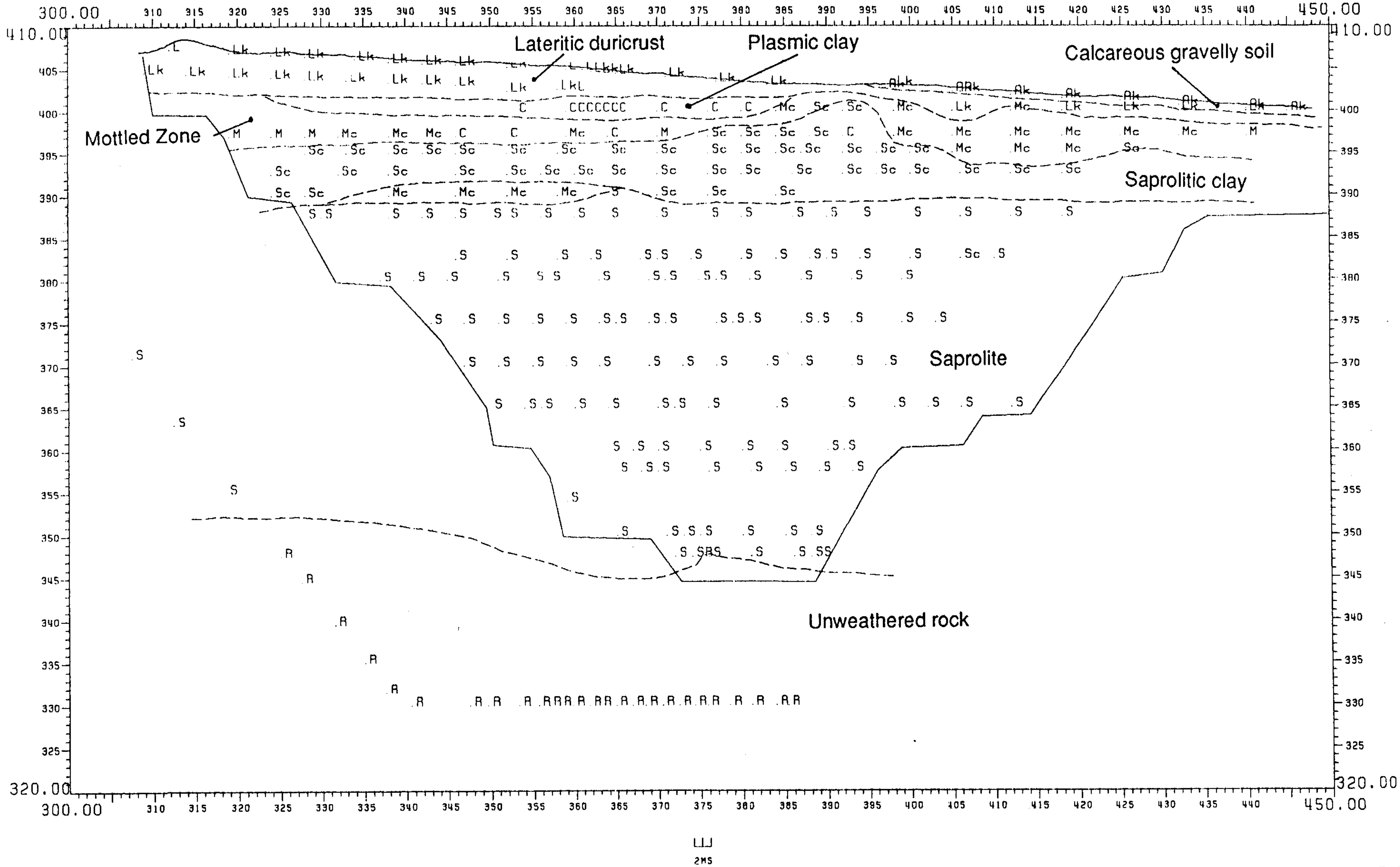
Mt. Percy is at the northern end of the Kalgoorlie-Kambalda greenstone sequence, about 8 km north of the Golden Mile and 1.5 km north of Mt. Charlotte. The Hannan's Lake Serpentinite, Devon Consols Basalt, Kapai Slate and Williamstown Dolerite here form part of the hinge zone and the steeply

Figure 5



300.00
450.00
410.00
320.00
Chlorite-talc ultramafics
Fuchsite-carbonate ultramafics
Porphyry
Fuchsite-carbonate ultramafics
Porphyry

Figure 6


Lateritic duricrust
Plasmic clay
Calcareous gravelly soil
Mottled Zone
Saprolitic clay
Saprolite
Unweathered rock
300.00
450.00
410.00
320.00

east-dipping limb of the Kalgoorlie Anticline. The sequence is cross-cut by a series of north-trending, west-dipping dextral faults, including the Maritana, Reward, Charlotte and Mystery Faults. The Golden Mile Dolerite and Black Flag Beds occur to the west of the Mystery Zone, separated from the other units by the Golden Mile fault. Mineralization is located in the Hannan's Lake Serpentinite in the Mystery Zone and the Devon Consols Basalt in the Union Club and Sir John Zones. In the Mystery Zone, the chlorite-talc-carbonate rocks of the Hannan's Lake Serpentinite are intruded by porphyries, with strong fuchsite-carbonate alteration occurring at the contact (Figure 5). Primary gold mineralisation is largely confined to a series of irregular, mostly steeply-dipping, lenses within the porphyries and adjacent alteration zones.

Geomorphology and the Regolith.

Mt. Percy is situated in a relatively high part of the landscape, in a region that has a total relief of only a few tens of metres. The elevation is probably due to the armouring effect of lateritic duricrust and an almost complete lateritic regolith, 50-70 m thick, is present over most of the area. The duricrust is developed most strongly over the chlorite-carbonate rocks and the Golden Mile dolerite and these form the highest points at the S end of the Mystery pit and Mt. Percy, upon which the water tank is situated. The zonation of the regolith on a section at 15850N is shown on Figure 6.

Soil

A thin cover of red-brown loamy soil, containing abundant lateritic nodules and pisoliths, overlies most of the Mystery Zone, although boulders of lateritic cuirasse outcropped in places. The soil was calcareous, with calcium carbonate dispersed in the fine grained matrix and present as calcrete nodules, channel fillings and coatings.

Lateritic duricrust, cuirasse and gravels

These were present as an almost continuous horizon over the deposit, varying from about 5 m thick over the talc-chlorite ultramafic rocks to less than 1 m thick over some porphyries and fuchsitic ultramafic rocks. The lateritic materials are pisolitic, nodular or, more rarely, vermiform, either strongly cemented as the large cuirasse blocks over the talc-chlorite rocks, or more weakly cemented as duricrusts and friable gravels elsewhere. Nodules, coatings and channel fillings of calcrete are present throughout the lateritic horizon, particularly in the upper, more friable material where it merges with the soil.

Mottled and plasmic clay zone

This zone is transitional between the saprolite and the lateritic duricrust and gravels. It consists of pale green-grey clays and silty clays strongly coloured by secondary iron oxides. In the plasmic clays, the iron oxides are present as diffuse impregnations throughout the matrix, whereas in the mottled clay they occur as secondary structures such as pisoliths and highly irregular nodules and aggregates.

Saprolite

The saprolite forms a broad zone 40-50 m thick. The transition from unweathered to weathered rock (the weathering front) occurs at the base of the pit at about 60 m depth, R.L. 345-350 m. The saprolite becomes softer and increasingly clay-rich towards the surface and, as a result of settling, consolidation and the development of iron oxide segregations, the rock fabrics are destroyed and it merges with the plasmic and mottled clays at about 15 m depth. Recognizable fabrics are preserved at shallower depths in the S wall of the pit, where there has been some erosion. Identification of the parent rock, at least into the three major units, is possible throughout most of the saprolite. The porphyries and fuchsitic ultramafics tend to be bleached in the mid-saprolite (20-40 m), commonly emphasizing the green colour of the fuchsite; this is particularly evident along some ultramafic/porphyry contacts. Green colouration also becomes more evident towards the upper saprolite, due either to an originally greater abundance of fuchsite or, more probably, to the development of chromian clays.

Geochemistry.

The distribution of Au with respect to Fe, Ca and Mg is shown on Figures 7 to 10. Gold is concentrated and dispersed laterally in the duricrust and soil but leached from the underlying clay-rich horizons. There is also some accumulation and dispersion in the upper saprolite. Although there is some apparent association between Au and Fe in the upper horizons, Au is particularly concentrated in the calcareous material. The Ca distribution is typical of many regolith profiles in the southern Yilgarn Block. It is one of the first elements to be released during weathering and is strongly leached from most of the regolith, accumulating as calcite in pedogenic calcrete in the surface horizons. Magnesium has a broadly similar distribution, but its host primary minerals are less easily weathered and it is less strongly accumulated in the near-surface.

