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AN EVALUATION OF GEOCHEMICAL PARAMETERS FOR TIN EXPLORATION IN SOIL COVERED AREAS IN THE CENTRAL BUSHVELD COMPLEX.

by

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ABSTRACT

The thick soil cover over most of the felsic rocks of the Bushveld Complex, presents a major obstacle in the search for Sn deposits. In order to define those parameters that might reflect the presence of Sn mineralisation under such conditions, an orientation study was made of soil geochemical parameters in an area of known Sn mineralisation. The area chosen was the farm Vlaklaagte 221JR in the central Bushveld Complex where quartz-vein greisen type Sn mineralisation is known to exist.

The soils overlying the mineralisation are latosols in which three periods of soil formation can be identified. A pebble layer representing an unconformity in the soil profiles, with transported soils on top and residual soils or palaeo-colluvium below, has a dominating influence on the mineralogical and geochemical dispersion patterns in the soils. A consequence is that the B horizon, to which most attention is usually paid during exploration, presents an entirely unsatisfactory sampling medium due to its development in either the transported or residual soil.

Mineralogical and geochemical data were used to identify the various weathering cycles and the relationships between primary and secondary anomalies. Special attention was given to the behaviour of Sn, Cu, Mo, Rb, Sr and Ba, which were then used to establish possible guidelines for exploration. Where Sn is used as a pathfinder element the pebble layer yielded the best results as a sampling medium. A combination of 1) the Sn concentration in a bulk sample in the lower section of the lower pebble layer, 2) the ratio of the Sn concentrations (using bulk samples) between the lower section of the lower pebble layer and the residual soils and 3) the distribution patterns of cassiterite grain-size populations in the lower pebble layer (lower section) proved to be the most sensitive means for exploration (provided that the Sn is associated with cassiterite and that the pebble layer is in direct contact with the residual soils).

Copper and Mo are also very sensitive pathfinder elements but their source is not necessarily the same as for Sn. They

are, however, always closely associated with the Sn deposits and can therefore be used effectively in tracing associated mineralisation which will eventually lead to the Sn deposits. The most sensitive parameters proved to be a combination of the Cu or Mo concentrations in the silt-clay fraction in the lower part of the C horizon and their concentrations in individual goethite pellets from the lower section of the lower pebble layer.

Rubidium/Sr and Rb/Ba ratios are useful in identifying highly differentiated or metasomatic zones with which Sn deposits are associated. The silt-clay fraction in the lower part of the C horizon is recommended for the latter.

The weathering cycles and the elemental dispersion patterns are found to be dependant on the following factors:-

- The palaeo- and present climatic conditions.
- The topography (palaeo- and present).
- The primary minerals with which the elements are associated and the weatherability of the minerals.
- The predominant end minerals in the soils and their elemental association.
- The mobility of the elements under different Eh-pH conditions.

UITTREKSEL

Die dik grondbedekking oor groot gedeeltes van die felsiese gesteentes in die Bosveld Kompleks, bied 'n groot hindernis in die soektog na Sn afsettings. In 'n poging om hierdie hindernis te oorbrug is 'n studie van geochemiese parameters in gronde in 'n gebied van bekende Sn mineralisasie gedoen. Die gebied wat gekies is, is die plaas Vlaklaagte 221 JR in die sentrale Bosveldkompleks waar die bestaan van kwartsaar-greisentipe Sn-mineralisasie bekend is.

Gronde wat die mineralisasie oorlê is latosols waarin drie periodes van grondvorming geïdentifiseer kan word. 'n Rolsteenlaag wat 'n onreëlmatigheid in die gronde verteenwoordig, met aangevoerde gronde bo-op en residuele gronde of paleo-kolluvium onder, het die domineerende invloed op die mineralogiese en geochemiese verstrooiingspatrone in die gronde. 'n Gevolg hiervan is dat die B-horison, waaraan normaalweg die meeste aandag gedurende eksplorasie geskenk word, ongeskik as 'n monsteringsmedium is, weens die ontwikkeling daarvan in óf die aangevoerde óf die residuele gronde.

Mineralogiese en geochemiese data is gebruik om die verweringssiklus en die verwantskappe tussen primêre en sekondêre anomalieë vas te stel. Spesiale aandag is geskenk aan die gedrag van Sn, Cu, Mo, Rb, Sr en Ba en moontlike riglyne is vir eksplorasie bepaal. Waar Sn gebruik is as 'n padvinderelement, het die rolsteenlaag die beste resultate as 'n monstermedium verseker. 'n Kombinasie van 1) die Sn konsentrasie in heelmonsters in die onderste gedeelte van die onderste rolsteenlaag, 2) die verhouding van Sn konsentrasies (heelmonsters) tussen die onderste gedeelte van die onderste rolsteenlaag en die residuele gronde en 3) die verspreidingspatrone in korrelgrootte populasies van kassiteriet in die onderste gedeelte van die onderste rolsteenlaag, blyk die mees sensitiewe metode te wees (met die voorbehoud dat die Sn geassosieer is met kassiteriet en dat die rolsteenlaag in direkte kontak met die residuele gronde is).

Koper en Mo is ook baie sensitiewe padvinderelemente maar hul bron is nie noodwendig dieselfde as vir Sn nie. Dit is egter

altyd baie nou geassosieer met Sn afsettings en kan dus effektief gebruik word in die opspoor van geassosieerde mineralisasie wat dan uiteindelik na die Sn afsettings sal lei. Die mees sensitiewe parameters blyk te wees 'n kombinasie van die Cu of Mo konsentrasies in die modder en klei fraksie in die onderste gedeelte van die C horison en hul konsentrasies in individuele goethiet pille vanuit die onderste gedeelte van die onderste rolsteenlaag.

Rubidium/Sr en Rb/Ba verhoudings is baie bruikbaar in die identifikasie van hoogs gedifferensieerde of gemetasomatiseerde sones, waarmee die Sn afsettings normaalweg geassosieer is. Die modder plus klei fraksie in die onderste gedeelte van die C horison word aanbeveel in laasgenoemde geval.

Die verweringssiklusse en die elementverspreidingspatrone is afhanklik van die volgende faktore:-

- Die paleo- en huidige klimaatstoestande.
- Die topografie (paleo- en huidig).
- Die primêre minerale waarmee die elemente geassosieer is en hul weerstand teen verwering.
- Die dominerende eindminerale in die gronde en hul elementassosiasie.
- Die mobiliteit van die elemente onder verskillende Eh-pH toestande.

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1 INTRODUCTION

The granites of the Bushveld Complex have been the major source of tin in South Africa for the past fifty years. Most of the tin was produced in the Zaaiplaats, Union and Rooiberg tin fields with insignificant amounts coming from the other districts (Fig. 1-1). The granites of the Bushveld Complex and the associated metasedimentary rocks are well exposed in these three tin fields, whilst in the remainder of the area they are only exposed as scattered outcrops or as near-vertical cliffs along the edge of the Sekhukhuni Plateau.

The Mineral Map of South Africa compiled by the Geological Survey of South Africa (1981) together with Fig. 1-1 indicate that tin mineralisation is known virtually everywhere where the upper parts of the granitic phase of the Bushveld Complex is exposed. It thus appears that the absence of known significant deposits elsewhere in the granites could reflect an absence of good exposures.

From an exploration point of view the question can therefore be asked whether adequate exploration techniques to detect tin mineralisation in covered areas exist or can be developed. The present investigation is aimed at evaluating known geochemical techniques for locating covered tin deposits and, if required, establish more effective techniques.

Three geochemical exploration techniques by which further Sn deposits could be located are:-

- A systematic drilling programme across the granitic rocks backed up by petrographic and lithogeochemical studies,
- A systematic geochemical investigation of the soils overlying tho granites,
- A systematic geochemical investigation of the gas-species in these soils.

The successful implimentation of the first alternative on a regional scale is financially prohibitive and techniques for gas analysis are not yet fully developed. Soils are often used in the exploration for tin (Taylor, 1979), but the techniques involved apply to climatic conditions differing significantly

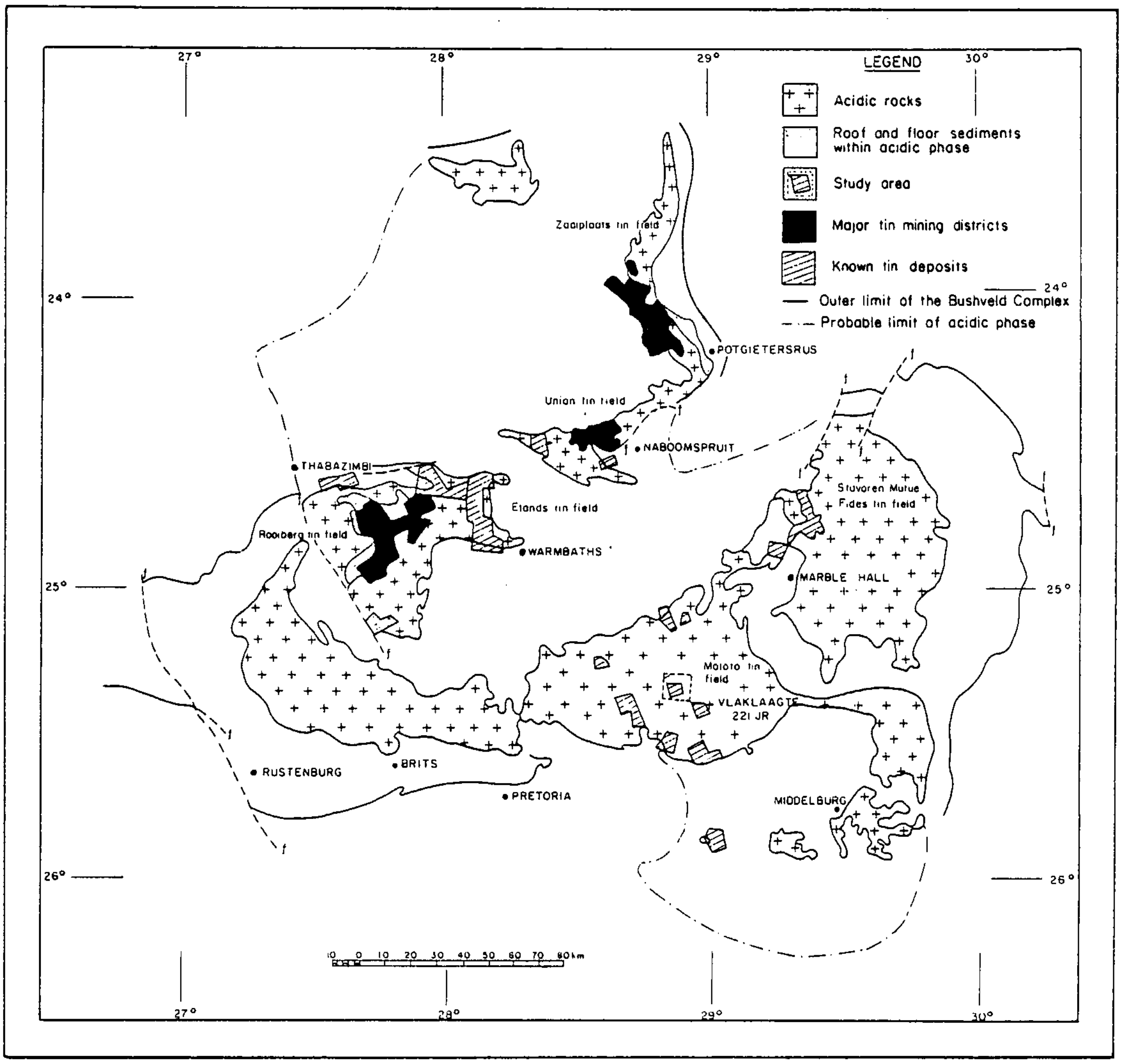


Figure 1-1: The distribution of the Bushveld granite showing the districts in which tin mineralisation is known.

from those in South Africa (Groves **et al.**, 1972; Hosking, 1971; Levinson, 1980; Omer-Cooper **et al.**, 1974). This study therefore concentrates on the geochemical sampling parameters for soils overlying the granites.

The chemical and mineralogical data on tin occurrences in the Bushveld Complex indicate that they often contain significant concentrations of Mo, Cu and F in addition to tin (Crocker and Callaghan, 1979; Steyn, 1962). Special attention was thus also devoted to the distribution of Cu and Mo in the soils.

The effectiveness of any geochemical exploration technique depends on the sampling approach used and this aspect forms a major part of this study. The area selected for study should be relatively undisturbed by prospecting and mining activities, poorly exposed, with insignificant farming activity. The Moloto district fulfills these requirements and it was therefore decided to carry out a study on the Sn occurrence on Vlaklaagte 221 JR (Fig. 1-1).

2 METHOD OF INVESTIGATION.

2.1 SAMPLING AND SAMPLE PREPARATION

A series of rock samples were collected from the area. These samples were crushed, pulverised and then analysed according to procedures described below. Thin and polished sections were made for mineralogical and petrological studies.

A number of prospecting pits were dug in both mineralised and unmineralised zones (positions indicated in Fig. 2-1). The soil profiles were logged and described (Appendix A). Various horizons were sampled (5 kg samples) and after drying at 110°C, three kilograms of each sample were screened into five size fractions (i.e. the gravel, coarse sand, medium sand, fine sand and silt-clay fractions). Mineralogical studies and chemical analyses were made of the bulk sample as well as the different size fractions.

Soil samples (5 kg) from the A_1 horizon were collected along five traverses crossing the greisen lodes and quartz fissures, and one traverse which is oblique to the others (Fig. 2-1). Sample spacing is 50 m along the first five traverses and 90 m in the last. The samples were dried at 110 °C and screened into selected size fractions. Copper, Mo, Rb, Sr, Ba and Fe_2O_3 were determind using the -0,075 mm fraction and Sn on the bulk sample.

2.2 ANALYTICAL TECHNIQUES

The major and trace elements, with the exception of Li, Be, F and B were determined by means of XRF using the procedures described by Frick and Kent (1984).

Lithium and Be were determined by atomic absorption spectrometry (AA) using the techniques of Jeffery (1975) and Abbey (1967). Pure element standards were used for Li and Be and good agreement was obtained between the values for the NIMROCK reference rock samples G, S and L and the reported values (Steele **et al.**, 1978). Coefficients of variation for replicate determinations were approximately 6% and 10% at levels of 50 ppm and 12 ppm respectively and 10% at a Be level of 7 ppm.