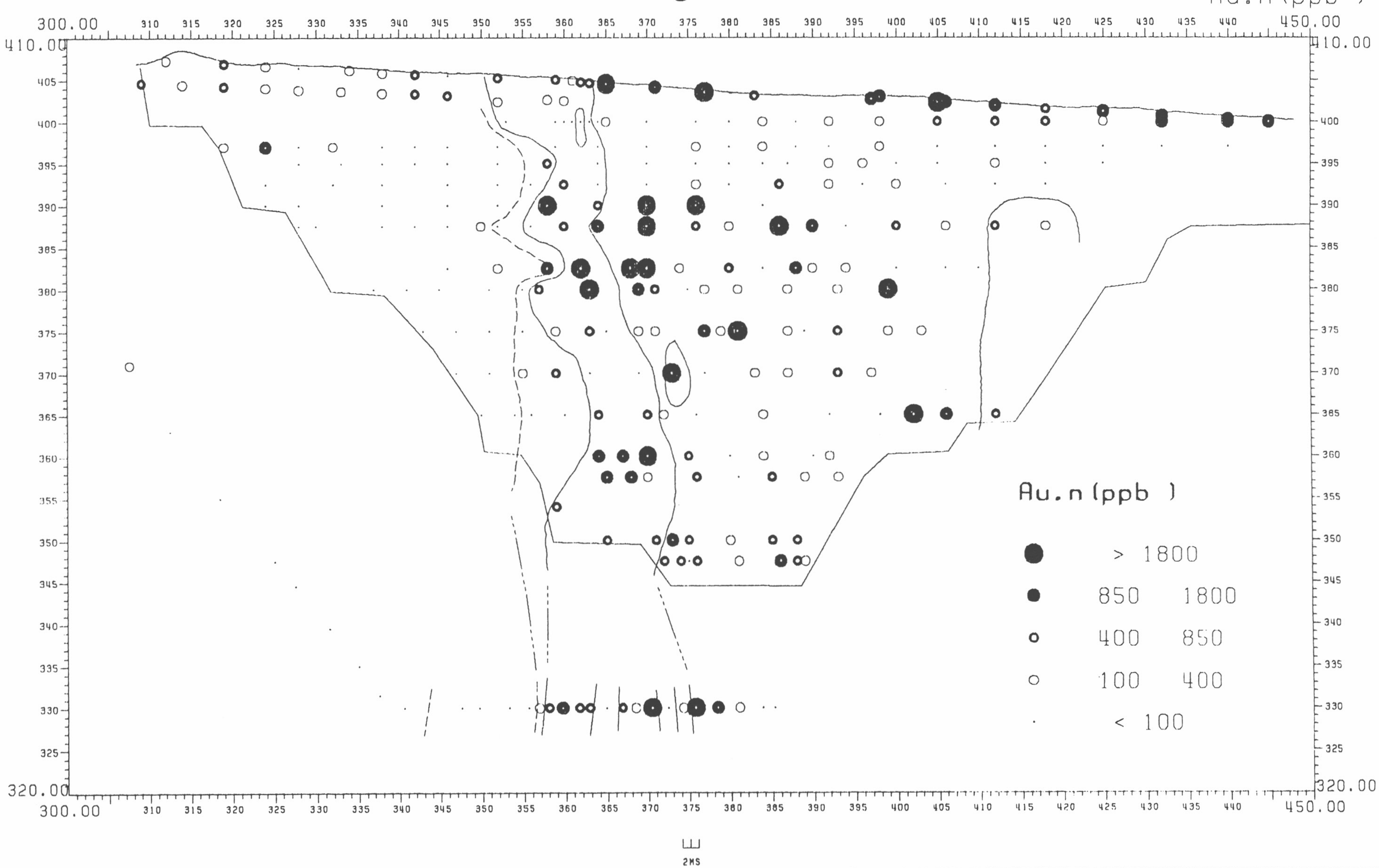
Field visit

The visit to Mt. Percy will consist of a traverse along the west and northern walls of the Mystery pit at RL 400 m (0-8 m below surface). It commences close to the southern end of the pit, where the massive cuirasse duricrust, developed over the chlorite-carbonate ultramafic rocks, forms a high point in the landscape. The porphyry and fuchsite-altered rocks can be seen in the south wall.

The duricrust and, in places, upper part of the mottled clay zone and some porphyry saprolite are visible in the bench wall. The landsurface is lower to the north as the massive duricrust gives way to lateritic gravels and calcareous gravelly soils. Closer to Mt. Percy, possible Black Flag beds are visible. Mt. Percy is formed by the Golden Mile Dolerite, which has weathered to the massive lateritic duricrust visible in the mine wall. The Mystery fault runs sub-parallel to the wall beneath the water tank and is marked by a fault ironstone.

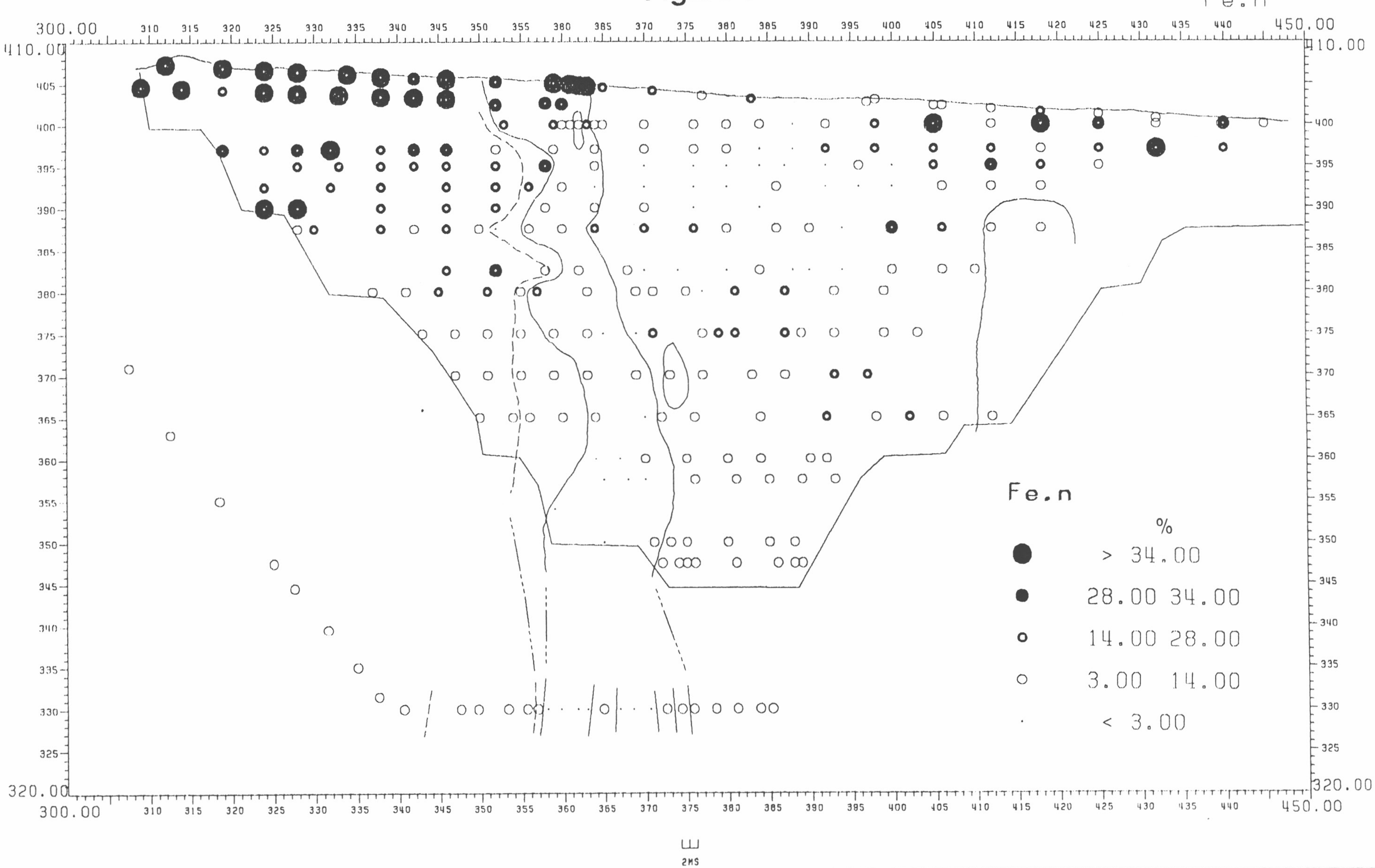
Strong mottling is visible in the north-east corner of the pit, developed in weathered ultramafic rocks. Massive exhumed boulders at the surface indicate the nature of the original surface.

Figure 7



Au.n (ppb)
300.00
450.00
410.00
320.00
Au.n (ppb)
> 1800
850 1800
400 850
100 400
< 100
2MS

Figure 8



8B

Figure 9

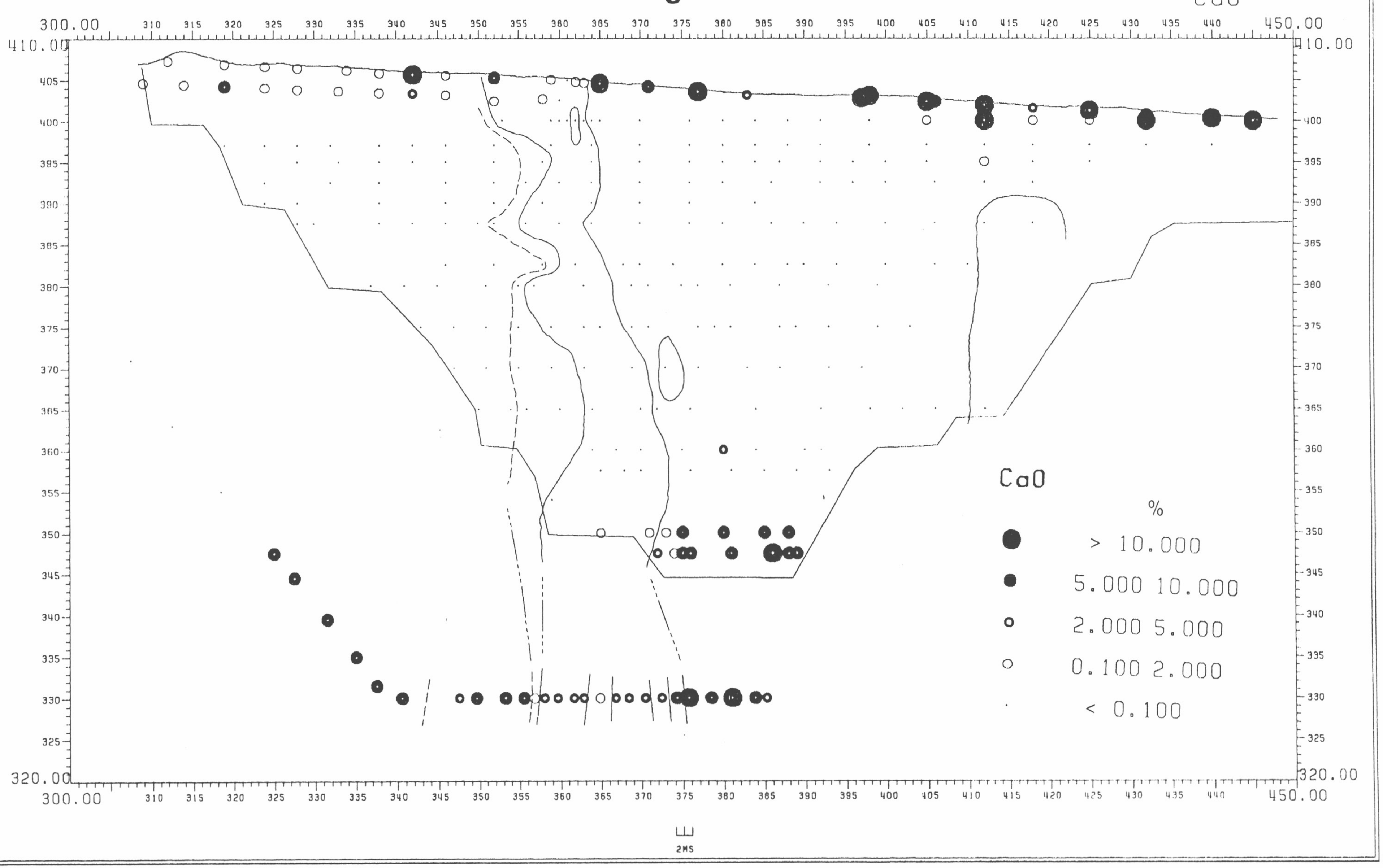
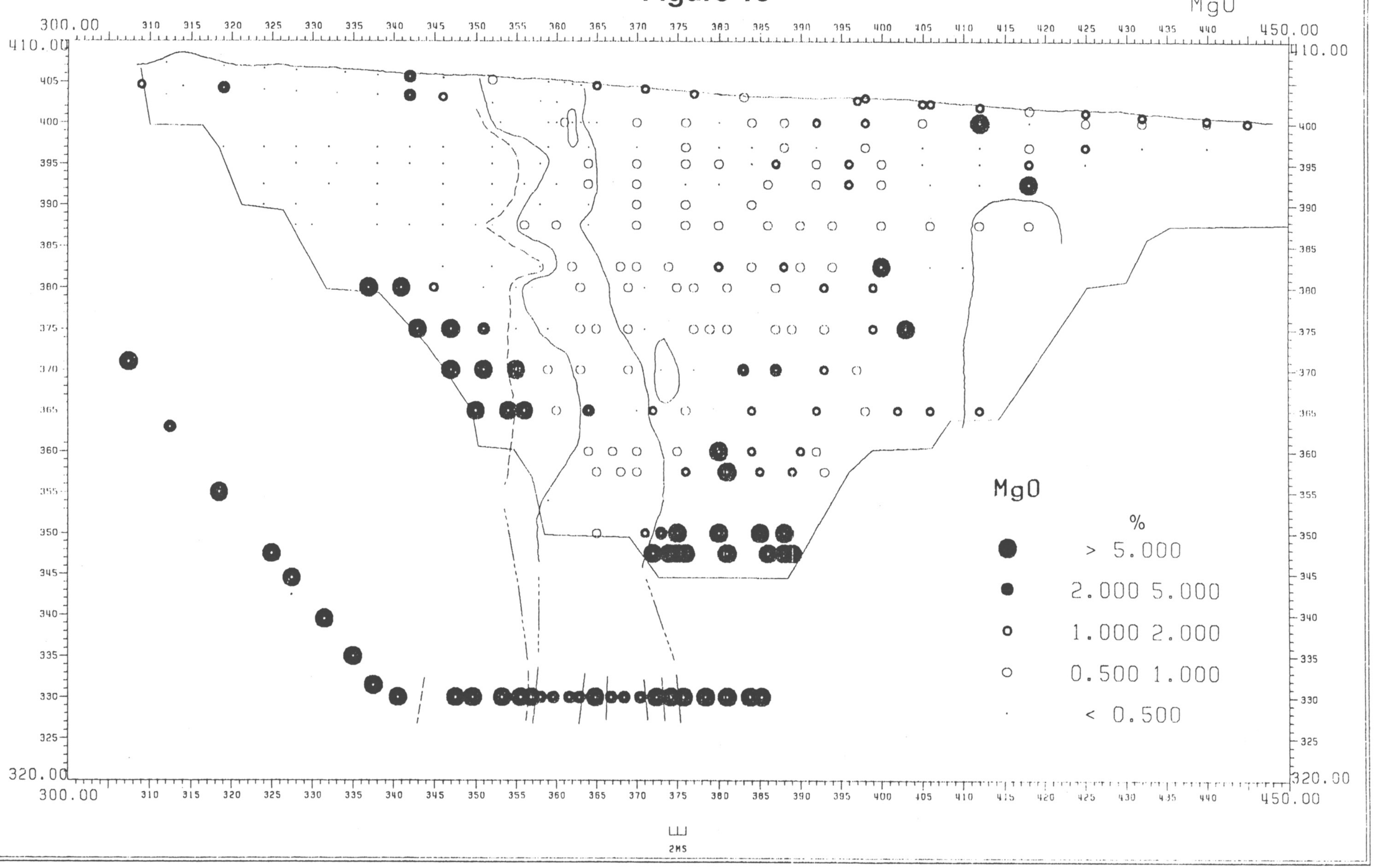

CaO
300.00
450.00
410.00
320.00
CaO
%
> 10.000
5.000 10.000
2.000 5.000
0.100 2.000
< 0.100
2MS

Figure 10



THE PANGLO GOLD MINE

The Panglo Gold Mine occurs 5 km south-east of the Paddington Mine, within steeply west-dipping carbonaceous shales and mafic to ultramafic volcanics, within a major shear zone. Mineralisation occurs as a relatively flat-lying body at a depth of 35 m below the surface. It is a new discovery with reserves of 1 Mt at 3.6 g/t Au.

Weathered Profiles

The weathered volcanic rock profile above mineralisation is shown in Figure 11. At the top there is a thin soil and a ferruginous calcrete zone with Au >0.1 g/t and elevated As, Ba, Mo Sb, Sr, V and Zr contents. This portion of the profile is at least partly transported. The underlying, leached saprolite is generally grey-brown to dark-brown and has ≤0.01 g/t Au but pathfinders such as As and W are present in places. Gold occurs in the dark brown to red saprolite with high levels of the pathfinders As, Mo, Sb and W associated with the mineralisation and into the hangingwall for approximately 5 m.

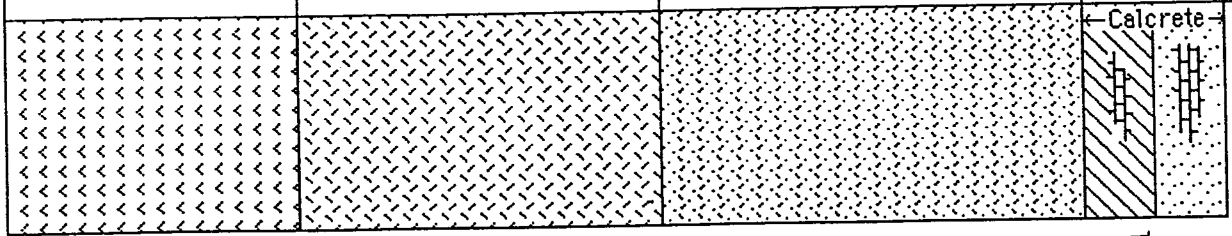
Profiles above mineralisation in shales show a thin, transported soil. Calcrete is not present over the shales (Figure 12). The leached saprolite contains alunite and is white to light brown and overlies brown to grey saprolite. Although the soil may contain approx 0.05 g/t Au, the saprolite is devoid of Au until approx 35 m depth. There the mineralisation is associated with As, Ag, Ba, Cu, Mo, Pb, Sb, Sn, Tl and W, with some of these elements persisting into the hangingwall. K-rich (muscovite-rich) rocks occur with the mineralisation. Lateral to mineralisation paragonite (Na-mica) + muscovite occurs instead of muscovite on its own (Figure 13) and alunite development is not so extensive.

Soils and Vegetation

The soils near the Panglo Mine may be divided into two main groups:-

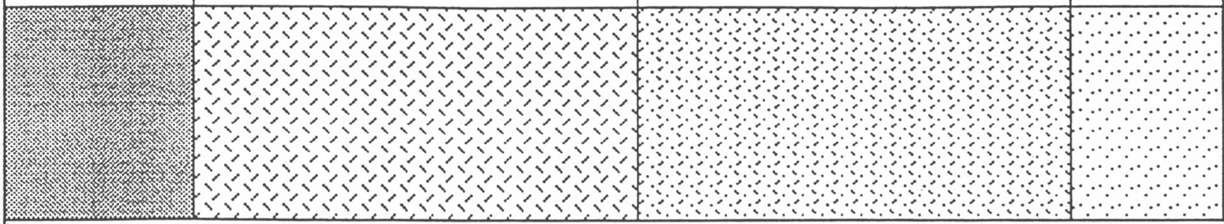
(i) Gravelly soils occur in high areas of the landscape and include those overlying the known southern limits of mineralization. They include those found in a Tertiary palaeochannel which occurs in the western part of the trench at 3700N. The soils consist of an organic-rich surface horizon, containing Fe-rich gravels in a matrix of sandy material. Beneath this, the soil is characterized by unconsolidated, Fe-rich, rounded to sub-rounded ferruginous nodules, varying in size from a few mm to several cms in diameter, in a sandy to loamy matrix. Saprolite, at or near the surface in certain areas, limits soil depth to a few cms. Carbonate occurs near the surface and continues to several tens of cms. It occurs as friable fragments and thin veneers on the ferruginous nodules in unconsolidated Fe-rich material and as coatings, up to several mm thick, on consolidated, near-surface saprolite.