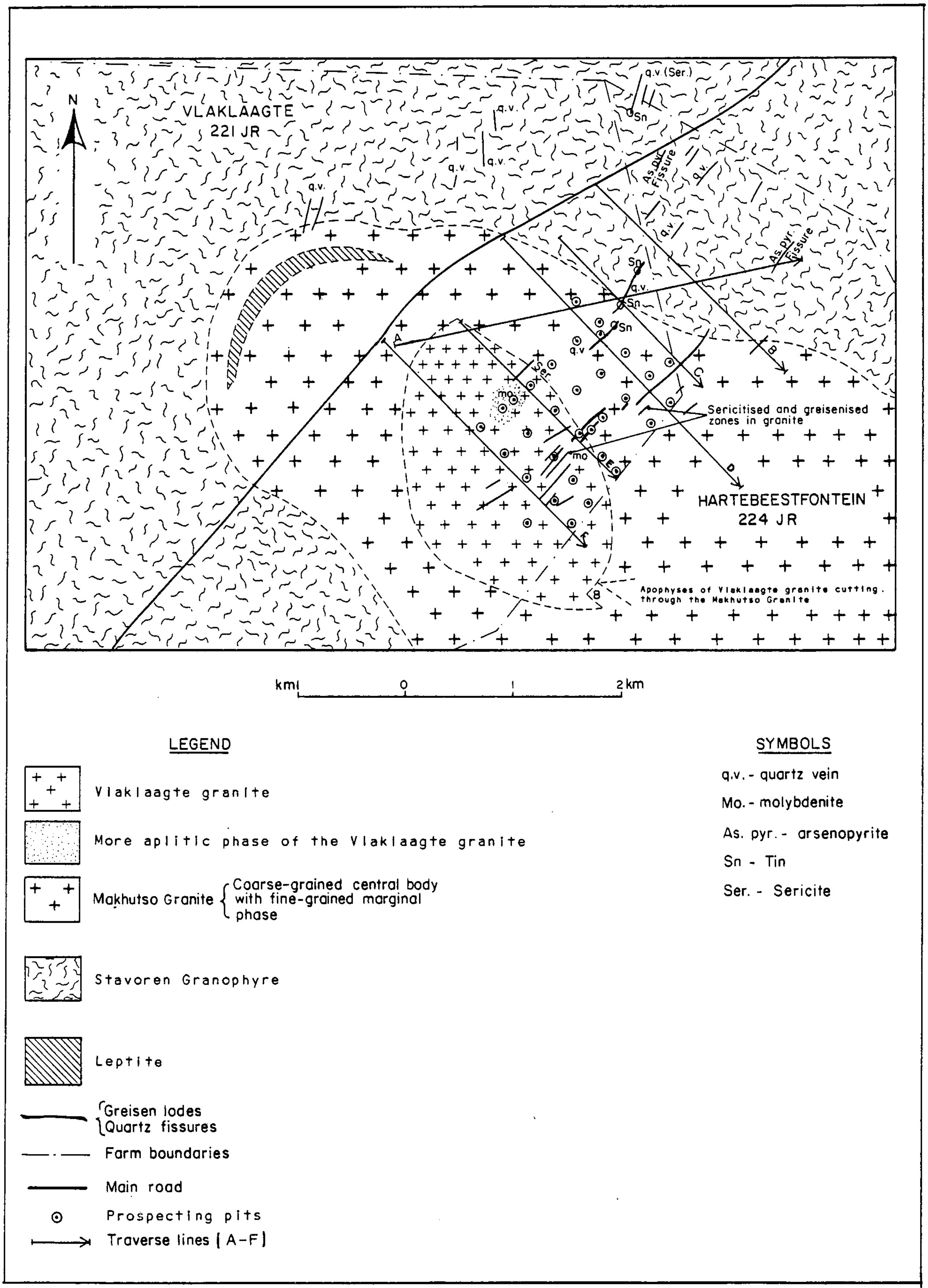


Figure 2-1: The geology of the study area showing traverses along which surface samples were collected and the positions of the prospecting pits.

Fluorine was determined by the standard addition method (Edge, 1979), using an ion-selective electrode and a specific ion meter. Excellent agreement was obtained between the concentrations measured in the NIMROCK samples (G, S and L) and the reported values. Coefficients of variation for replicate determinations were approximately 9% and 3% at fluoride levels of 300 and 4200 ppm respectively.

Boron was determined by inductive coupled plasma (ICP) emission spectrometry. The general analytical procedure followed is that described by Owens **et al.**, (1982). CANMET SY-2 and SY-3 (Abbey, 1983) were used for reference and good agreement between the measured and reported values were obtained. The coefficient of variation for replicate determinations was approximately 10% at a level of 100 ppm B.

The rock samples were studied in thin and polished sections. A stereo microscope was used for the visual mineralogical identifications on the soils. A X-ray diffractometer was used for the semi-quantitative estimations of the mineralogical compositions. Bulk sample fractions were used for the latter.

Heavy mineral separates from some horizons in selected profiles were identified by means of a scanning electron microscope fitted with an energy dispersive spectrometer.

3. THE GEOLOGY, GEOMORPHOLOGY AND SOIL DISTRIBUTION OF THE STUDY AREA.

Any geochemical soil sampling programme is influenced by a vast number of parameters which include, amongst others, the geology of the bedrock, the depth, composition, distribution and origin of the overburden, the surface topography, the sub-soil topography and the climatic conditions. Because all these factors interplay on one another, it is impossible to use empirical models to deduce any one factor and a thorough investigation of each one is essential.

3.1 GEOLOGY

Fig. 2-1 shows the generalised geology of the Sn/Mo occurrence on the farm Vlaklaagte 221 JR, amended after the mapping of De Bruiyn and Rhodes (1975) and of Wessels (1940). According to the former the Makhutso Granite is intrusive into both the granophyric roof-rocks (Stavoren Granophyre) and the Main Bushveld granite (Nebo Granite). They describe the Makhutso Granite as a greyish biotite-rich granite which consists of a fine-grained marginal phase and a coarse- grained central body. The latter is intruded by a fine-grained, sometimes aplitic, grey biotite granite which was described by Merensky (1908) as the ore carrier. This fine-grained granite, the Vlaklaagte granite, is probably an equivalent of the Koornkopje granite described by Marlow (1976).

Apophyses of the Vlaklaagte granite were observed (Fig. 2-1, point B) cutting through the Makhutso Granite. This supports the contention of Merensky (1908) that the Vlaklaagte granite is younger and has intruded into the Makhutso Granite. It is not evident from the field evidence whether the Vlaklaagte granite, which intruded into fissures in the partly consolidated Makhutso Granite, represents a later magma or is a late-stage product of the Makhutso magma. The intrusive contact between the Vlaklaagte granite and Makhutso Granite is, however, very sharp (Fig. 3-1). The approximate boundaries of the Vlaklaagte granite, indicated in Fig. 2-1, were in places inferred because of the lack of outcrops.

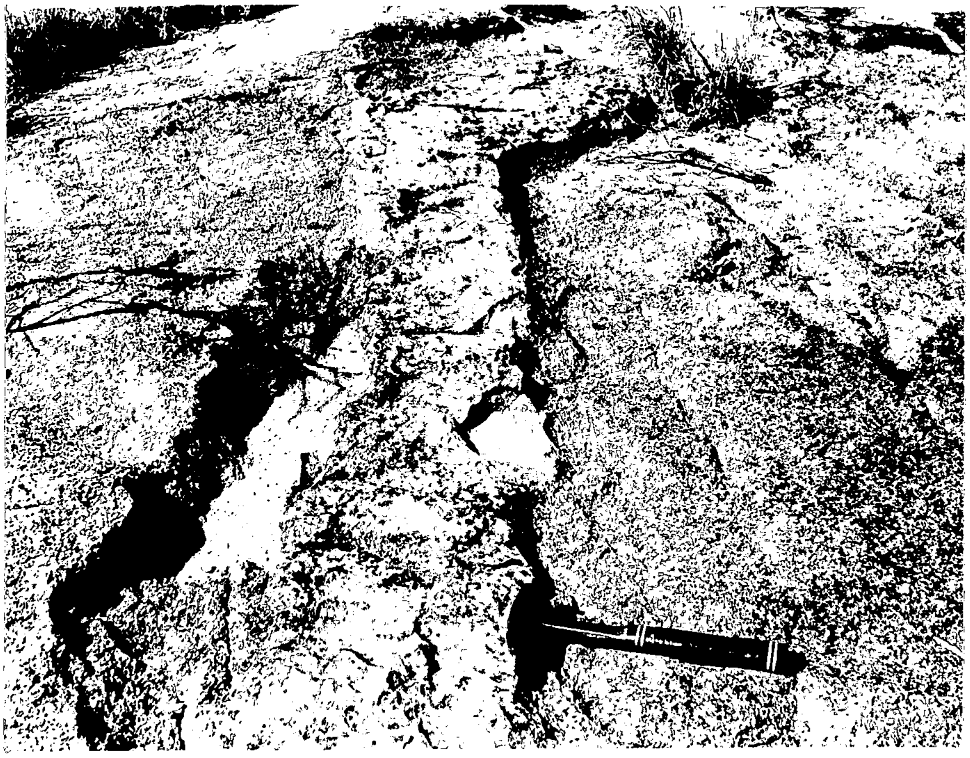


Fig. 3-1: Photograph showing the sharp intrusive contact between the Vlaklaagte granite (fine-grained) and the Makhutso Granite (coarse-grained).

The tin mineralisation is associated with a well-defined zone of irregularly shaped greisen lodes and quartz veins which strike NNE and occur in the granophyre as well as the Vlaklaagte and Makhutso Granites. These structures represent a major zone of fissuring in the Bushveld granite and granophyre (Fig. 2-1). The medium grained greisen bodies are marked by intensive prophylitic alteration and the presence of fluorspar. The greisen lodes are surrounded by halos of red colouration, probably due to secondary alteration, which decrease in extent away from the greisen lode contacts.

The quartz veins are in places pegmatitic, associated with the greisens and form single discontinuous bodies and swarms of almost parallel veins in the granites and granophyre. They carry variable amounts of arsenopyrite, chalcopyrite, bornite, cassiterite and molybdenite, but are badly exposed and have not been well prospected. Wall-rock alteration around the more sulphide-rich veins is limited.

The Mo mineralisation is mainly present in an aplitic differentiate of the Vlaklaagte granite near to the north-northwestern contact with the Makhutso Granite. Disseminated molybdenite flakes are scattered throughout the Vlaklaagte granite in areas where the greisen bodies and quartz-pegmatite veins occur.

From the geological evidence, it is concluded that the erosion of the batholith has reached a level where a large part of the greisenisation halo is exposed.

According to the field evidence the aplitic phase is restricted to a specific zone in the Vlaklaagte granite, whilst the greisens are restricted to the roof zone of this granite as well as to the lower contact zones of the Makhutso Granite.

Using Schcherba's (1970a) classification of greisenisation halos, it is concluded that the Vlaklaagte granite corresponds to the inner halo (endo-intrusional zone) and is characterised by endo-greisens, whereas the Makhutso Granite and Stavoren Granophyre represent an outer halo (exo-intrusional zone) and are characterised by their associated exo-greisens and hydrothermalites. The Vlaklaagte deposit is therefore classified as a quartz-vein greisen in aluminium-silicate rocks (Schcherba, 1970b).

According to Groves (1972), Gee and Groves (1971) and Schcherba (1970a) the style of mineralisation in these types of batholiths and their satellites, is distinctive whilst the deposits are usually located in or close to the roof zones of the late biotite and muscovite-bearing intrusives. The occurrence of sulphides and arsenides in the quartz veins represents the outer rim of the outer halo.

3.2 CLIMATE AND GEOMORPHOLOGY

The study area is situated on the temperate, eastern plateau of Southern Africa with mean monthly temperatures ranging from 10 °C in June-July to 25 °C in January (Juta & Co., 1979). Diurnal temperature ranges, especially in winter, are large and at night temperatures may fall below zero.

The annual precipitation varies between 500 mm and 1000 mm, occurring predominantly in the summer months (Juta & Co., 1979) either as thunder showers or as continuous gentle rain. The surface run-off increases from heavy after thunder showers to slow run-off after gentle showers. In Fig. 3-2 the surface topography of the area is shown. The undulating topography ranges between 1280 m and 1370 m above the east-draining, perennial Klipspruit stream. The gradients of the slopes are low and the summits of the higher ground flat. Soil transportation is at present minimal and thus influences present soil profile formation. The area is soil covered with grassland being the natural vegetation. A few scattered trees, mountain syringa (**Kirkia Wilmsii**) which are known to flourish in thick sandy soils, also occur on the ridges.

The sub-soil topography, i.e. the topography of the bedrock below, controls the direction of groundwater movement. Fig. 3-3 illustrates the sub-soil topography and the thickness of the regolith, as determined by the auger boreholes and prospecting pits dug in the area. The pedogenetic horizons together with mineralogical and geochemical data for each pit are presented in Appendix A.

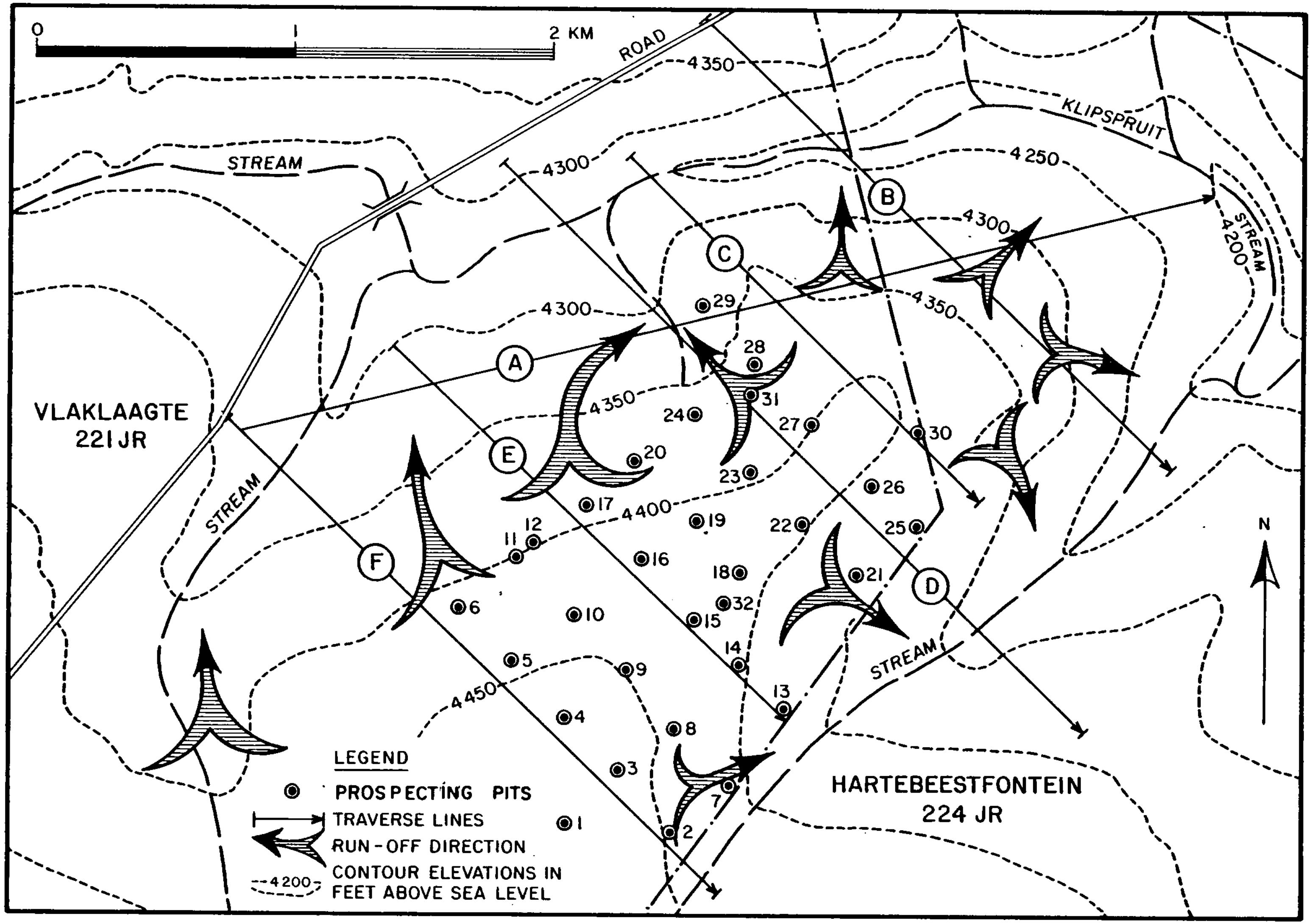


Figure 3-2: Topographical map of the area showing the traverse lines, prospecting pit positions and surface run-off patterns.