(ii) Clay-rich soils are dominant in the broad valley flats of the northern and central sections over the mineralised zone. They consist of a veneer of sand-rich material overlying pale grey to yellow, homogeneous clays. Blocks of weathered rock are common within the soil profile and are either



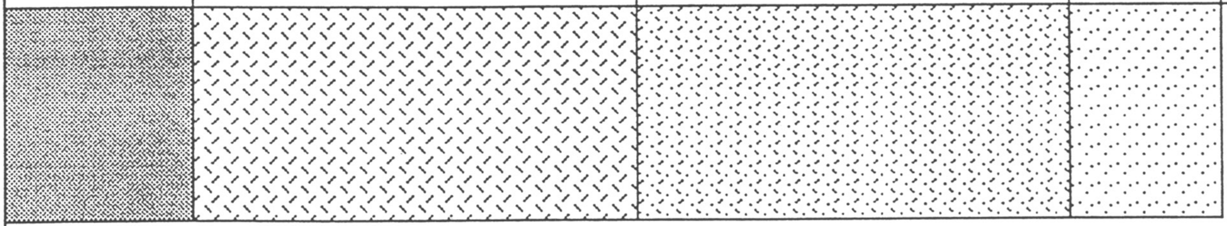
	Fresh Rock	Saprolite	Leached Saprolite		Transported laterite	Soil
Thickness (m)		20-30	aprox 40		0.2-12.0	
Qtz	●	●	●	●	●	●
Plag	●					●
Calc	●				●	●
Dol						
Hem		●	●	●	●	●
Goe		●	●	●	●	●
Magh						●
Musc	●	●	●	●	●	●
Parag						●
Chl/V	●		●		●	●
Talc		●	●		●	●
Kaol		●	●	●	●	●
Smec				●	●	●
Amph	●					●
Pyrite						
Hal	●	●	●	●		
Colour	Grey	Dark brown to red	Dark Brown	Grey-brown	Red-brown	Brown
Cr ppm	180	260	300	400	660	320
Au ppm	0.01	<0.01 to 3.0	<0.01	0.01	0.10	0.03
K_2O %	1.2	1.3	1.5	2.2	0.2	0.6
MgO %	5	0.5	0.5	0.3	0.7	1.5
Fe_2O_3 %	9	15	17	19	40	17

Figure 11. Schematic profile over mineralised mafic volcanics, Panglo.



	≥30			approx 25		<1.0	Thick-ness(m)
Fresh Rock	Saprolite			Leached saprolite		Soil	
●	●		●	●	●	●	Qtz
						●	Plag
						●	Calc
●							Dol
				●	●		Alunite
		●	●	●	●	●	Hem
	●	●	●	●	●	●	Goe
						●	Magh
●	●	●	●	●	●	●	Musc
	●					●	Parag
●	●	●	●	●		●	Chl/V
						●	Talc
	●	●	●	●	●	●	Kaol
		●	●	●	●	●	Smec
●							Pyrite
	●	●	●	●	●		Halite
Black to Grey	Grey to Buff	Brown	Brown	Light Brown to Grey	Light Brown	Brown	Colour
70	70	100	300	110	330	380	Cr ppm
1.0	0.2	1.5	<0.01	<0.01	0.01	0.05	Au ppm
1.9	1.8	2.3	3.3	2.7	3.6	0.8	K_2O %
9	3	7	6	7	10	7	Fe_2O_3%

Figure 12. Schematic profile over mineralised shale, Panglo



	Fresh Rock	Saprolite		Leached saprolite		Soil
Thickness(m)		≥30		approx 25		<1.0
Qtz	●	●	●	●	●	●
Plag	●					●
Calc	●					●
Dol	●					
Alunite				●	●	
Hem					●	●
Goe		●	●	●	●	●
Magh						●
Musc	●	●	●	●	●	●
Parag			●	●	●	●
Chl/V	●					●
Talc	●					●
Kaol		●	●	●	●	●
Smec				●		●
Pyrite	●					
Halite		●	●	●	●	
Colour	Black to Grey	Yellow	White to Grey	White to Pale Brown	White to Pale Brown	Brown
Cr ppm	60	130	230	210	230	700
Au ppm	<0.01	<0.02	<0.02	<0.02	0.02	0.05
K_2O %	3	1.6	2.6	2.3	2.6	1.0
Fe_2O_3 %	3	1.5	1.7	0.8	1.8	9

Figure 13. Schematic profile over barren shale, Panglo.

pale (clay-rich) or red (Fe-rich). Carbonate occurs within the profile as friable aggregates and veneers on ferruginous material.

The diversity and abundance of the vegetation is largely determined by the characteristics of the soil. Salt- and drought-tolerant species e.g. *Maeriana* spp. and *Atriplex* spp. (<0.5 m in height) with minor *Eremophila* spp. (up to 2 m) dominate the clay-rich soils of the broad valley floor to form an open heathland. Where soils are thin, the vegetation is sporadic and the total biomass is low. Tall *Eucalyptus* spp. trees (up to 20 m) with an under-storey of *Eremophila* spp. (1-2 m) form a medium dense woodland over the gravelly soils. There is a sharp transition between these two vegetation communities reflecting the different soil types, although individual examples of plant species occur sporadically in both communities.

The general location of the following profiles are shown on Figure 14. Their specific locations within the trench are shown in Figure 15. The geochemistry of these profiles is shown in Figures 16-19.

Stop No. 1

Profile A in Figure 16 at co-ordinates 2278E, 3700N. This profile is developed upon transported material filling a Tertiary palaeochannel. The palaeochannel fill consists primarily of a sediment of pisoliths and nodules, which include fragments of amphibolite. Drilling indicates the palaeochannel to be 10 m thick and is comprised of gravels overlying mottled clays. These lie on clay-rich saprolite several tens of m thick, derived from the weathering of mafic volcanics. There is some Au (0.1 to 1 ppm) at the boundary between the clay-rich mottles in the palaeochannel and the clay-rich saprolite, which probably indicates enrichment at the old land surface, pre-dating the Tertiary. Economic grades of Au (>3 ppm) occur as a supergene deposit within the saprolite at about 40 m.

The principal horizons in the profile are:-

0-10 cm Red, clay-rich, sandy loam with ferruginous fragments (up to 20 mm). Carbonate is present as minor aggregates and coatings and there is some organic material.

10-65 cm Sandy loam with gravels. Large amounts of carbonate is present as coatings and aggregates. The carbonate concentration first progressively increases and then decreasing downwards.

65 cm - 2.2 m Sandy loam with gravels. Though the amount of carbonate decreases downwards, some carbonate is present as pendants and lines old root channels. Little, if any, carbonate is present in the lower parts of the horizon.

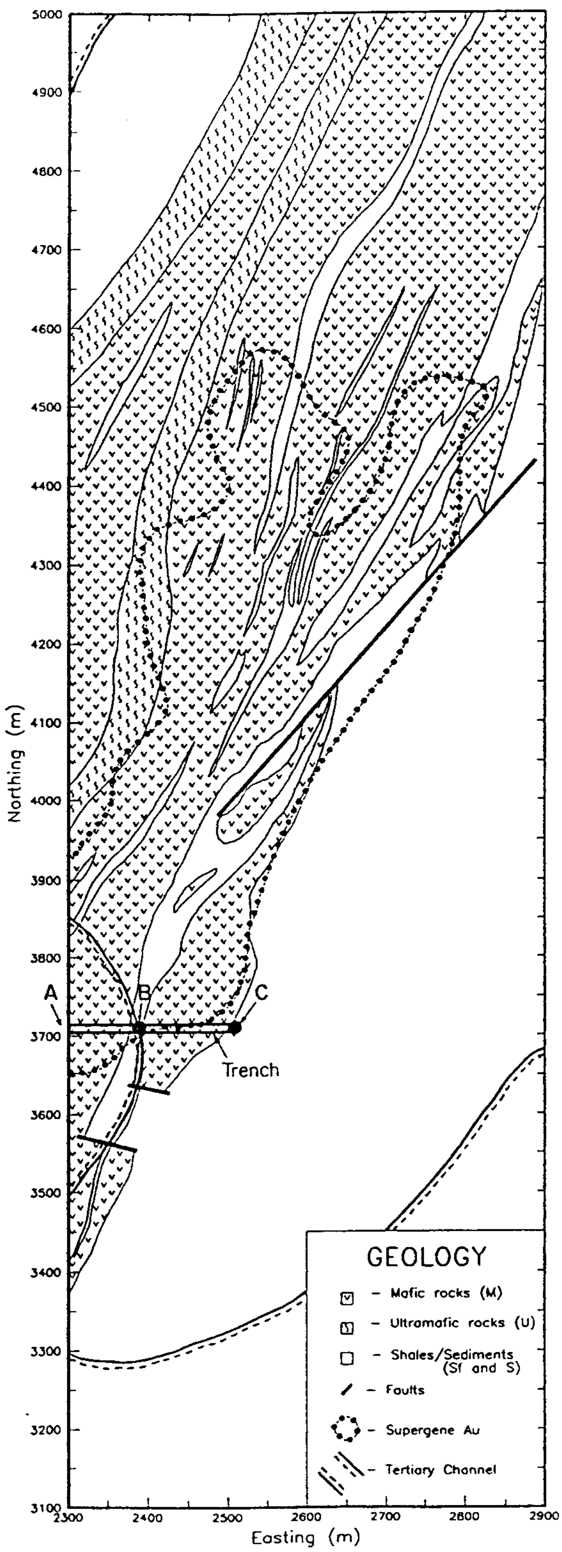


Figure 14. Geology of the Panglo Area showing the positions of the supergene mineralisation, the paleochannel and the profiles.

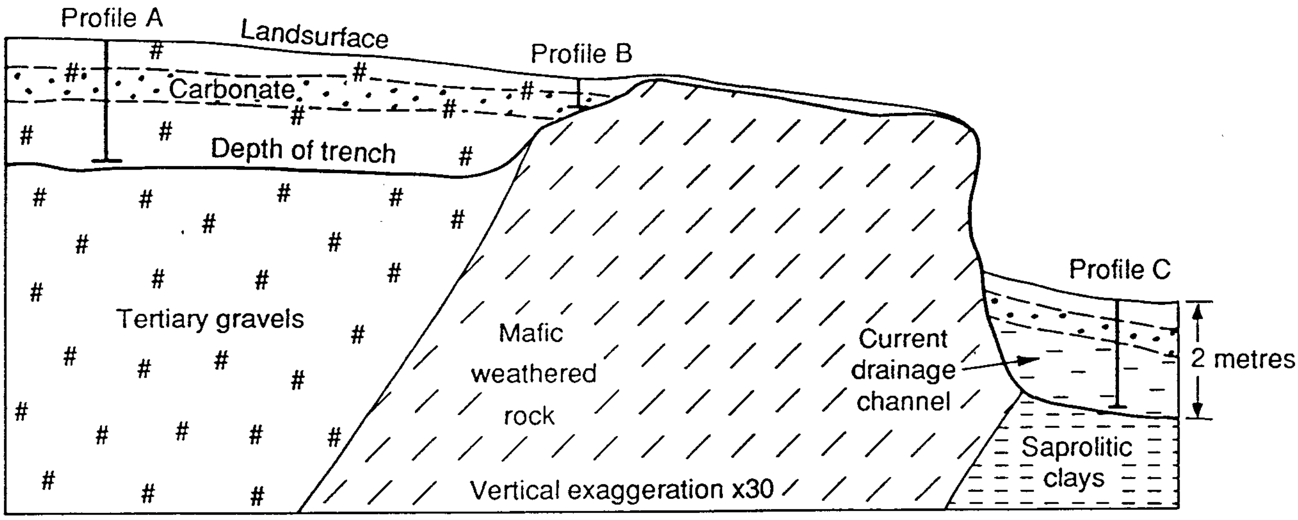


Figure 15. Section through the trench showing the positions of the profiles

Figure 16. Distribution of elements in profile A.

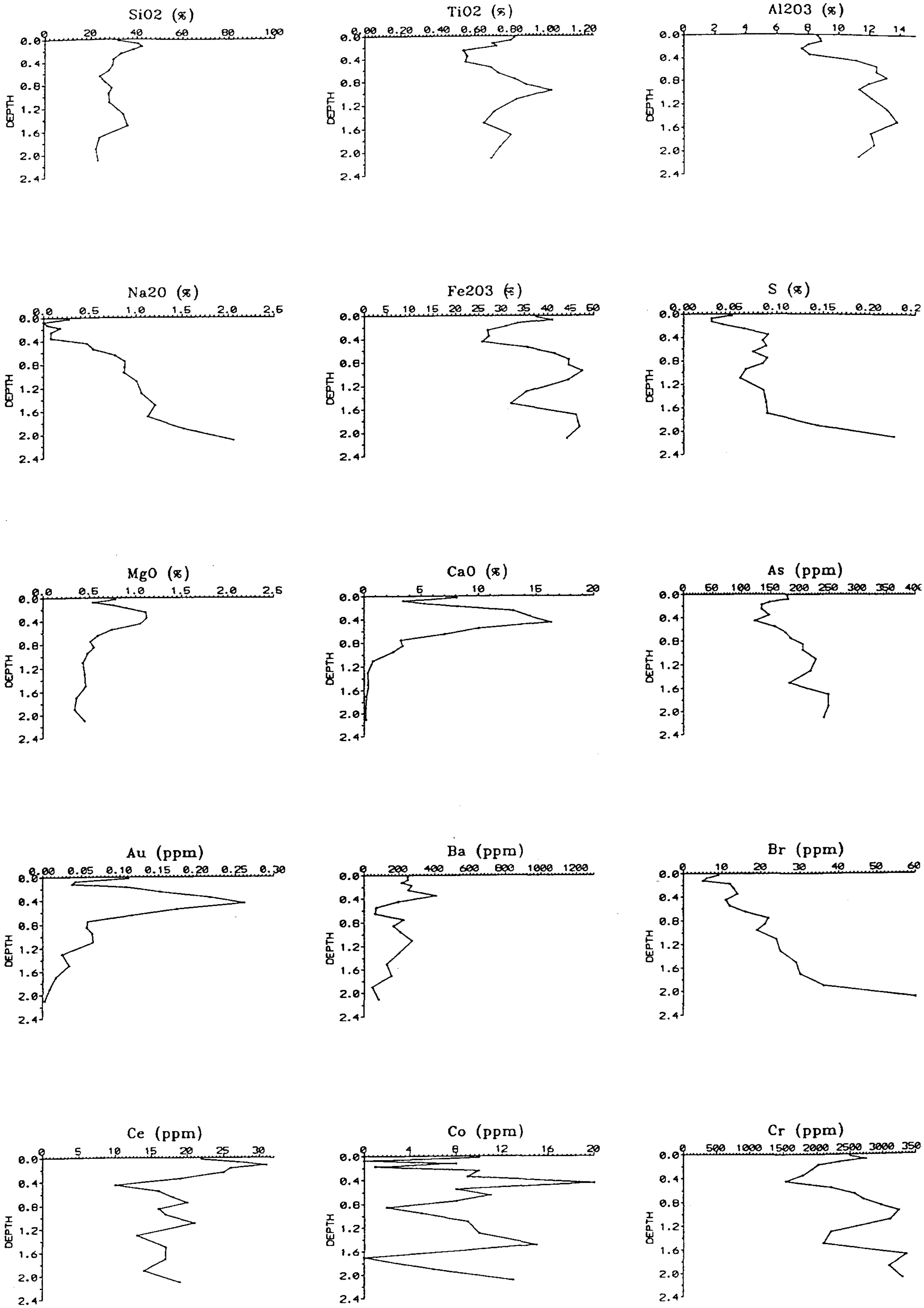
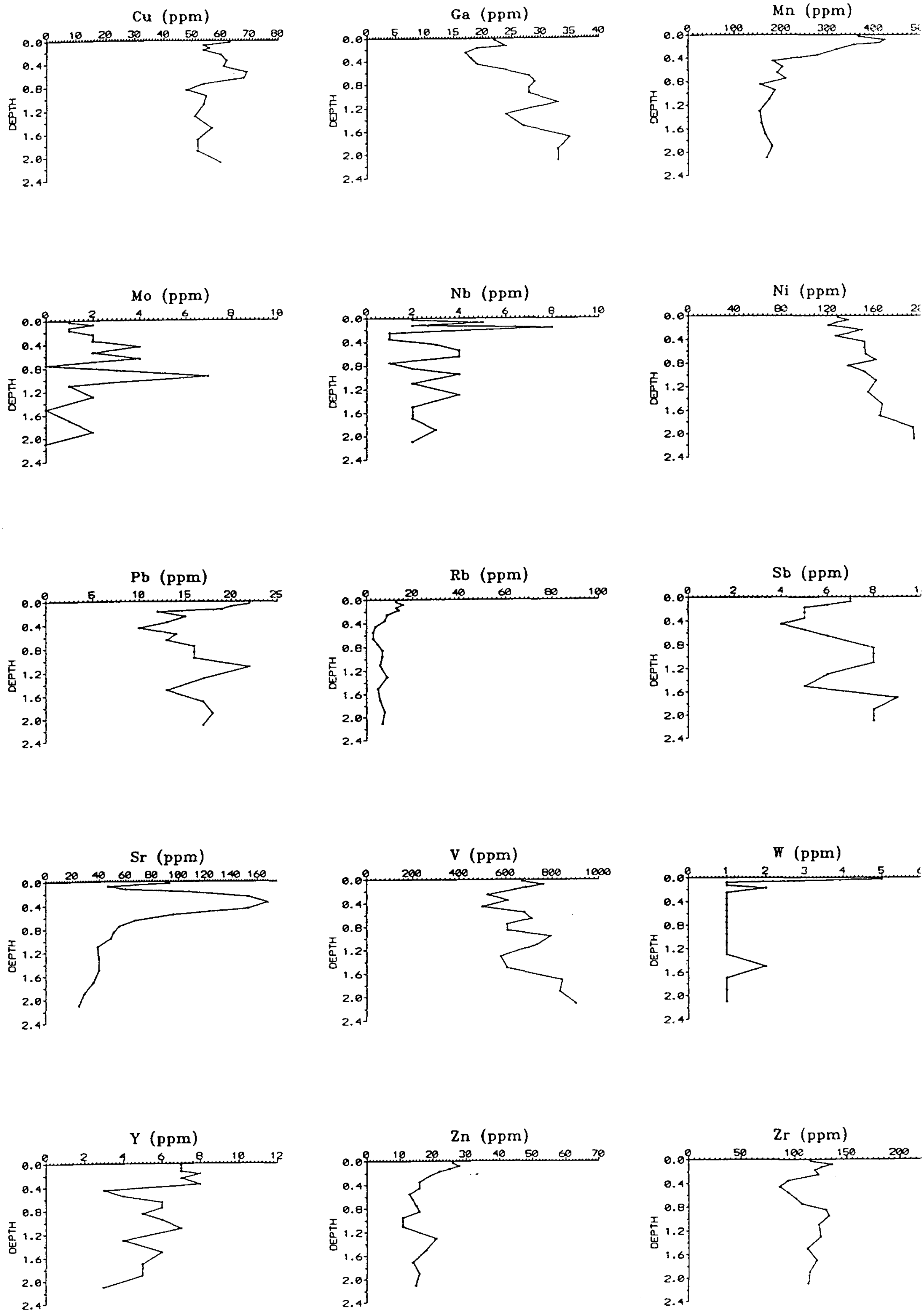


Figure 16 (contd)



The principal minerals present in the profile are hematite, goethite (in the gravels) and quartz. Calcite increases to a maximum at about 0.5 m and then decreases. Little XRD-detectable calcite appears below about 1 m. Kaolinite, although present, is not abundant. Some halite is present towards the base of the profile.