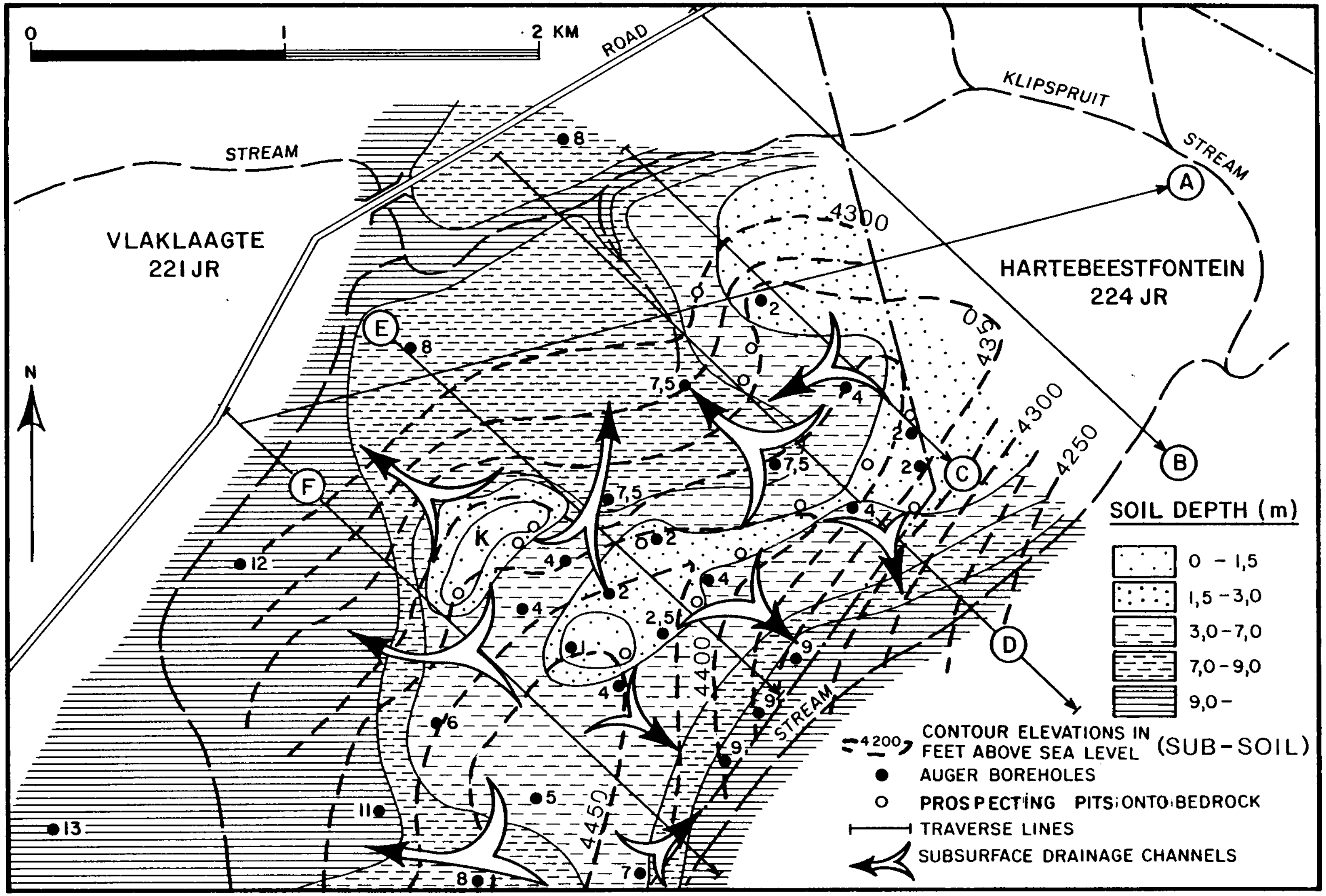


Figure 3-3: A schematic presentation of the soil depth, sub-soil topography and the sub-soil drainage patterns.

The thickness contours shown in Fig. 3-3 indicate a good correlation with the topography shown in Fig. 3-2. In general there is a decrease of the soil thickness in the higher-lying parts of the area and a significant thickening in the lower parts, especially near the drainage channels. A slight local high is seen at position K in Fig. 3-3. This could have a minor effect on the subsurface groundwater drainage and is probably related to the presence of aplitic granite at this location.

3.3 THE COMPOSITION, DISTRIBUTION AND ORIGIN OF THE SOILS

3.3.1 Surface soils

The surface soils, using the azonal classification in Table 3-1, and the distribution of the different soil types are depicted in Fig. 3-4. Although it is expected that residual soils should occur on the top of the ridge, it is evident from the map that the entire area is covered with transported soils, either colluvium (most of which was not transported very far) or alluvium. This appears to be the characteristic weathering phenomena of granitic rocks (Fairbridge, 1968).

The two most characteristic granite landforms in the area together with the weathering phenomena expected for each are shown in Fig. 3-5. The flat ridges (Fig. 3-5B) contain spheroidal granite boulders which outcrop intermittently on top of the ridges. The hollows in between are filled with colluvium which covers the residual soils (Fig. 3-5B, pit 22). Colluvium also covers residual soils on the slopes of the ridges (Fig. 3-5B, pits 21 and 23). The residual soils along the slopes below granite domes are also covered with colluvium (Fig. 3-5A). It is therefore clear that no "**in situ**" residual soils are found at the surface in this area.

The most abundant soil-type consists of upper slope colluvium together with pockets of colluvium on the crests (Fig. 3-4). On the upper slopes the colluvium is between 1,5 and 2 m thick. The lower slopes of the ridges are covered by middle slope and foot slope colluvium that varies from 2 to 5 m in thickness.

Alluvial sediments are confined to the drainage channels

TABLE 3-1: AN AZONAL CLASSIFICATION OF SOILS IN RELATION TO PARENT MATERIAL AND TOPOGRAPHY.

<table>
<tr><th colspan="3">SOIL TYPES</th><th>OCCURENCE</th><th>MODE OF FORMATION</th><th>COMPOSITION</th><th>STRUCTURE</th></tr>
<tr><td rowspan="3">REGOLITH</td><td colspan="2">RESIDUAL SOILS (SAPROLITE)</td><td>IN SITU</td><td>WEATHERING IN SITU</td><td>MATERIAL NOT REMOVED FROM ITS GENETIC SITE</td><td>INTERSTITIONAL GRAIN RELATIONSHIPS UNDISTURBED</td></tr>
<tr><td rowspan="2">TRANSPORTED SOILS</td><td>COLLUVIUM</td><td>INCREASING DISTANCE OF TRANSPORTATION
CREST (POCKETS);
UPPER SLOPE;
MIDDLE SLOPE;
FOOT SLOPE</td><td>COMBINED
GRAVITY;
SOIL CREEP·
SHEET EROSION;
RAINWASH</td><td rowspan="2">HETEROGENEOUS MATERIAL (SOIL) REMOVED FROM ITS GENETIC SITE
MATERIAL BECOMES MORE HETEROGENEOUS</td><td>MATERIAL BECOMES MORE ROUNDED AND SORTED
INTERSTITIONAL GRAIN RELATIONSHIPS DISTROYED (MATERIAL UNSORTED)</td></tr>
<tr><td>ALLUVIUM</td><td>VALLEYS;
STREAMS;
RIVERS</td><td>WATER TRANSPORTED</td><td>INTERBEDDED LAYERS OF SORTED AND PARTLY SORTED MATERIAL</td></tr>
</table>

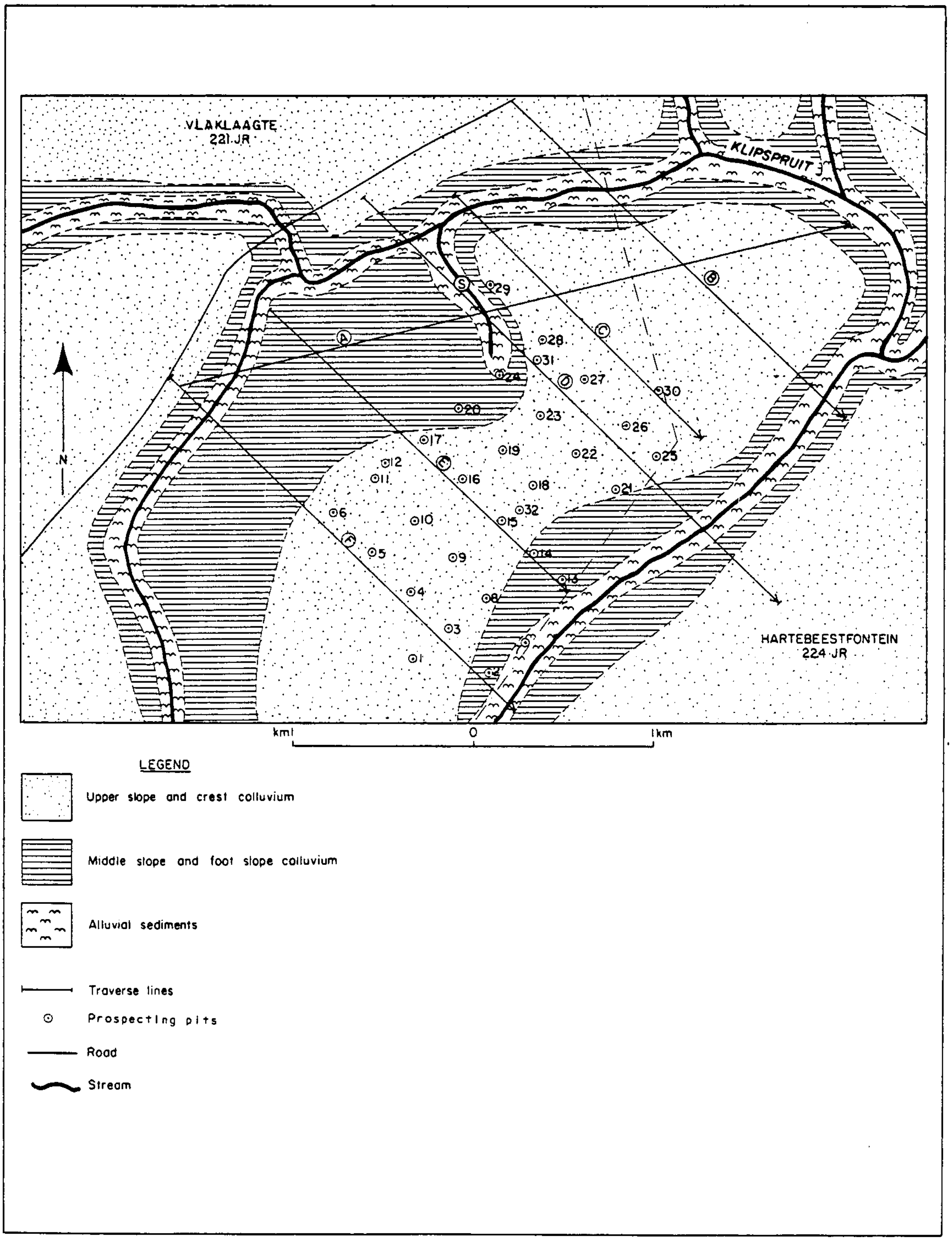


Figure 3-4: Map indicating the approximate boundaries of the different types of surface soils.

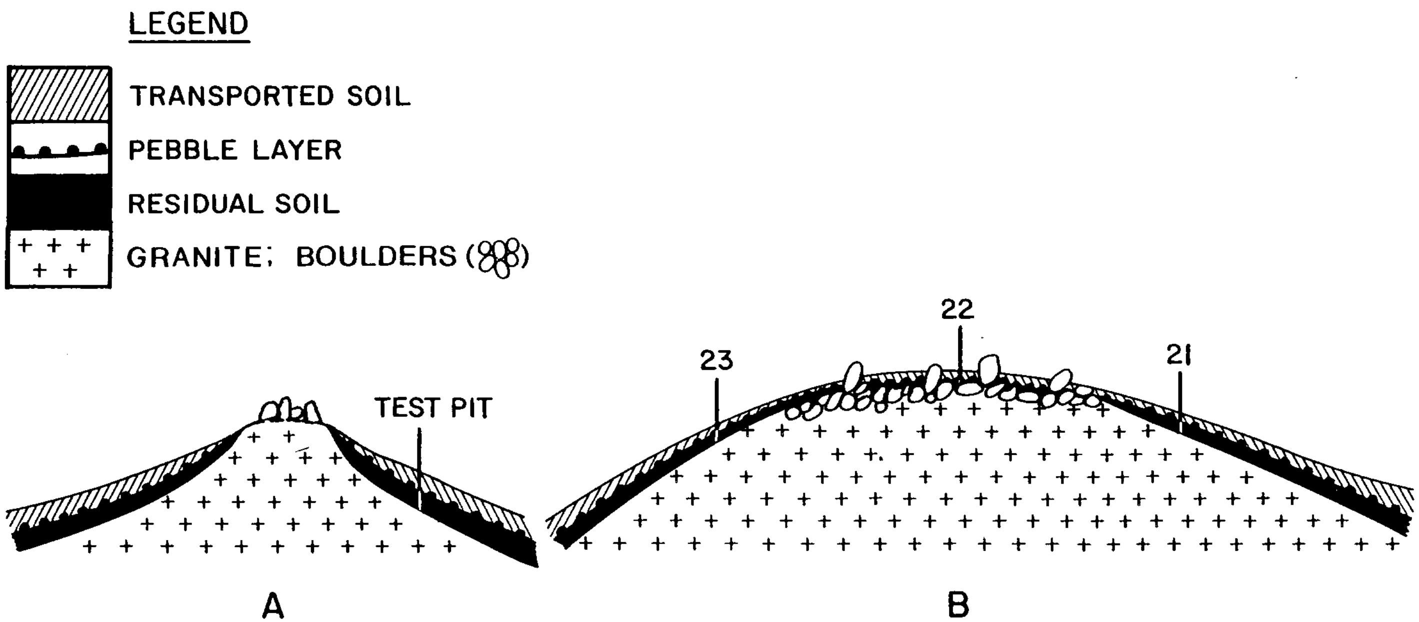


Figure 3-5: A schematic presentation of the two characteristic granite landforms in the area together with the weathering phenomenon of A) a granite dome marked by exfoliation and B) a flat ridge with occasional outcrops of spheriodal granite boulders.

and range from 2 to 10 m in thickness. Along the creeks the sediments form typical "vlei" deposits containing peaty carbonaceous soil. At location S (Fig. 3-4) the alluvial material has been worked by miners and judging from the extent of trenching, some cassiterite must have been recovered. Along the Klipspruit the alluvium consists predominantly of sandy quartz.

3.3.2 Subsurface soils

The presence of colluvium and alluvium excludes the possible development of normal soil horizons from residual soils by pedogenetic processes. True genetic soil horizons, although poorly developed, can, however, be recognised in the transported soils. The soil profiles (Appendix A) also show that the homogenising processes of soil formation have destroyed most of the evidence of deposition in the transported material. The only evidence of stratification that remains in the soils is a well-marked zone of angular and sometimes rounded quartz pebbles or rubble. This "stone line" or "pebble layer" separates the transported soils from the residual soils and solid bedrock.

Two distinctive topographically bounded soil profiles are distinguished. The more general one is a lateritic (latosol) soil profile, also known as a ferrisol or ferralitic soil profile using the classifications after Bridges (1970) and Simonson (1957). These soils are usually moderately acid.

Lateritic soils usually develop under conditions of fairly high rainfall, high temperatures, intense leaching and strong oxidation (Levinson, 1980). According to Vermaak (1984) such conditions which were suitable for the formation of lateritic soils, existed during several palaeo-cycles since the Lower Pleistocene.

The second type of soil profile is restricted to topographic depressions and can be classified as a "vlei" profile (James, 1957). In contrast to the lateritic profiles which have a distinct stratified colluvial component, the vlei profiles have a stratified alluvial component.

3.3.2.1 Latosol (lateritic) profile

Generalised soil profiles of the ridge and upper slope areas are illustrated in Fig. 3-6. The diagnostic horizons shown here are based on the soil classification system of MacVicar **et al.**, (1977).

Before discussing the diagnostic horizons in detail, the relationship between the pebble layer and the B horizon needs clarification. The pebble layer is a non-diagnostic zone and has a variable position in the soil profile (Fig. 3-6). Its position varies considerably and depends on the thickness of the transported soils above it. If the transported soils are thick, the entire B horizon can be developed above the pebble layer (Fig. 3-6A). Alternatively the B horizon may be developed entirely below it in the residual soil (Fig. 3-6B). Since the pebble layer represents an unconformity the profile in Fig. 3-6B can be considered to represent a partly stripped palaeo-profile whilst that in Fig. 3-6A is a completely stripped palaeo-profile.

A typical A horizon, developed through leaching by downward percolating rainwater, can be sub-divided into three horizons:-

A_1 horizon: This is a dark-coloured, orthic A horizon which MacVicar **et al.**, (1977) describe as "normal" for the majority of soils in South Africa. It is also the zone of maximum biological activity, characterised by humus mixed with mineral matter. The soils are medium textured and weakly structured with a thickness of less than 30 cm.

A_2 or E horizon: Maximum leaching takes place in this zone, which is pale greyish in colour. The material has a loose structure and consists predominantly of quartzitic sands with most of the clays leached from it. This zone is usually less than 35 cm thick and is very poorly developed in some profiles.

A_3 horizon: The A_3 horizon has developed only where the B horizon occurs in the transported soils (Fig. 3-6A). It is brown in colour and transitional into the B horizon but displays the characteristics of the A rather than the B horizon.

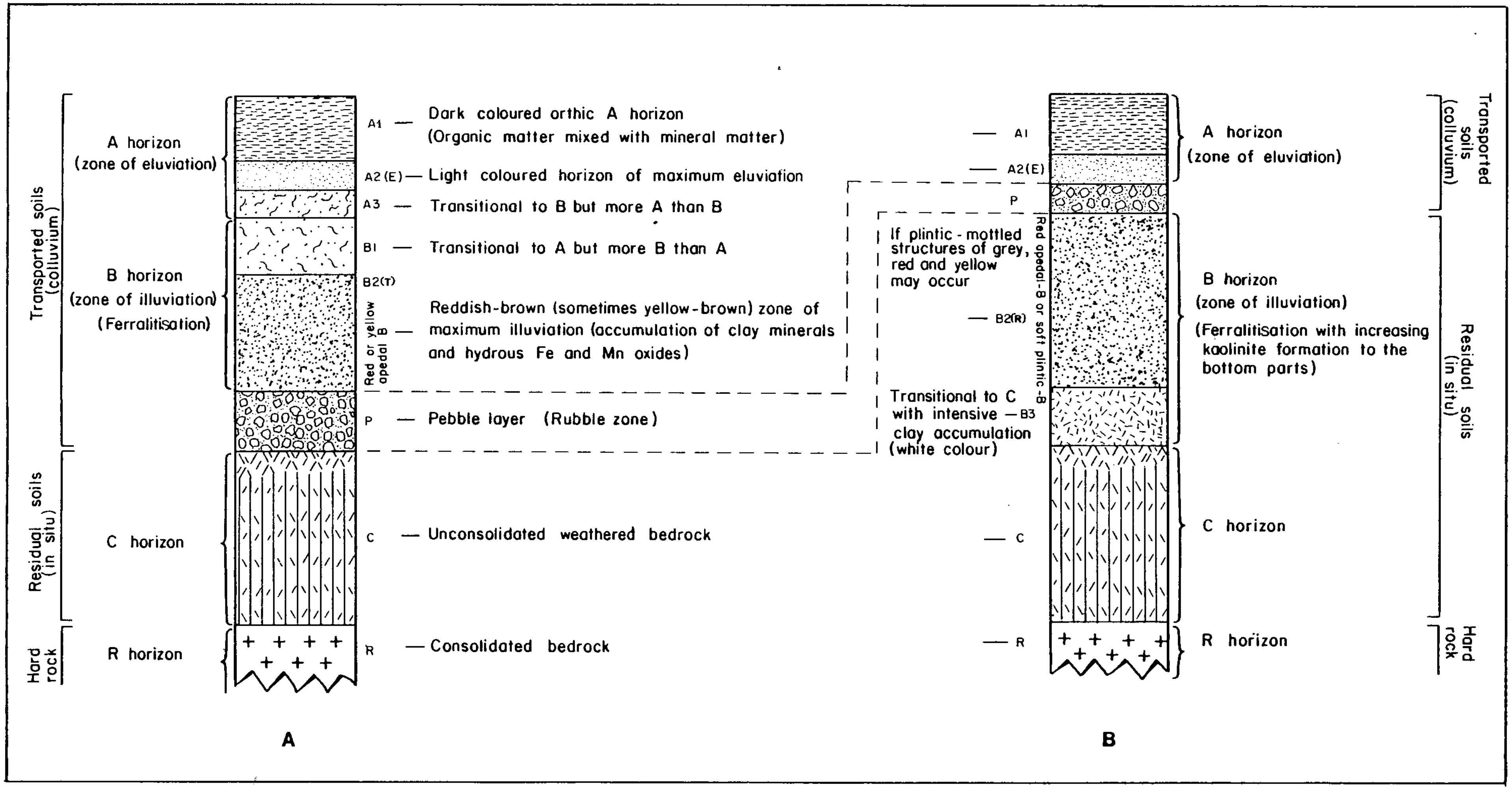


Figure 3-6: Generalised latosol soil profile with A) a stripped and B) a partly stripped palaeo-profile.

A typical B horizon can be sub-divided into three zones, marked by illuviation (accumulation):-

B_1 horizon: This brown-reddish zone is transitional to the A3 horizon and formed under conditions of illuviation, accumulating leached material from the A horizon. The zone displays more characteristics of the B horizon.

B_2 horizon: This is the zone of maximum illuviation of metals, clays and Fe and Mn oxides. The Fe and Mn oxides usually cause a red colouration in the soils. The zone can be classified as a red apedal B_2(T) horizon when it developed in transported soils and is marked by structureless soils in which the individual soil particles are coated with iron oxides. However, in cases where the parent material has a low Fe^{2+} content or where the soils have a higher average moisture content a yellow brown apedal B_2(T) horizon develops (MacVicar **et al.**, 1977).

When the B horizon is developed in the residual soils it is a dark red apedal B_2(R) horizon with a soft plintic structure which preserves the granitic texture. This zone sometimes displays red, yellow and grey mottles (concretions) which are due to the accumulation of clay minerals and Fe and Mn oxides. According to MacVicar **et al.**, (1977) and Bayliss (1972) the mottled structures are characteristic of zones which are periodically saturated with water. The clay (kaolinite) content in the B_2(R) horizon increases gradually down to the B_3 horizon.

The thickness of the transported soils above the pebble layer, shown in Fig. 3-7, gives an indication of the type of B horizon that can be expected in the area.

B_3 horizon: The B_3 horizon develops only when the B horizon is situated in the residual soils (Fig. 3-6B) and is then transitional to the C horizon. It contains some unconsolidated material from the C horizon, is whitish in colour and marked by intensive clay accumulation. Mottled structures, marked by dominant white concretions (possibly gleyish), are observed in this zone.

C horizon: This zone consists of **"in situ"** unconsolidated weathered bedrock and its thickness depends on the susceptibility

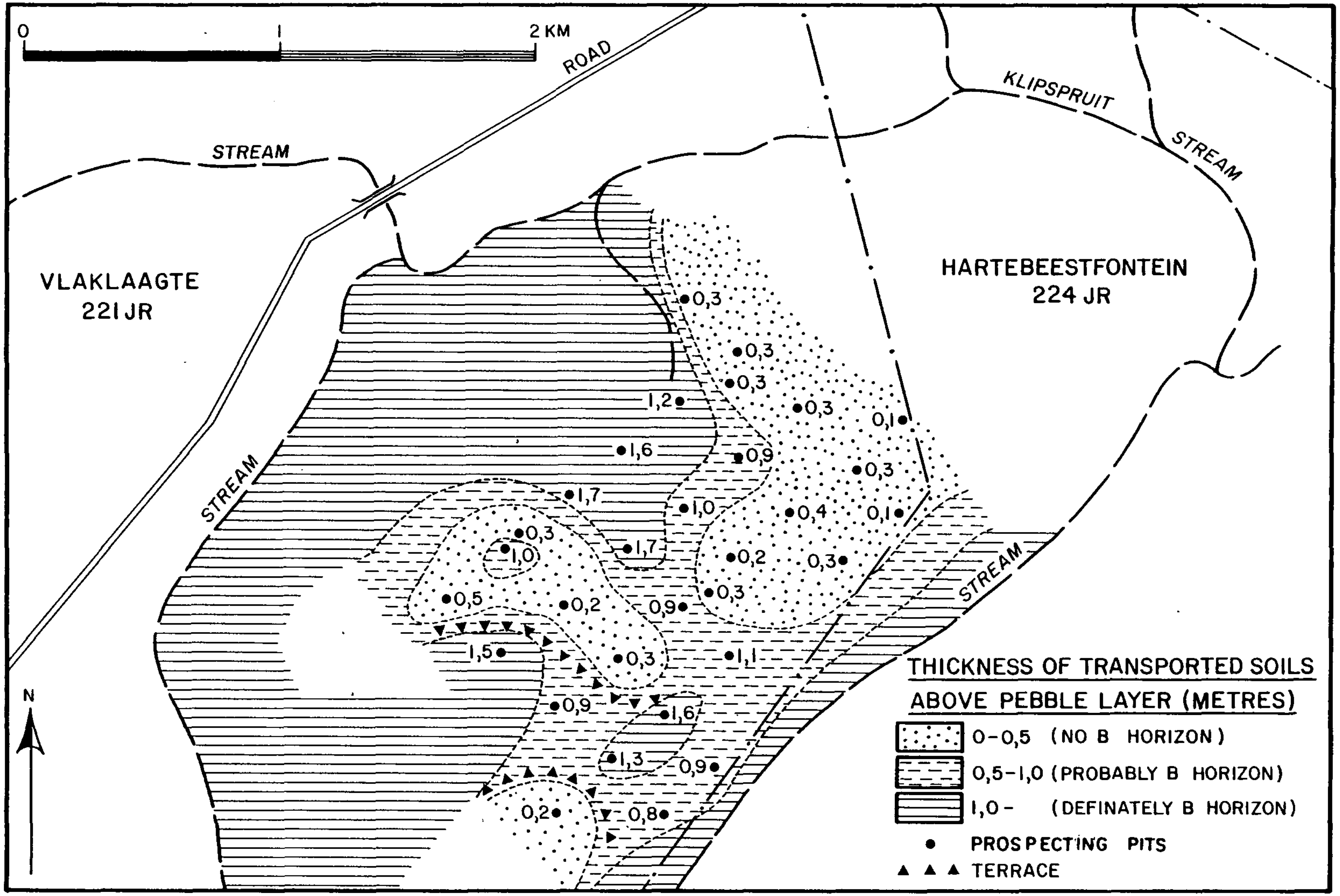


Figure 3-7: The approximate thickness of the transported soils above the pebble layer.

of the bedrock to weathering. Table 3-2, based on field observations, lists the rock types in the study area in order of decreasing susceptibility to weathering.

TABLE 3-2. RELATIVE WEATHERING SUSCEPTIBILITIES OF THE ROCK TYPES IN THE STUDY AREA.

High susceptibility	Grey Makhutso Granite Grey Vlaklaagte granite
Medium susceptibility	Stavoren Granophyre Granite aplite
Low susceptibility	Quartz pegmatite

From this it is concluded that the C horizon is thicker above the Makhutso Granite than above the aplitic granite under the same weathering conditions.

R horizon: This is solid bedrock (parent material) which contributes material to the C horizon.

Pebble layer or rubble zone (P horizon): This horizon consists of quartz pebbles and rubble and marks a palaeo-surface that may have formed through the selective removal and redeposition of material under high energy conditions during a period of unusually high rainfall (Fig. 3-8). James (1957) describes a "stone line" or "pebble zone" in Rhodesian soils and in part accounts for it as a consequence of the activities of termites bringing fine material to the surface with the consequent sinking of larger material. The possibility that the top of the zone could mark the point below which soil creep does not take place is also mentioned.

Brink and Williams (1977) described this zone as a "pebble marker" and regarded it to be the result of gravity and rainwash which may have taken place in the Pleistocene or even in the Tertiary.

Evidence found in the pebble layer on the farm Vlaklaagte 221 JR tends to support the contentions of Brink and Williams (1977).