The near-surface material is rich in Ti, Fe, Mg and Ca, which are probably associated with the coarser material. Below this, Ca concentrations increase and are associated with the calcite. There appears to be an antipathetic relationship between Ca and Fe suggesting that calcite has been introduced at a later stage and has diluted the Fe minerals.

There is a very strong association between Au and the alkaline earth elements Ca, Mg and Sr throughout the profile. The lowest Au concentration (<0.01 ppm) occurs at the base of the profile. Peak concentrations of Au (0.26 ppm) and the alkaline earth elements (e.g. 16% CaO) occur at 45 cm depth.

Arsenic, Ce, Cr, Cu, Mn, Pb, Rb, Sb, Sr, V, W, Y, Zn and Zr are concentrated near the surface and are probably associated with Mg, Ca, Fe and Zr minerals. Throughout the profile, Fe oxides are correlated with the distributions of Ti, Al, As, Cr, Ga, Pb, Sb and V, and, to a lesser extent, with Y and Zr between 0.6 m and 1.2 m. Concentrations of these elements are comparatively low (especially Fe) when Ca contents are high and this is consistent with late stage introduction of carbonate.

Sulphur, Br and Na concentrations increase with depth, particularly below about 1.6 m. This may be due to continued evaporation of brackish drainage water that has flowed into the trench.

Stop No. 2

Profile B in Figure 17 at co-ordinates 2375E, 3700N. Here weathered mafic volcanics outcrop. The profile consists of a thin, poorly developed soil overlying ferruginous saprolitic fragments of Fe-rich nodules, that are partially cemented by carbonate. These overlie indurated, weathered mafic volcanics. The zones of Au mineralisation are similar to Profile A.

The principal horizons in the profile are as follows:

0-5 cm	Thin, sandy soil with large quantities of ferruginous lithorelics. Carbonate is present as coatings, aggregates and separated veneers. Some organic material is present.
5-80 cm	Sub-rounded and angular cobbles of ferruginous lithorelics. Their size and degree of induration increase with depth to become massive boulders (>10 cm) of weathered rock at the bottom of the profile. Carbonate is present as a matrix, aggregates and coatings throughout the profile but becomes less abundant with depth.

Figure 17. Distribution of elements in profile B.

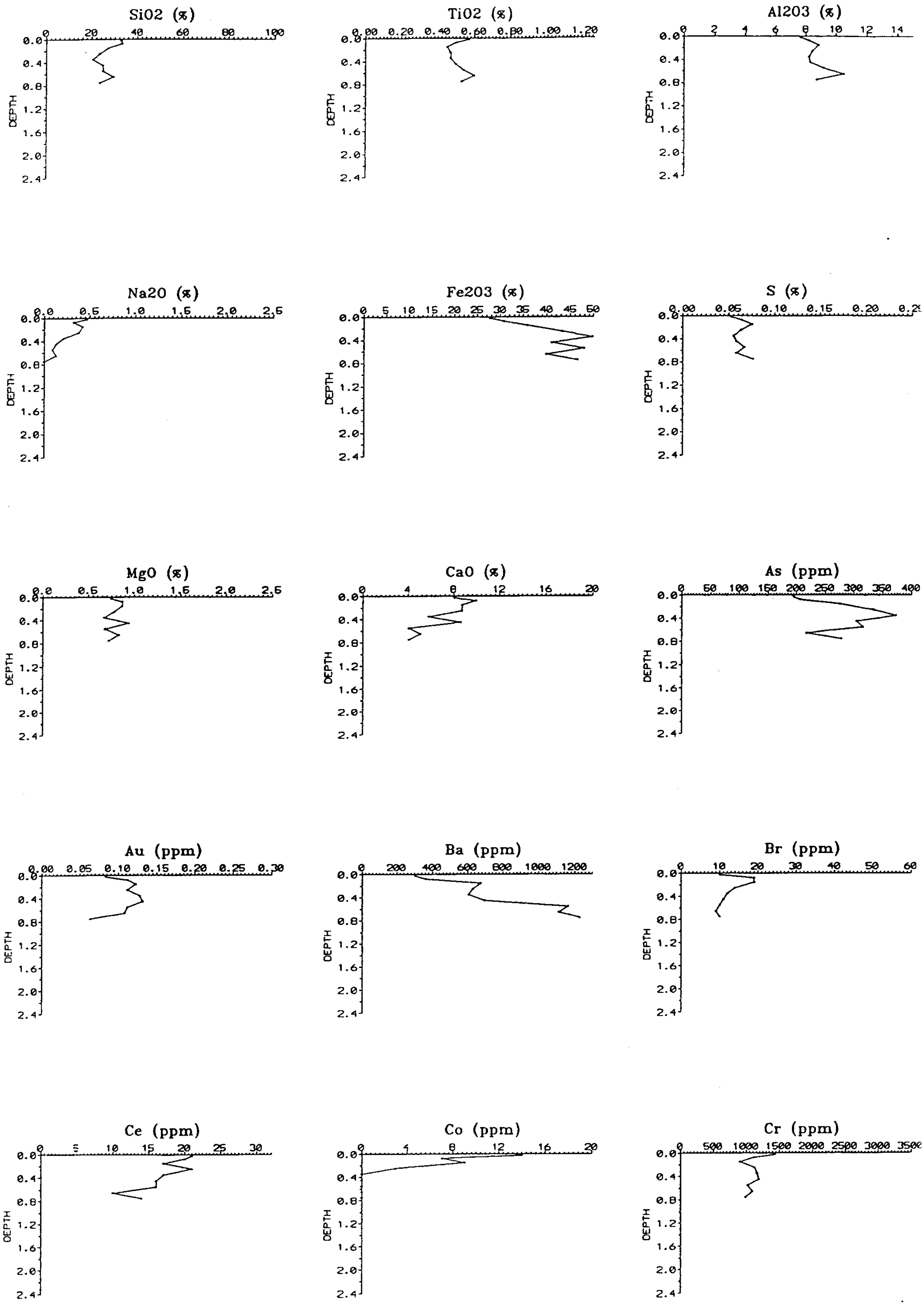
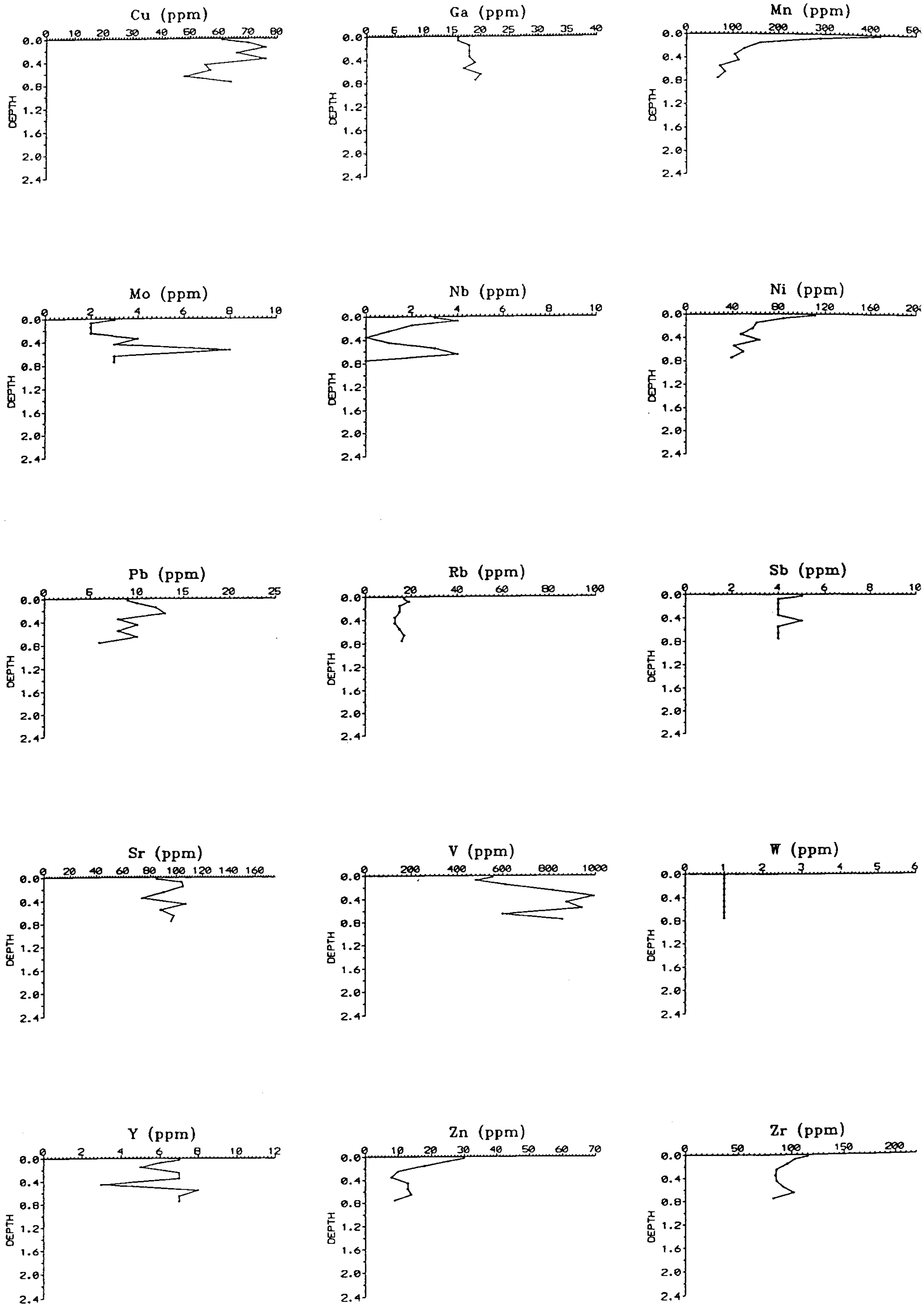


Figure 17 (contd)



The principal minerals present in the profile are hematite and goethite with some calcite and quartz. Hematite and goethite tend to increase in concentration down the profile where calcite decreases. The profile is kaolinite poor.