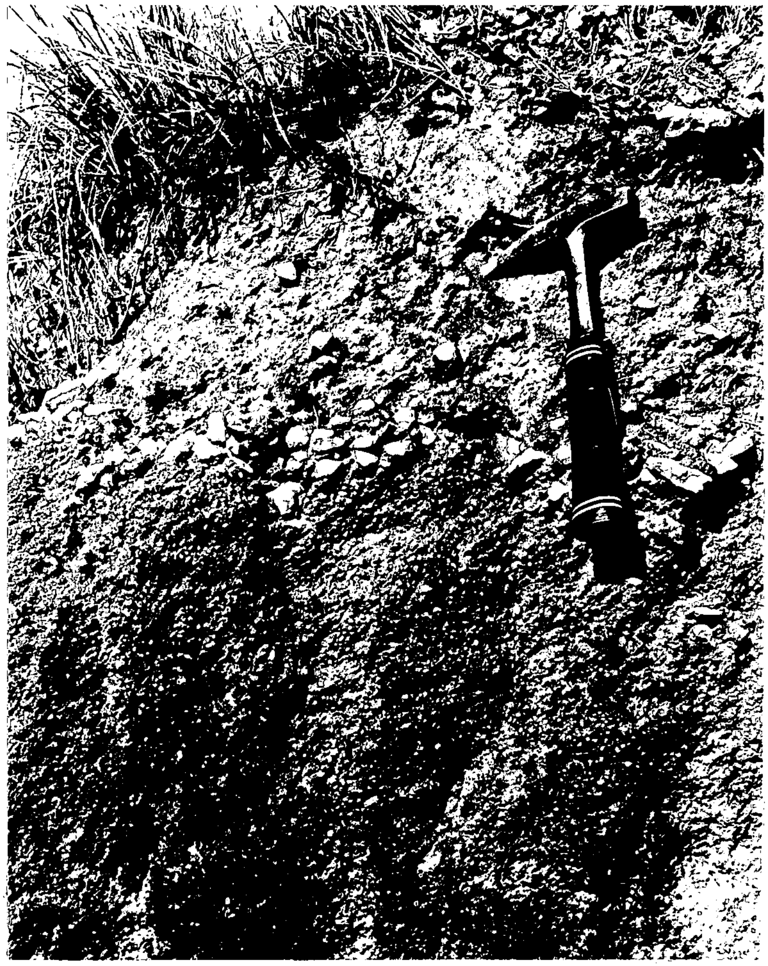


Fig. 3-8: The pebble layer.

These include:-

- The elongated quartz pebbles, specifically those along the slopes, have an orientation which coincides with the present surface run-off direction (Fig. 3-9).
- The quartz pebbles become more rounded down slope, which is an indication of the distance of transportation.
- The size of most of the quartz pebbles (essentially on the ridge) indicates that they originated from quartz pegmatite veins; the latter are found only in some parts of the area.
- Relatively unaltered greisen and quartz veins, observed in some of the pits end at the pebble layer with no sign of a continuation above it. This indicates that that the soils above the pebble layer are not "**in situ**".
- Weakly structured soils which occasionally show grading due to transportation are present above the pebble layer. Below it the granitic structure is preserved.

The pebble layer is particularly well developed on top of the ridge where it occurs as a thin sheet of large angular and subangular quartz pebbles and more resistant rock material. The latter includes boulders of greisen and greisenised granite. The quartz pebbles decrease in size and become more rounded and sorted further down slope, whilst the pebble layer becomes thicker (Fig. 3-9). This indicates that intensive rainwash did take place on top of the ridge and above the resistant aplitic granite.

Due to the fact that the B horizon tends to develop at a fixed depth with the lower limit at about 1.5 m from the surface, the pebble layer may occur at virtually any position in the soil profile, between the A and R horizon (Fig. 3-6).

3.3.2.2 Vlei profiles

These soils are the result of flooding and waterlogging in the shallow valleys. The profiles are built up of different layers of stratified alluvium and it proved impossible to recognise any conventional soil stratigraphy in it.

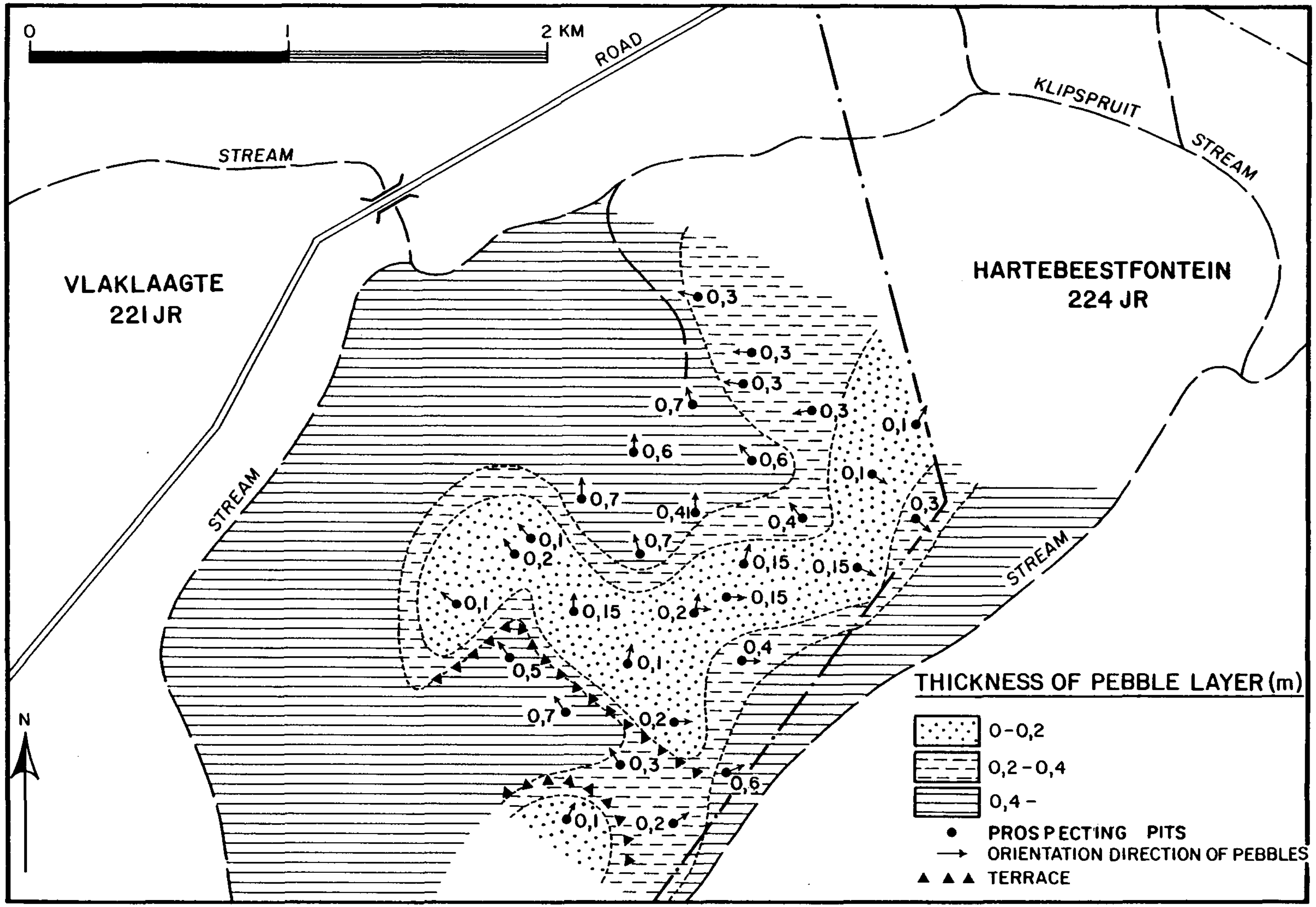


Figure 3-9: Map showing the approximate thickness of the pebble layer.

The vlei profiles are characterised by an organic-rich grey-black horizon. No B horizon was observed due to the fact that the soil profiles are build up of interbedded layers of leached quartz sand and organic rich clay (Appendix A, profile 13).

The interlayering reflects the variation in climatic conditions during the period of soil formation. The quartz sands represent periods of high energy whilst the organic-rich clay layers represent periods of lower energy and sedge vegetation. This could be explained by successive flooding, torrential rains or capturing of the river upstream.

3.3.3 Bedrock material

Although the classification of MacVicar **et al.** (1977) covers diagnostic horizons in unconsolidated material (soils), they make no provision for weathering zones in bedrock material. Fig. 3-10 illustrates typical weathering zones which are referred to as R1, R2, R3 and R4 in the R horizon of profile 6 (Appendix A) on the Vlaklaagte granite. They result from "**in situ**" chemical weathering and represent different stages of the chemical breakdown of the bedrock.

In profile the zones are as follows:

R4 zone:- An inner zone with relatively fresh, unaltered to slightly altered grey Vlaklaagte granite.

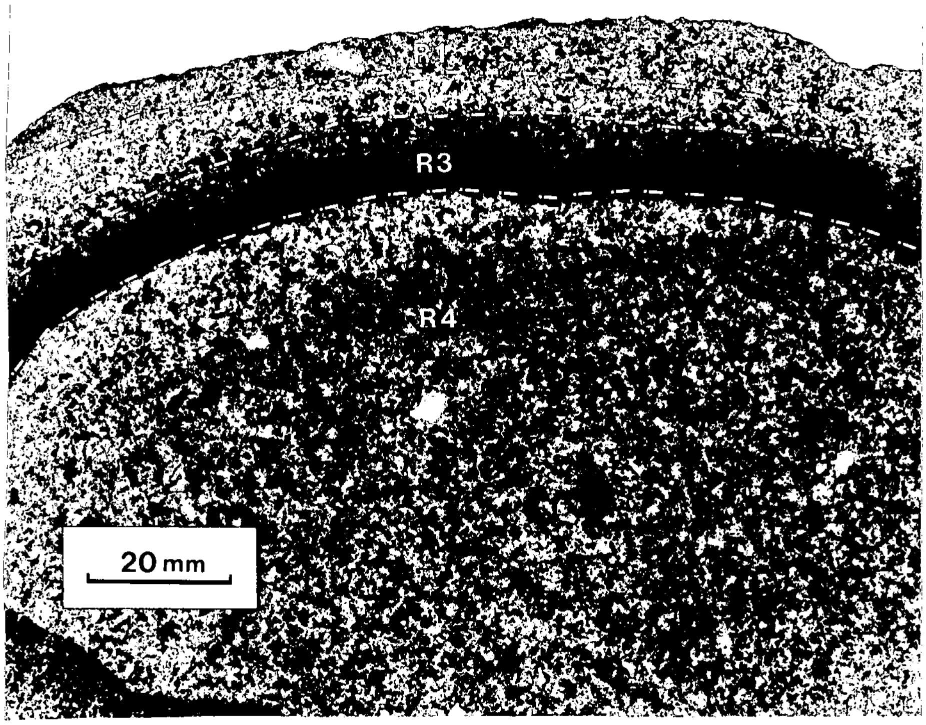
R3 zone:- A red oxidation zone of altered granite.

R2 zone:- A whitish-grey leached (reducing) zone of altered granite.

R1 zone:- A brown zone of highly altered granite.

3.3.4 Genesis of soil profiles

In Fig. 3-11 a generalised schematic soil profile from the top of a ridge down to the valley is presented. It is assumed from the stratigraphic position of the pebble layer, that most of the palaeo-colluvium and residual soils on top of the ridge and upper slopes were redeposited on the lower slopes at the time of formation of the pebble layer. The pebble layer therefore overlies the residual soils or bedrock on the ridge and upper



LEGEND

R1 - Highly weathered zone
R2 - Reduced zone
R3 - Oxidised zone
R4 - Unaltered zone

Fig. 3-10: Weathering zones in the bedrock material.

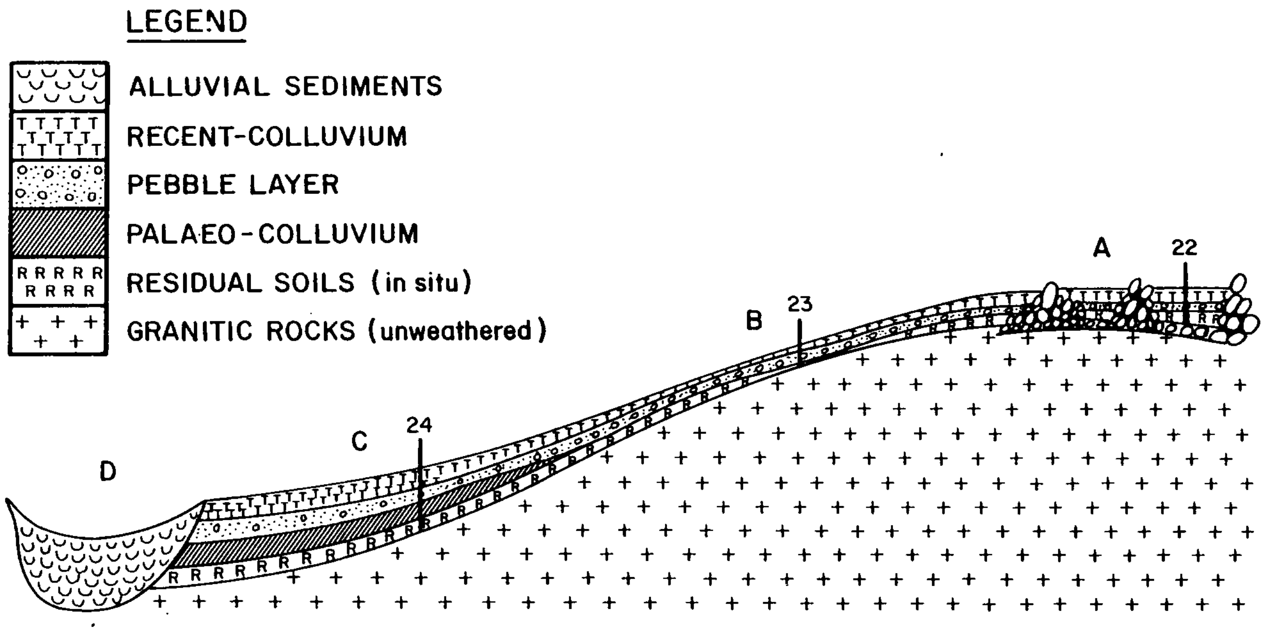


Figure 3-11: A schematic representation showing the succession of soils in the area: (A - upper slope and localised pockets on the crest; B - middle slope; C - foot slope and D - valley floor).

slopes. At the lower foot slopes, material from the higher ground is redeposited on palaeo-colluvium not removed during this high energy period (Appendix A, profile 24).

The transported soils above the pebble layer represent a more recent stage of colluvial deposition. Variations in thicknesses of these transported soils (Fig. 3-7) largely coincide with the variation in thickness of the pebble layer (Fig. 3-9). The pebble layer represents high energy conditions, whilst the recent transported soils represent lower energy conditions.

From the above evidence it is clear that at least three distinct periods of soil profile development existed in the study area. Two drier periods are separated by a period of moderate stripping. It is possible that several periods of stripping occurred since the Lower Pleistocene as portrayed by Vermaak (1984). Following the above processes soil profile development continued in both the remaining palaeo-profiles and the newly formed sediments, thus resulting in superimposed profiles. Fig. 3-12 is a schematic presentation of the proposed sequence of events.

The high-rainfall conditions causing the formation of the pebble layer also caused the development of the typical lateritic profiles still witnessed in the residual soils. Bayliss (1972) and Sherman and Kanehiro (1954) suggest that the mottled and pallid zones usually develop in the upper and lower C horizon respectively, which are evidently not their position in the present profiles. The present profiles are characterised by a lateritic, mottled B horizon and a lower gleyed (pallid) zone. On the foot slopes the mottled and pallid zones are expected to remain in the top part of the C horizon (Fig. 3-12).

The formation of mottled or gleyed zones have resulted from watersaturation in the zone of lateral groundwater movement (i.e. the C horizon) during the Pleistocene or Tertiary. These zones which are typical of high rainfall and oxidising environments then remained as non-diagnostic palaeo-zones in the present soil profiles.

This is the main reason why these mottled and gleyish zones occur in the residual soils directly above or in the upper part

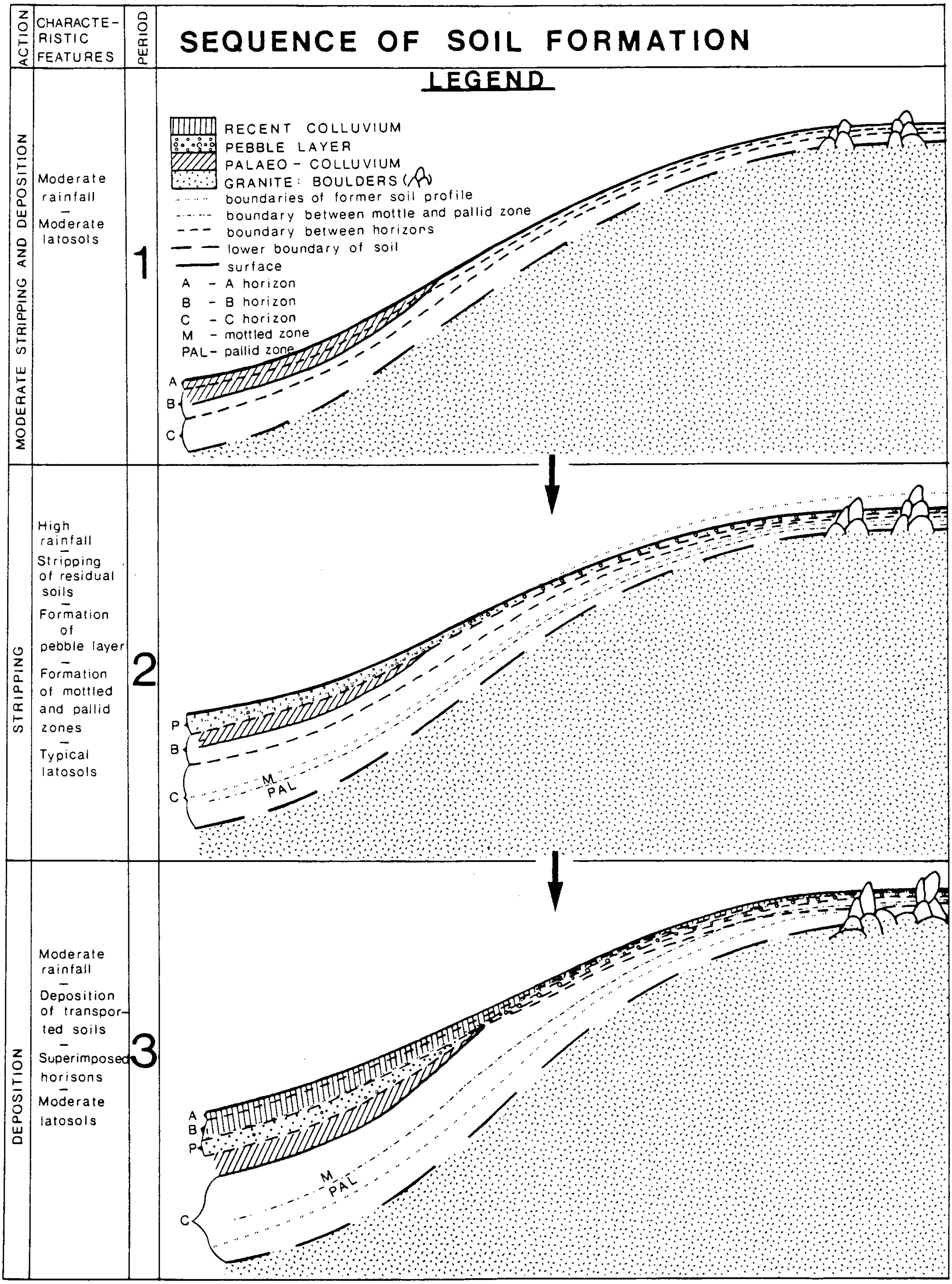


Figure 3-12: A schematic presentation of the proposed sequence of events during soil formation in the area.

of the C horizon and below the pebble layer. In the more recently transported soils above the pebble layer similar zones do not occur and are due to the relatively drier conditions which prevailed in the Holocene. The soils developed during the Pleistocene or Tertiary appear to be typically lateritic.

The Holocene soil profiles in the transported soils are less lateritic due to the lower rainfall and the absence of a fluctuating watertable. These soils can thus be classified as either Shepstone Form or Hutton Form soils (MacVicar **et al.**, 1977). The presence of an A_2 horizon fits the model of the Shepstone Form and when not developed, the model of the Hutton Form soils is applicable.

4. PETROGRAPHY AND MINERALOGY

A study of the petrography and mineralogy of the various rock types in the area is essential as they act as the source for all the secondary material. The rock types studied are the Stavoren Granophyre, Makhutso Granite, Vlaklaagte granite, granite aplite and all the associated alteration products.

The Stavoren Granophyre is typically fine-grained and has a red colour. It consists of turbid grains of orthoclase micrographically intergrown with quartz. Plagioclase (albite-oligoclase) occurs mainly as a colourless phase in microperthite. The ferromagnesian minerals are biotite and hornblende whilst the accessory minerals include zircon, sphene, apatite, fluorite, magnetite, ilmenite and hematite.

The Makhutso Granite is a grey, coarse-grained biotite granite which is porphyritic in places. Altered subhedral orthoclase, quartz (which mainly occupies irregular interspaces), euhedral oligoclase, biotite (anhedral and interstitial) and hornblende are the major constituents. Intergrowths of orthoclase and plagioclase are common whilst micrographic intergrowths between quartz and orthoclase are also present. Myrmekite is often present in minor amounts and saussurite and sericite occur as minor alteration products of the plagioclase and orthoclase respectively. The biotite and hornblende are slightly chloritised. The accessory minerals include muscovite, sphene, zircon (malacon) and opaque minerals such as magnetite, ilmenite, hematite and pyrite which are usually associated with biotite.

The Vlaklaagte granite is a grey fine-grained granite which is porphyritic in places. It is intrusive into the Makhutso Granite and is considered to be the equivalent of the Koornkopje granite (Marlow, 1976). Except for the fine-grained texture and the abundance of biotite and molybdenite, no mineralogical difference exists between it and the Makhutso Granite. Molybdenite is visible in hand specimen and is restricted to more aplitic samples of the granite.

The granite aplite associated with the Vlaklaagte granite, is porphyritic in places and displays a very fine-grained texture.

Euhedral phenocrysts of quartz, oligoclase, orthoclase and biotite are disseminated in an allotriomorphic matrix of the same minerals. Alteration and replacement in the Vlaklaagte granite are observed, which are the result of greisenisation and the formation of quarz-pegmatite veins.

In hand specimen the endo- and exo-greisens reveal a medium- to fine-grained texture with a grey appearance (Fig. 4-1). Disseminated dark minerals (biotite and/or cassiterite) occur in these rock-types. Only isolated grains of cassiterite were found in most of the greisens and pockets of high grade ore are less common. Two examples of telescopic zonation are shown in Fig. 4-2. They include zonation around a massive greisen body (Fig. 4-2a) and zonation resulting from flash greisenisation, due to the sudden opening of fissures, (Fig. 4-2b).

Each telescopic zone has a characteristic mineralogical composition and assemblage of alteration products, which indicate that alteration increases to the inner zones i.e.:-

An outer zone of unaltered Vlaklaagte granite.

A partly greisenised zone (Fig. 4-3a) of fine-grained, partly recrystallised quartz, saussuritised oligoclase, sericitised alkali feldspar and chloritised and/or epidotised biotite. Abundant epidote was recognised in the thin sections. Fluorite and cassiterite fill the veins.

A greisenised zone. A flash greisen (Fig. 4-3b) consisting of subhedral fractured quartz and anhedral topaz which are cemented in a fine-grained matrix of sericite, biotite and chlorite. Fluorite, magnetite, ilmenite, cassiterite and secondary quartz are present as veins and interstitial grains.

The greisen (Fig. 4-3c) consists of euhedral sericite and biotite, subhedral secondary quartz and minor anhedral plagioclase (oligoclase). Fluorite, chlorite, topaz and cassiterite are also abundant whilst gilbertite often occurs depending on the amount of F available. Magnetite, ilmenite and fluorite are often observed filling veins.

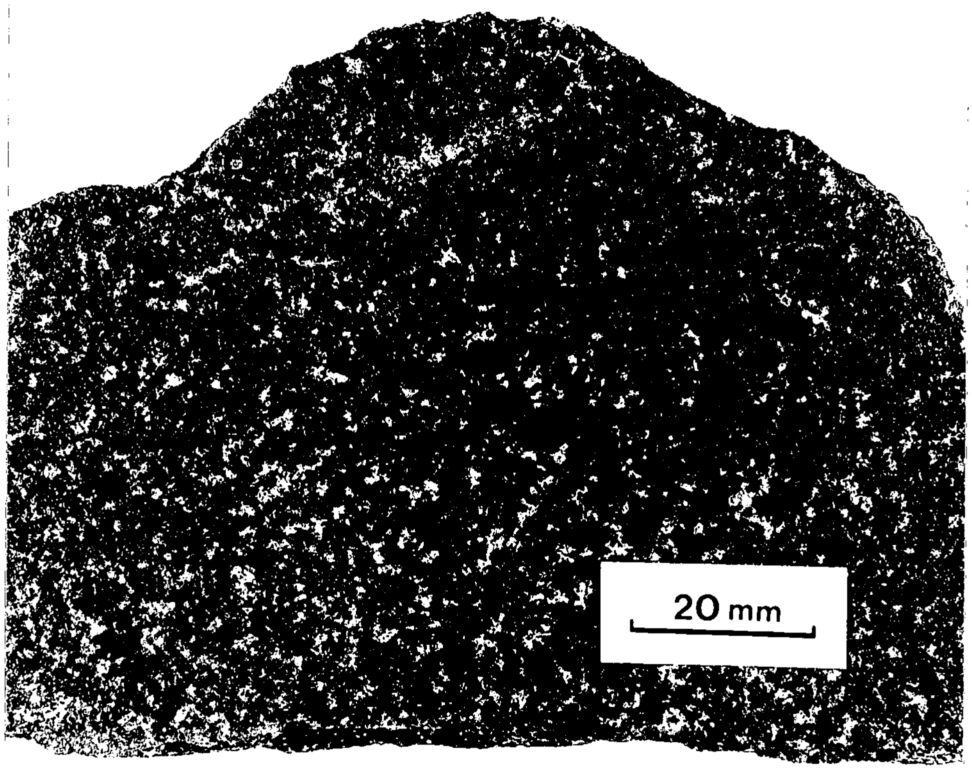
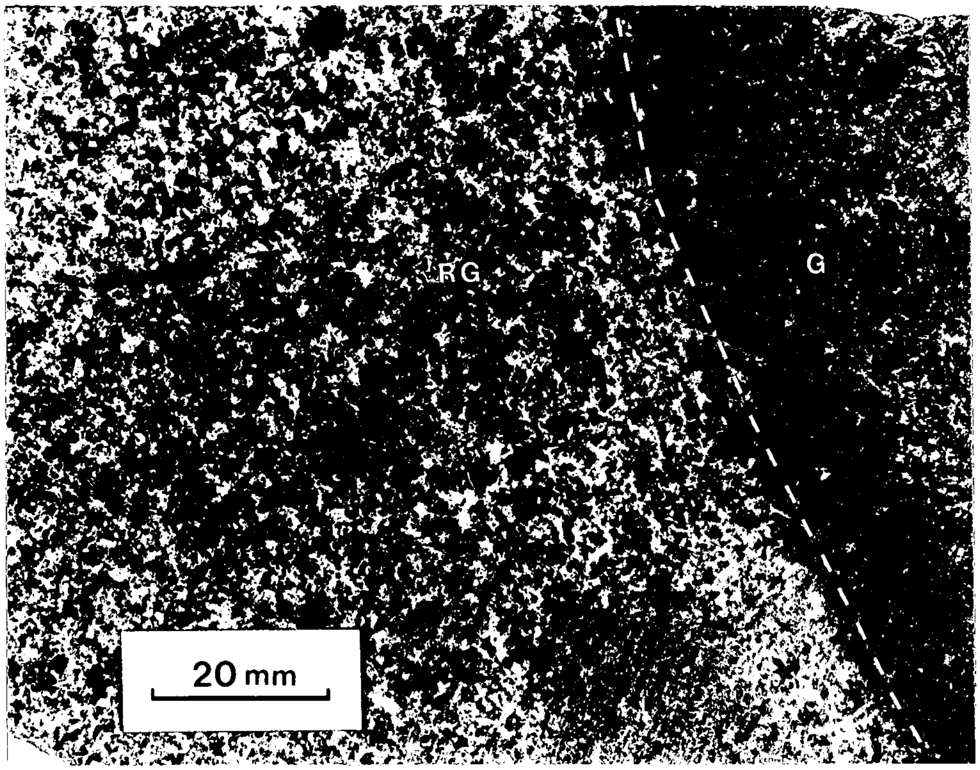
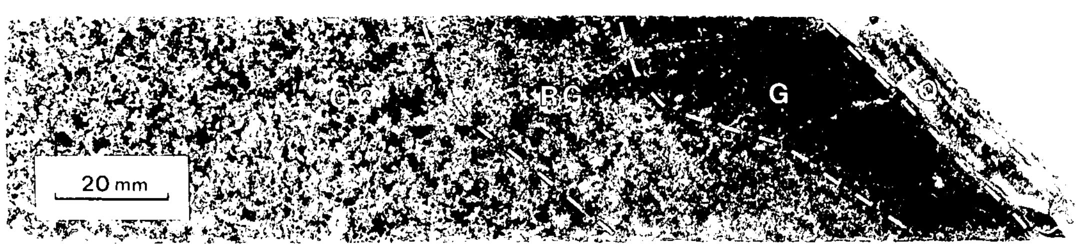


Fig. 4-1: Greisen in handspecimen.



a

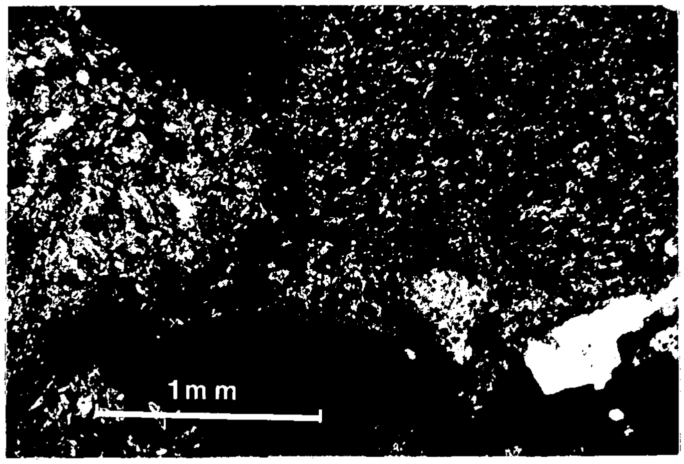


b

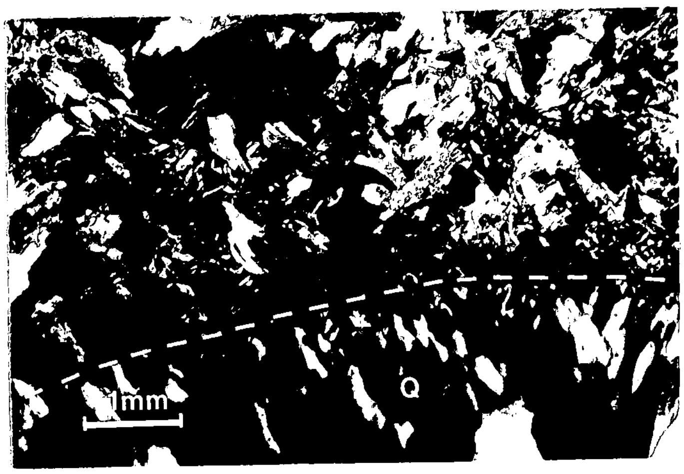
LEGEND

Q - Quartz vein
G - Greisen
RG- Red granite (altered)
GG- Grey granite

Fig. 4-2: Part of the zonation around a massive greisen body in Vlaklaagte granite (a) and zonation of a flash greisen vein in Vlaklaagte granite (b).



a



b

c

Fig. 4-3: Red altered Vlaklaagte granite in thin section (a), flash greisen in contact with a quartz vein (Q) in thin section (b) and greisen in thin section (c).