The relative influence of weathered mafic volcanic rocks and introduced carbonate are reflected in the subtle antipathetic relationship between Fe and Ca concentrations. Close examination of the ferruginous material indicates that any Ca present occurs as coatings or in cracks. The emplacement of calcite within the matrix and cracks is consistent with the late stage introduction found in Profile A.

The distribution of Au shows a tendency to decrease down the profile and, on this evidence alone, is seen to be weakly related to the carbonate distribution. Maximum concentrations of Au (about 0.13 ppm) occur at about 0.5 m and occur with CaO concentrations of about 9%. This Ca-Au association is further and better demonstrated at Stop No. 3.

Interpretation of minor and trace element distributions in this profile is primarily determined by the distinction made between the Fe oxide and the calcite (Ca) phases and less so with Na and Si. Thus sympathetic associations are found between (i) As, Cu and V, and Fe, (ii) Mg, Pb and Sr, and Ca, (iii) Br with Na and (iv) Ti and Zr, and Si. Many minor and trace elements, e.g. Ce, Nb and Rb, show no distinct distribution trends in the soil profile.

Stop No. 3

This stop allows close examination of the carbonate-coated ferruginous material.

TABLE 1

COMPARISON OF ELEMENT CONCENTRATIONS BETWEEN THREE TYPES OF MATERIAL

Amount	Carbonate	Red saprolite	White saprolite
High	Mg, Ca, Au, Ba, Cu, Mn	Si, Al, Fe, Ni, Ti, Cr, V, Zr	Si, Al, Ca, Na, Ti, Zr
Low	Si, Al, Fe, Na, Ti, Cr, V, Zr	Mg, Ca, Au, Ba, Cu, Mn	Fe, Mg, Au, Ba, Cr, Mn, V

Stop No. 4

Profile C in Figure 18. Co-ordinates 2505E, 3700N. This profile is developed in a modern drainage channel, above unmineralised shales. It is dominated by considerable quantities of transported clay and quartz. The boundary of the transported horizon, which is near the base of the trench, is marked by clay-rich saprolite, derived from the underlying shales.

Figure 18. Distribution of elements in profile C.

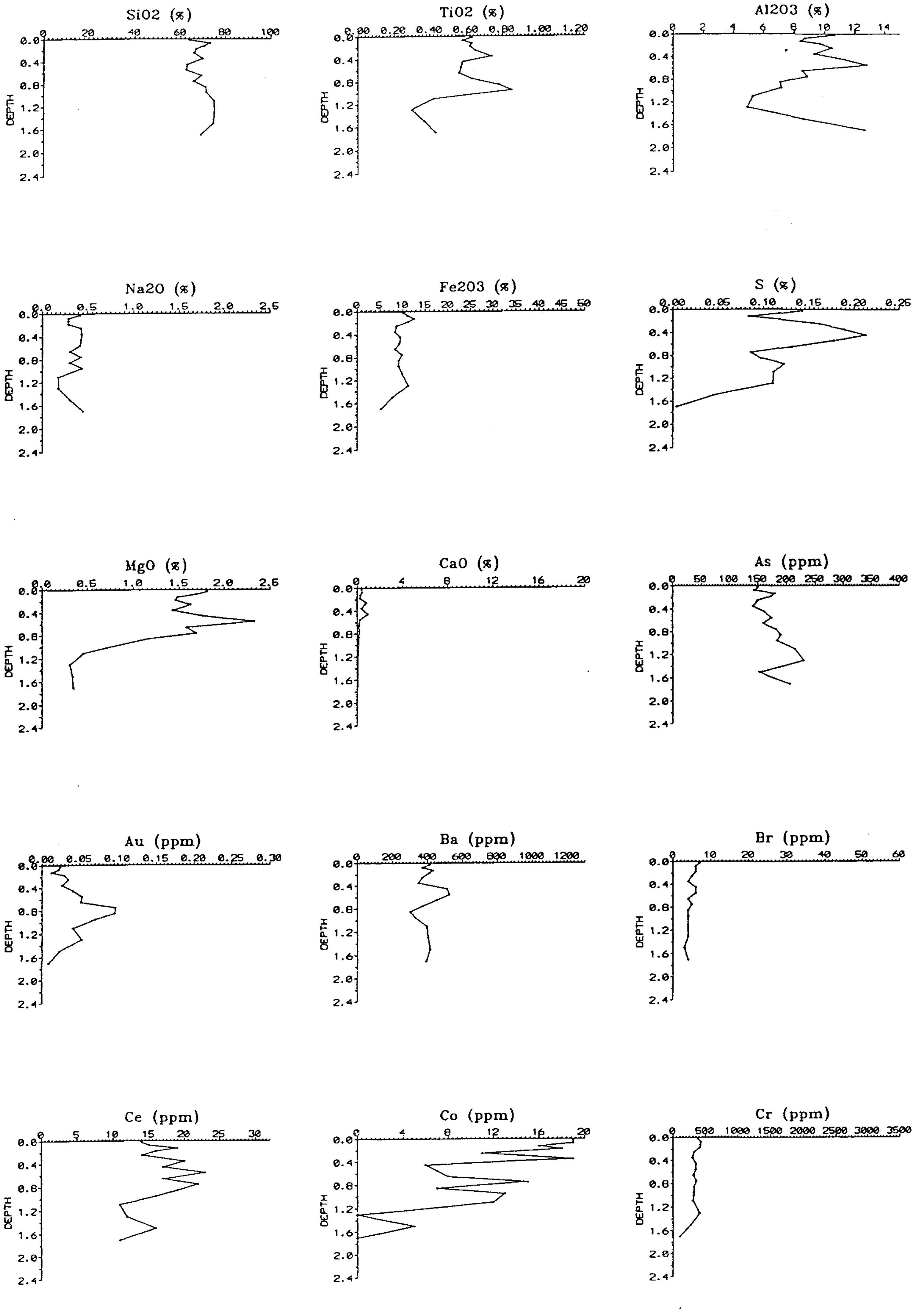
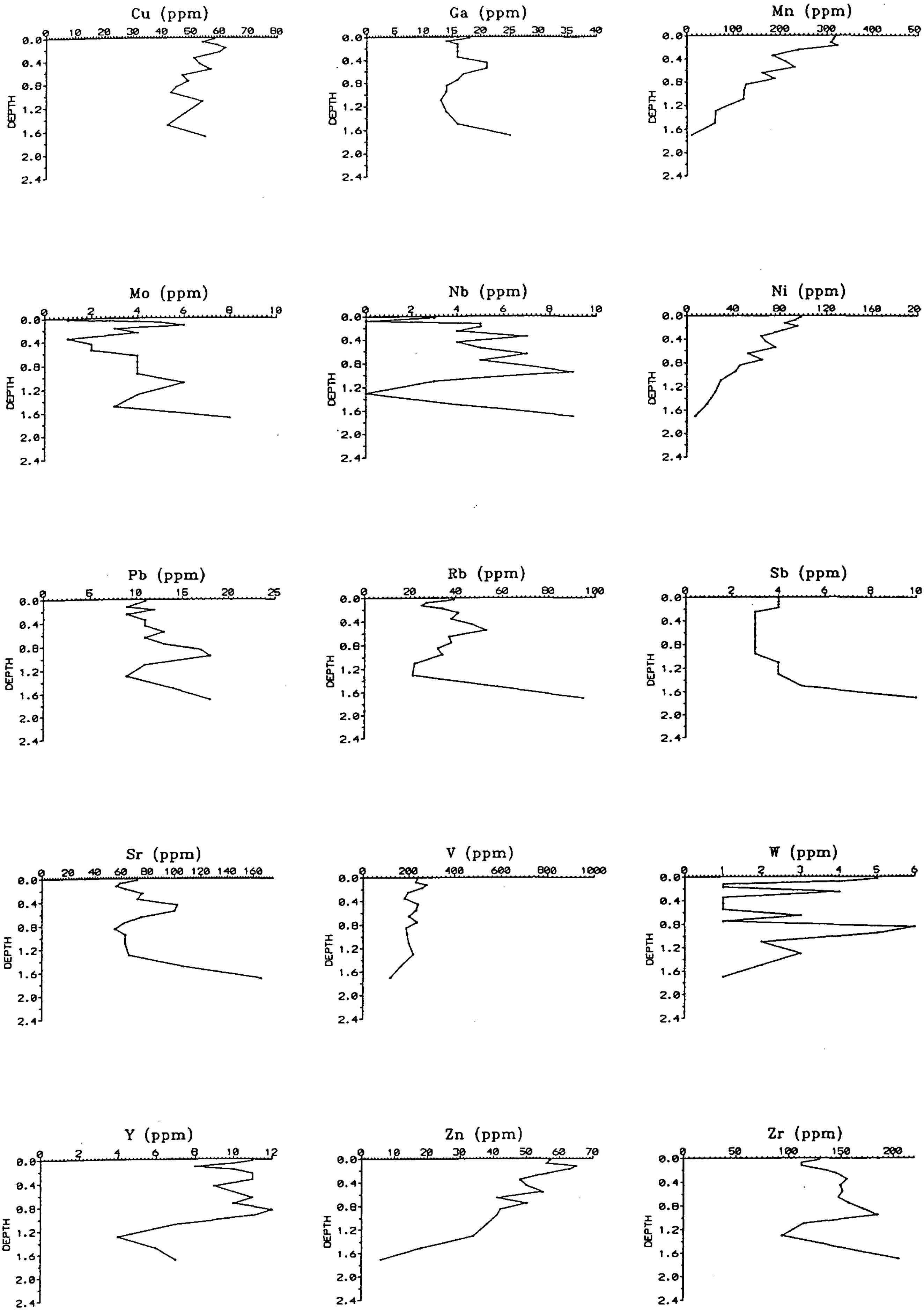