A monomineral greisen facies (inner zone), not necessarily present in massive greisens. This zone consists of quartz veins with a comb-texture. Crystals of cassiterite were also observed in the veins.

Pegmatitic quartz veins near the contact with the roof rocks (i.e. the Makhutso Granite and Stavoren Granophyre) are associated with flash greisenisation. The quartzitic veins in the outer halo (exo-zone) contain chalcopyrite, bornite, arsenopyrite, minor cassiterite and ferberite. These veins represent the end phase of the greisenisation. The Makhutso Granite in contact with these veins is chloritised containing predominantly chamosite.

The greisens are regarded to be mesothermal (marked by extensive sericitisation) and the sulphide zone as epithermal (marked by chlorite and epidote).

The observed telescopic zones are typical of pneumatolitic-hydrothermal deposits (Park and Macdiarmid, 1975). These zones normally grade into lower temperature zones in the cooler wall rocks. As a result of the temperature gradient that existed chlorite and epidote, which are typical epithermal minerals, are associated with the red altered zone which occurs outside the mesothermal greisen zone.

5 MINERALOGICAL WEATHERING AND DISPERSION PATTERNS IN THE SECONDARY ENVIRONMENT.

The importance of various types of weathering under different temperature and rainfall conditions is stressed by Peltier (1950). According to his classification, the prevailing weathering action in the study area is expected to entail moderate chemical processes. The most common weathering features observed are the zoning of rocks and soils caused by the chemical breakdown and alteration of minerals.

It was shown in Chapter 3 that the weathering products in the study area can be divided into residual and transported materials. The pebble layer, which consists mainly of transported material, has unique mineralogical weathering and dispersion patterns that are discussed separately.

Grain-size is a function of both mechanical and chemical weathering and justifies some discussion in this chapter.

5.1 RESIDUAL MATERIAL

The residual material is subdivided into bedrock material and unconsolidated material on the basis of differences in the density and compaction of the material.

5.1.1 Bedrock material

A study of thin sections of each of the four zones (R1, R2, R3 and R4, Chapter 3.3.3) which consist of bedrock material revealed the following:

R4 zone (Inner zone consisting of fresh to slightly altered grey granite):-

The feldspars range from fresh to slightly altered with dissolution and etching along twin planes and grain boundaries. Oligoclase is more susceptible to weathering than the potash feldspar. The biotite is in places slightly chloritised and the quartz is unaltered.

R3 zone (Red oxidation zone of altered granite):-

The potash feldspar displays a reddish colour and is partly illitised[1].

The plagioclase is almost completely sericitised (De Lapparent, 1909; Millot, 1970) with the subsequent formation of secondary quartz and biotite. Primary biotite is intensively chloritised and hematitised (goethitised) but the quartz is unaltered.

R2 zone (Whitish-grey leached zone of altered granite):-

The plagioclase is almost completely kaolinised (probably metahalloysite) with relicts of sericite in it. The potash feldspar is more sericitised than kaolinised but exsolutions of hematite are absent. The biotite has a light colour and is chloritised with the formation of secondary magnetite and/or ilmenite. Quartz still remains unaltered. This zone is therefore reducing.

R1 zone (Brown zone of completely altered granite):-

The complete decomposition of plagioclase and to a lesser extent K-feldspar and biotite results in the disaggregation of the granite. Illite, kaolinite (probably also metahalloysite) and mixed layered clay minerals are slightly hematitised and/or goethitised and the dissolution of biotite has led to the formation of hematite. Pseudomorphs of orthoclase are still vaquely recognisable but the quartz remains unaltered.

5.1.2 Unconsolidated residual material

Lying directly on the bedrock material is a profile of unconsolidated residual material.

The mineralogical dispersion patterns in the unconsolidated material are complex. This has resulted from the interaction of a number of weathering agents.

The typical soil profile of this material consists of a C horizon and a B horizon with the A horizon conspicuously absent.

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[1]X-ray diffraction peaks were too small to distinguish between poorly crystallised sericite and illite.

C horizon:- The almost complete weathering of plagioclase and to a lesser extent orthoclase and biotite, result in the complete disintegration of the granite. Individual quartz grains still preserve the original granitic texture. The plagioclase is sericitised (illitised), kaolinised (metahaloysite) and hematitised. Most of the potash feldspar is only partly sericitised, illitised and hematitised and even less kaolinised. The leaching of biotite probably resulted in the formation of chlorite. Magnetite, ilmenite, hematite, goethite and zircon are the most common heavy minerals. Cassiterite and topaz are only present in material overlying the more differentiated granites. A mottled and pallid zone is expected in the upper parts of the C horizon on the footslopes. In the latter situation mineralogical dispersion patterns similar to those described for the B_2 and B_3 horizons are applicable.

B_3 horizon:- This horizon is marked by quartz grains which preserve the granitic texture and are embedded in a white clay matrix of predominantly kaolinite with less commonly illite, vermiculite and other mixed-layer clay minerals. The plagioclase is completely altered but less altered biotite and kaolinised K-feldspar grains are still present. The quartz grains are frequently coated with iron oxide. Magnetite, ilmenite and zircon are the most abundant heavy minerals with cassiterite and topaz also present above differentiated granite.

B_2(R) horizon:- The granitic texture is preserved in this horizon and the quartz which is coated with iron oxides is unaltered and present as the dominant mineral. Iron oxides and clay minerals are particularly abundant in this horizon. The unmixing of the clay minerals and the iron oxides sometimes result in a mottled texture. Feldspar and biotite grains are absent and the most common heavy minerals are hematite, goethite, magnetite, ilmenite and zircon. Cassiterite and topaz are only present in mineralised areas.

Microscopic examination of the minerals in the Makhutso Granite, the Vlaklaagte granite and its differentiates, indicates that the stability increases in the sequence plagioclase > biotite > potash feldspar > ilmenite, magnetite, cassiterite, zircon, topaz and quartz. A diagram illustrating the possible pathways of mineral transformation during the weathering sequence established from observations made in thin sections and on mineral grains, is presented in Fig. 5-1.

In the soils studied, sodium plagioclase weathers to sericite and ultimately to kaolinite and iron oxides. De Lapparent (1909) and Millot (1970) also report the formation of potassic and not sodic sericite from sodium rich plagioclase as an intermediate product. Sericite can thus be expected as an intermediate product in the weathering of sodium plagioclase and not saussurite. This may be due to the fact that both Na and Ca are highly mobile and are leached rather than involved in neomineralisation.

According to Sand (1956) and Bates (1952) sodium-rich plagioclase usually alters to halloysite during hydrolysis. Bates (1952) points out that halloysite forms only under water but if it is exposed to a dry atmosphere it dehydrates to metahalloysite which is difficult to distinguish from kaolinite. These soils which form during a wetter period followed by a dry period, could contain kaolinite with minor amounts of metahalloysite.

Biotite is altered to chlorite, chlorite-vermiculite and ultimately to vermiculite and iron oxides (Stephen, 1952). Walker (1949) points out that mica-vermiculite interlayered minerals form initially, but with advanced weathering alter to vermiculite.

Observations on Vlaklaagte indicate that the K-feldspar alters to illite and eventually to kaolinite, thereby suggesting a variation in the rates of hydrolysis and removal. Loughnan (1969) points out that in the alteration (hydrolysis) of potash feldspar, illite is formed if the rate of hydrolysis exceeds the rate of removal, but if the converse is true, kaolinite is expected. Therefore, if potash is retained during hydrolysis, illite and not kaolinite forms as an intermediate residual product.

It is thus evident that in the study area quartz, the kaolinite group clay minerals, vermiculite, iron oxides (goethite and hematite), ilmenite, magnetite, cassiterite, zircon and topaz are the most stable end products in the secondary environment. X-Ray diffraction examination of the fine fraction of typical profiles for the ridge and upper slopes has indeed pointed to

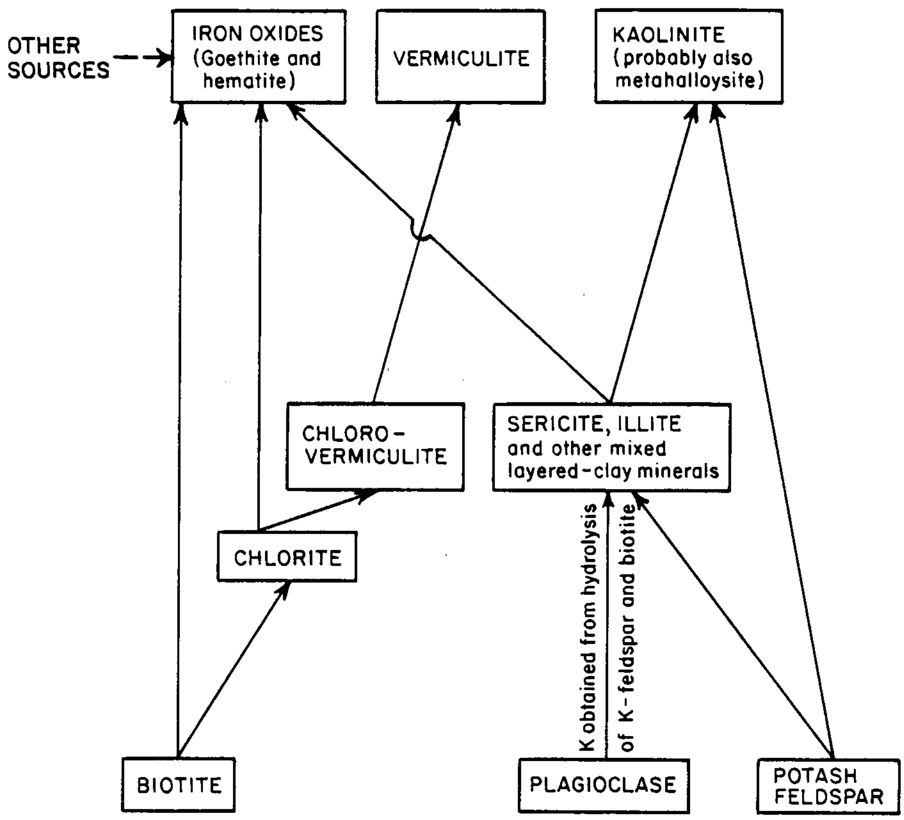


Figure 5-1: Chemical weathering of the rock-forming silicates.

the presence of quartz, kaolinite, illite, goethite, hematite, chlorite and clay mixtures with a basal spacing between 10 and 14 A. The latter are expected to include vermiculite.

The relative concentration of the kaolinite group, illite, chlorite and the iron oxides (goethite plus hematite) in the residual soil profiles, is depicted in Fig. 5-2. From this diagram it is evident that the kaolinite group clay minerals which are the most abundant clay minerals in the B horizon, are enriched in the B_3 horizon. Conversely illite is the dominant clay mineral in the R horizon and its concentration decreases upwards.

Chlorite is almost exclusively present in the R and C horizons and may represent an intermediate stage in the weathering of biotite. The unidentified clay mixtures with basal spacings between 10 and 14 A, which include vermiculite, are enriched in the B_2(R) horizon which represents a highly leached end product. Goethite and hematite are enriched in the B_2(R) horizon. This is due to the oxidation of the Fe^{2+} to the Fe^{3+} state.

A good correspondence is observed between the distribution of iron minerals and kaolinite in the B_3 and B_2(R) horizons and those found by Bayliss (1972) in the lower and higher C horizons of a typical lateritic soil. This indicates that the B_3 and B_2(R) horizons had to form under water-saturated conditions. These mottled and pallid zones are expected to be present in the upper part of the C horison on the foot slopes (Fig. 3-12).

Electron-microscopic examination of the mineral fraction with an S.G. greater than 2,692 confirmed the presence of magnetite, ilmenite, zircon, goethite and hematite. Cassiterite and topaz are only present in soils directly above mineralised granitic rocks. The concentration of heavy minerals increase from the C horizon to the B_2(R) horizon. This is due to the eluvial concentration of the more resistant minerals.