Figure 18 (contd)



The principal horizons are:-

0-20 cm	Clay-rich sand with appreciable quantities of ferruginous, siliceous and carbonate fragments and little organic material.
20-60 cm	Clay-rich sand with some carbonate and other coarse fragments present.
60-90 cm	Mainly clay-rich sand with some sand occurring as friable aggregates with minor quantities of coarse material.
90-1.6 m	This horizon is dominated by coarse, angular quartz with some finer-grained, sub-rounded quartz fragments. Some coarse lithorelics have similarities with the mafic volcanics found in Profile B.
1.6-1.8 m	Yellow, grey and red, clay-rich sand with some layered, mica-rich nodules. There are few, if any, coarse quartz or ferruginous fragments.

Calcite is restricted, in the upper part of the profile, to a few, small, friable aggregates whose structure suggests they were derived from the calcite coating the adjacent mafic volcanics e.g. those found in Profile B. The ferruginous fragments throughout the profile contain both goethite and hematite. The fragments in the upper part of the profile also show similarities with the mafic volcanics of Profile B. Considerable quantities of quartz occur as angular, detrital fragments (up to 5 mm in length), especially in the lower parts of the profile, immediately above the clay-rich saprolite. The major clay present is kaolinite. Muscovite increases in abundance at the base of the profile.

Calcium and Mg decrease markedly down the profile and are associated with calcite and fragments of mafic volcanic rocks. Aluminium concentrations are closely related to the distribution of the clays. Silicon contents are high throughout the profile but peak near the base where the volume of quartz fragments increases. Iron concentrations are low compared with Profiles A and B.

The gold distribution is largely in the fine (<0.2 mm) fraction. There is a weak association between Au and Ca (Au = 0.035 ppm, CaO = 0.82 %) in the upper part of the profile but the highest Au concentration (0.075 ppm) occurs in the fine fraction associated with kaolinite and muscovite.

The Na, Br, Ga, Mo, Nb, Rb, Sb, Sr and Zr distributions are closely correlated with Al. Their concentrations tend to be high at about 0.5 m, low at 1.3 m, before peaking in concentration at the bottom of the profile (1.7 m). Some of these elements (e.g. Na and Rb) are probably associated with isomorphous replacements in the muscovite. Gallium is probably associated with Al in muscovite and kaolinite. Sulphur, Co, Mn, Ni and Zn abundances decrease down the profile and may be associated with more than one soil mineral e.g. calcite, barite or with organic matter.

Stop No. 5.

This stop is to demonstrate the vegetation study. Two traverses were sampled: 3700N and 4200N. Only the survey over 3700N will be discussed here, although data from 4200N will be used for comparison.

Eremophila spp. and *Eucalyptus* spp. grow on the gravelly, well drained soils of the palaeochannel and similar soils developed over mafic rocks. Halophytes (salt-tolerant plants) grow in the clay-rich, poorly drained soils developed over the current drainage channel which overlies sedimentary rocks. Many *Eremophila* spp. and *Eucalyptus* spp. occur along 3700N and were the species most sampled.

The distribution of Au shown by vegetation sampling is broadly similar to that found in the soils, though contrasts tend to be higher in the gravelly soils (Figure 19). Gold contents are much higher in *Eremophila* spp. (up to 0.059 ppm) than *Eucalyptus* spp. (up to 0.042 ppm). *Eucalyptus* spp. east of the drainage channel contain more Au (up to 0.042 ppm) than *Eucalyptus* spp. found over mineralization to the west (up to 0.01 ppm) and may be of significance since they contain more than three times the background Au values for *Eucalyptus* spp. (0.012 ppm). Furthermore, the background data suggest that *Eucalyptus* spp. are not as effective as *Eremophila* spp. in accumulating Au. The Au content of *Eremophila* spp. on 3700N are generally richer than those on 4200N. In Figure 19, the top diagram shows the concentration of Au in the ash of a number of plant species. This may be compared with the lower diagram, which shows the concentration of Au in pulverised augered soil samples, after cyanide digestion, along the equivalent traverse.

Apart from Au, there is little relationship between the composition of the vegetation and that of the soils. This feature is most clearly seen with Fe, Mn, Ca, Ni and V. The concentrations of these elements in augered soil samples tend to decrease towards the drainage whereas in vegetation they tend to increase. Soils nearer the channel are thin because weathered rock occurs close to the surface. Sodium and ash contents are greatest for plants in the channel vegetation samples and are comparable with halophytes found on line 4200N.

The Cu contents of *Eremophila* spp. are higher than those in *Eucalyptus* spp. The values are comparable with those found for *Eremophila* spp. at 4200N and background areas, suggesting that appreciable quantities are required by this genus for normal plant function. Soil Cu contents are similar for the two traverses.

Sodium contents of *Eucalyptus* spp. are much greater than those found in *Eremophila* spp. but not as great as the salt-tolerant channel genera such as *Atriplex* spp. Sodium enrichment in *Eucalyptus* spp. may reflect the ability of its roots to reach, absorb and accumulate salts from the groundwater.

Calcium enrichment in *Eremophila* spp. is greater on 3700N than 4200N and may reflect higher abundance of pedogenic carbonate in the soil.

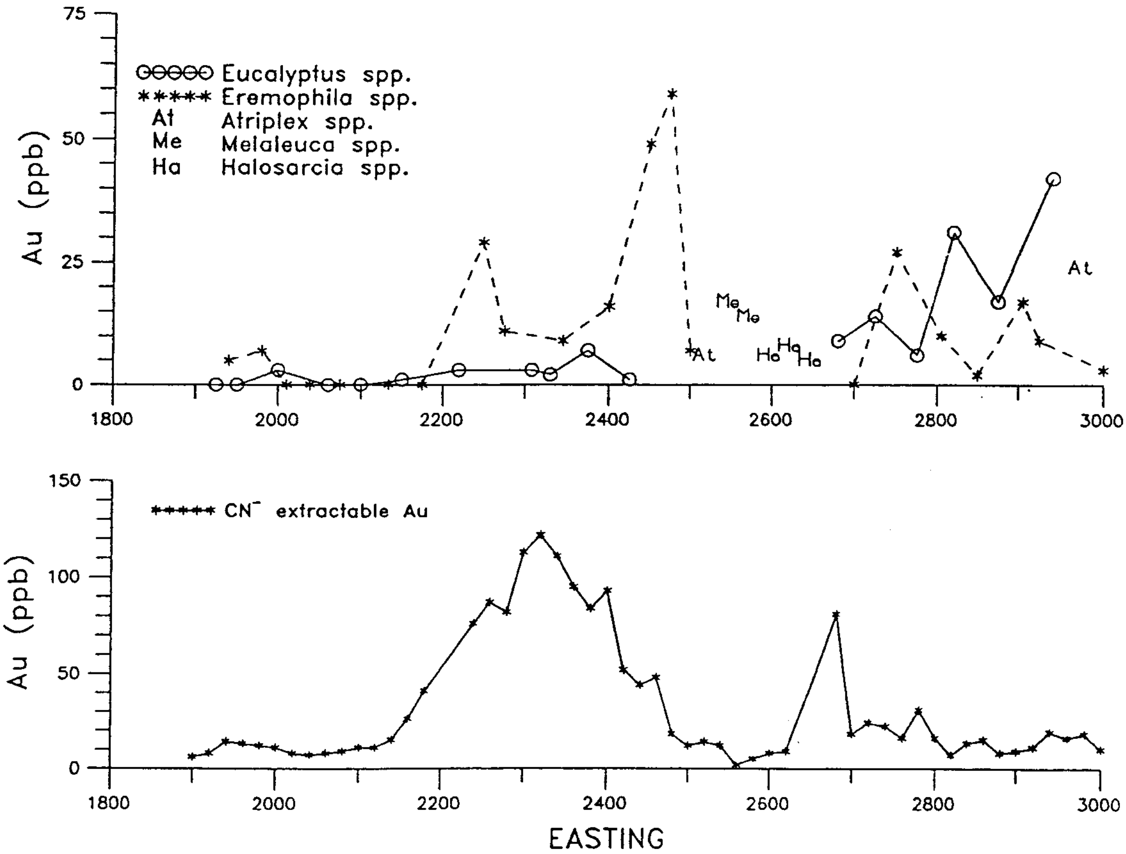


Figure 19. Au contents for vegetation and soils along 3700N.