Chemical and physical degradation of the heavy minerals cause their grain size to decrease in the upper horizons. Magnetite, ilmenite and zircon are present throughout the profile in small quantities. Goethite and hematite are enriched in the upper horizons (particularly the B_2(R) horizon). If the parent rock

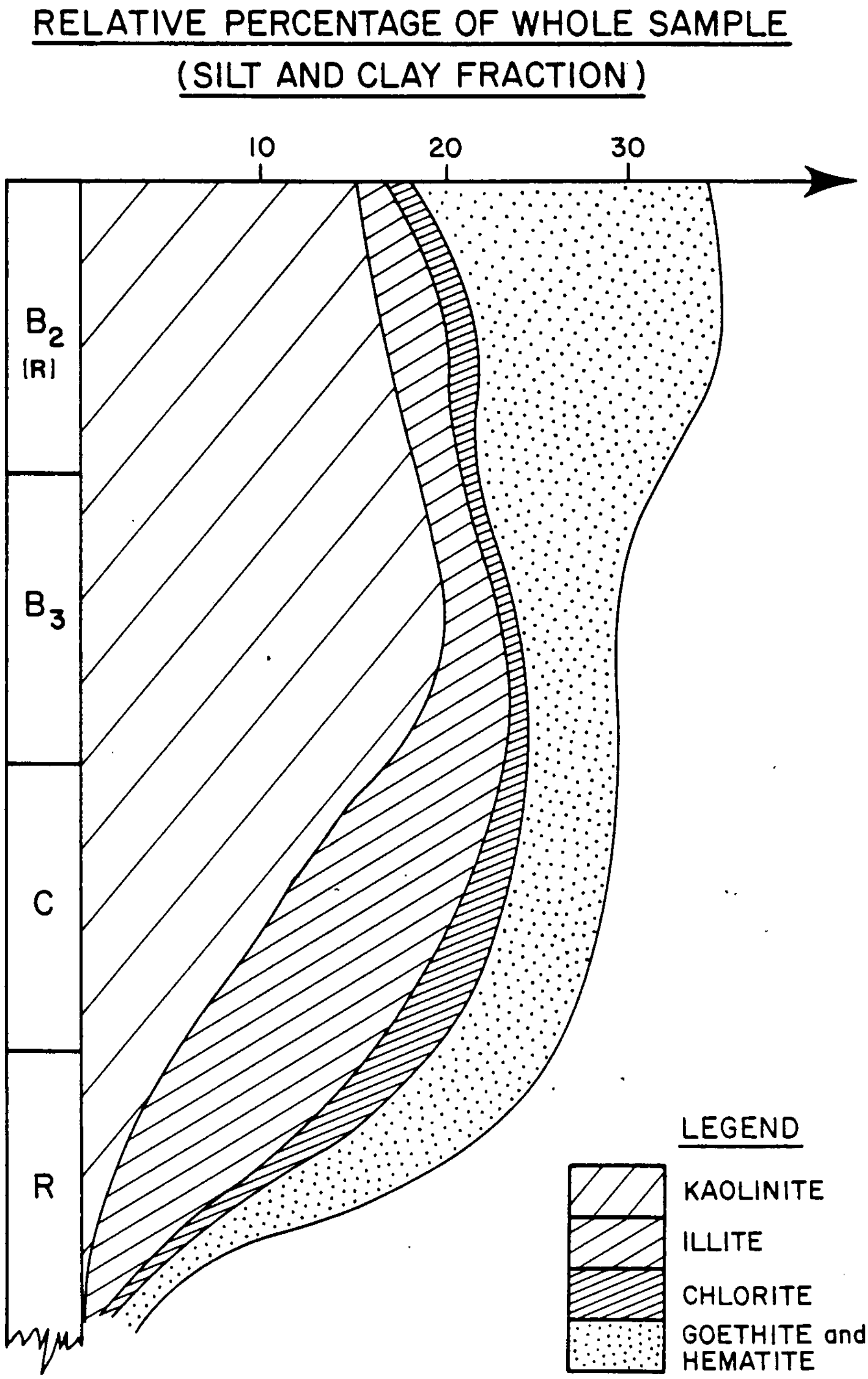


Figure 5-2: Diagram showing variations in the concentrations of clays and Fe-oxides in the silt-clay fraction in the residual soils.

is particularly rich in iron, the C horizon is also extremely rich in hematite. When present cassiterite and topaz are found throughout the whole profile.

5.2 TRANSPORTED SOILS

The extremely complex mineral distribution and weathering patterns in this environment result from the complex interplay of chemical and physical weathering processes. The complexity of these soils does not allow the construction of a single model that fits all the possible mineralogical dispersion patterns. Each layer of transported soil could have had a different source and therefore a different mineral assemblage.

5.2.1 Colluvium (Latosols)

The sedimentary characteristics of the colluvial deposits in the area are almost completely destroyed by the homogenising pedogenetic soil formation processes. The origin of the soil is therefore best reflected by the distribution of the heavy minerals in each layer. Since it is impossible to identify sedimentological units in the colluvium, it is treated as a single profile with diagnostic horizons (A and B) based on mineralogical differences. These horizons formed due to eluviation and illuviation of clay minerals and iron oxides.

Most of the clay minerals are reworked, i.e. leached in the A horizon and redeposited in the B or even lower horizons. The reworking process is both physical and chemical (Millot, 1970); some of the colloidal clay particles are physically washed down from the upper eluviated to the lower illuviated zones. The minerals present in the silt-clay fraction are quartz, kaolinite group minerals, goethite, minor illite, hematite, vermiculite and unidentified mixed-layer clay minerals. Kaolinite predominates and is enriched in the B horizon (particularly the B_2 horizon).

5.2.2 Alluvium (Vlei profiles)

The various layers of stratified alluvium show no evidence of homogenisation. Each layer reflects the energy conditions prevailing during its deposition. The quartzitic sands consist mainly of rounded and subangular quartz with minor resistant minerals such as ilmenite, magnetite, zircon and cassiterite. Kaolinite is the dominant mineral in the organic rich clay bands with less quartz and traces of ilmenite, magnetite, zircon and cassiterite.

5.3 PEBBLE LAYER

The pebble layer is a complex mixture of relict and redeposited transported material. Both relict and redeposited components can be distinguished in the relatively thin pebble layer on the crest and upper slopes, but the latter component is predominant in the thicker layer on the middle and lower slopes.

The layer on the crest and upper slopes consists of large quartz pebbles, rock debris and weathering resistant heavy minerals such as ilmenite, magnetite, hematite, goethite, zircon, cassiterite and topaz, which remained behind during the wash-out processes and are moved over short distances. These pebbles and mineral grains are angular to subangular with almost no sign of transportation.

The layer on the middle and lower slopes consists of a mixture of smaller redeposited, rounded and subangular quartz pebbles and grains, goethite pellets, clays and weathering resistant heavy minerals. All these materials originated some distance away and were redeposited with decreasing energy conditions.

In the pebble layer on the crest and upper slopes the redeposited material mainly fills the gaps between the coarser relict material. This is a result of the redeposition of material during the decrease in the energy conditions that followed a period of high energy.

On the middle and lower slopes, where the pebble layer mainly consists of transported material, grading of the material has taken place in some of the profiles (Appendix A, profiles 16 and 17). This grading is due to a decrease in the energy conditions which prevailed during the formation of the pebble layer.

5.4 GRAIN-SIZE DISTRIBUTION IN THE LATOSOL PROFILE

Grain-size distribution proved to be a means of distinguishing between transported and residual soils. It is also useful in determining the source, sand grade and texture of the soil (MacVicar **et al.**, 1977). The size fractions used in this study are the >2 mm fraction (gravel), the .425 - 2 mm fraction (coarse sand), the .180 - .425 mm fraction (medium sand), the .075 - .180 mm fraction (fine sand) and the <.075 mm fraction (silt plus clay).

The grain-size distribution in typical soil profiles from the area is illustrated in Fig. 5-3a and b. These figures illustrate the grain-size distribution in typical soils above the Vlaklaagte granite and Makhutso Granite respectively.

It is evident from the diagrams that the gravel-sized fraction in the residual soils overlying the Makhutso Granite exceeds the coarse sand fraction whilst the reverse is true for residual soils overlying the Vlaklaagte granite. In transported soils the weight percentage of the gravel fraction always drops to below that of the coarse and medium sand fractions depending on the source of the material and the distance of transportation. The dominant fraction in the residual soils usually yields a finer fraction when transported and becomes finer as the distance increases. As a result of this the coarse and medium sand fractions tend to be dominant in the transported soils originating from the Makhutso Granite and Vlaklaagte granite respectively.

The pebble layer is marked by a dominant gravel fraction and depleted coarse and medium sand fractions (Fig. 5-3a and b). The weight percentages of the fine sand and silt-clay fractions are very low in both transported and residual soils with a slight increase in the B horizons (mainly due to the accumulation of clay minerals in these horizons).

It is possible to distinguish between the residual soil, pebble layer and transported soils by plotting the average weight percentages for the gravel, coarse sand and medium sand fractions on a triangular diagram (Fig. 5-4). The soils derived from the Vlaklaagte granite (finer-grained) and the Makhutso Granite (coarser-grained) can also be distinguished on this diagram.

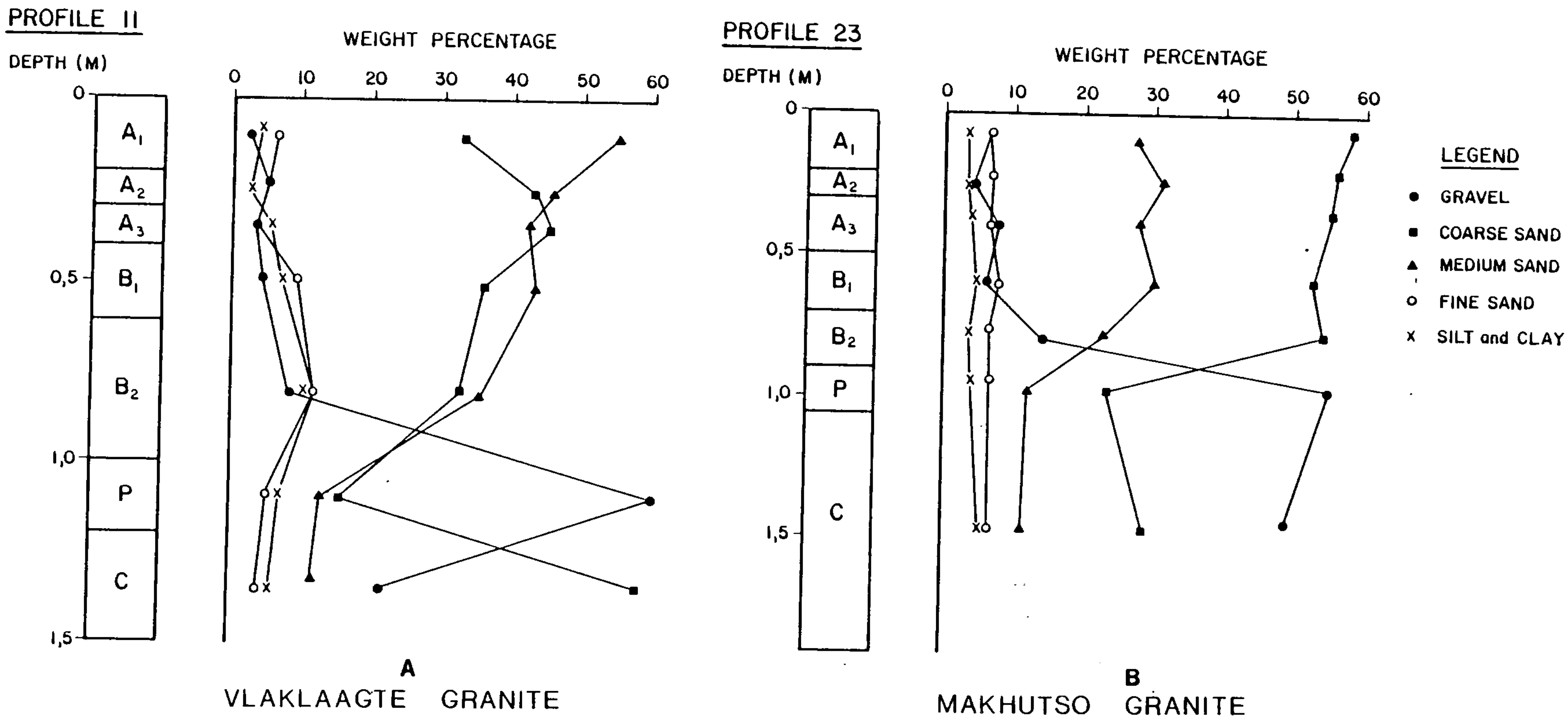
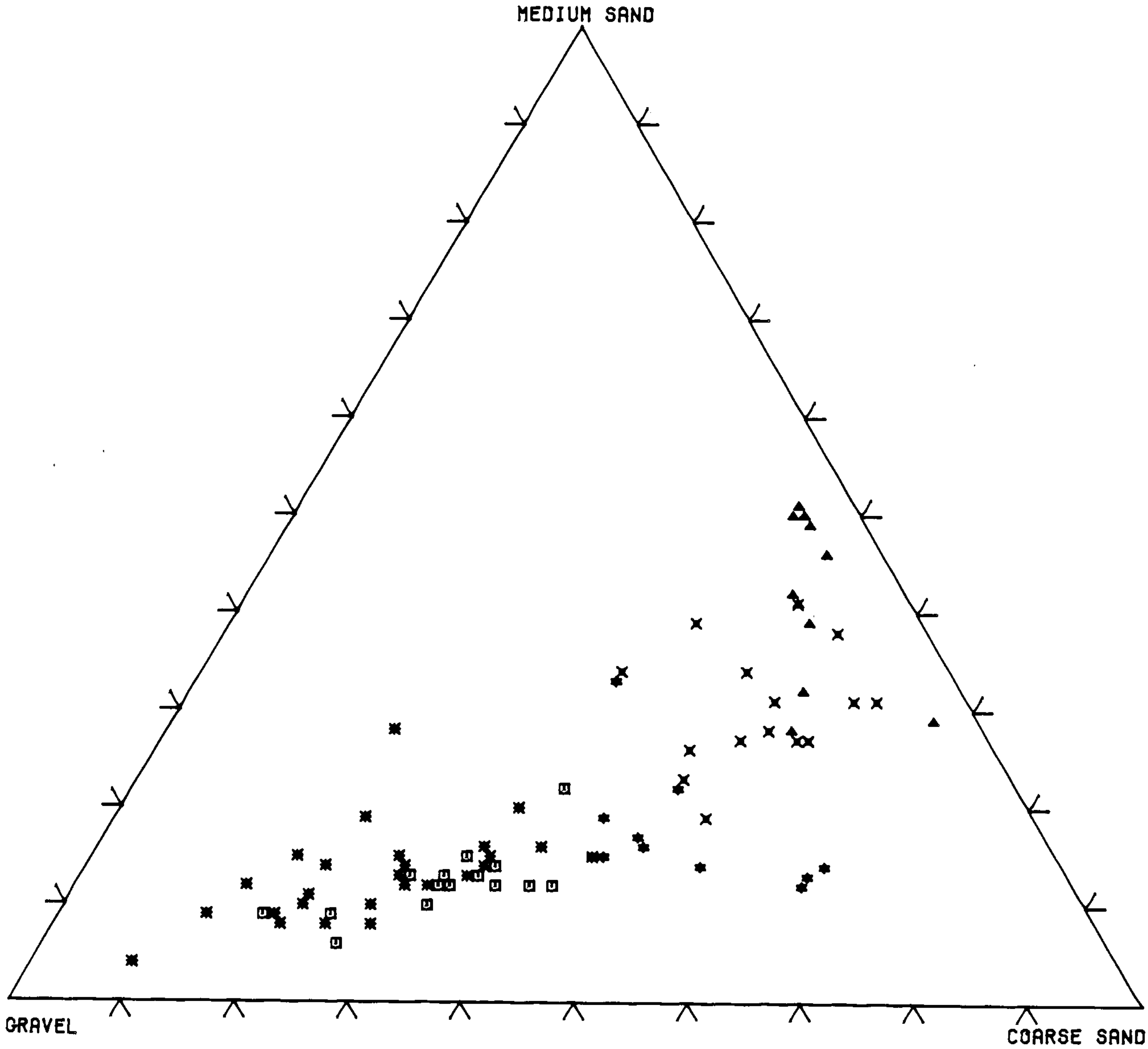


Figure 5-3: Grain-size distribution in A) a soil profile in the Vlaklaagte granite and B) a soil profile in the Makhutso Granite.



LEGEND

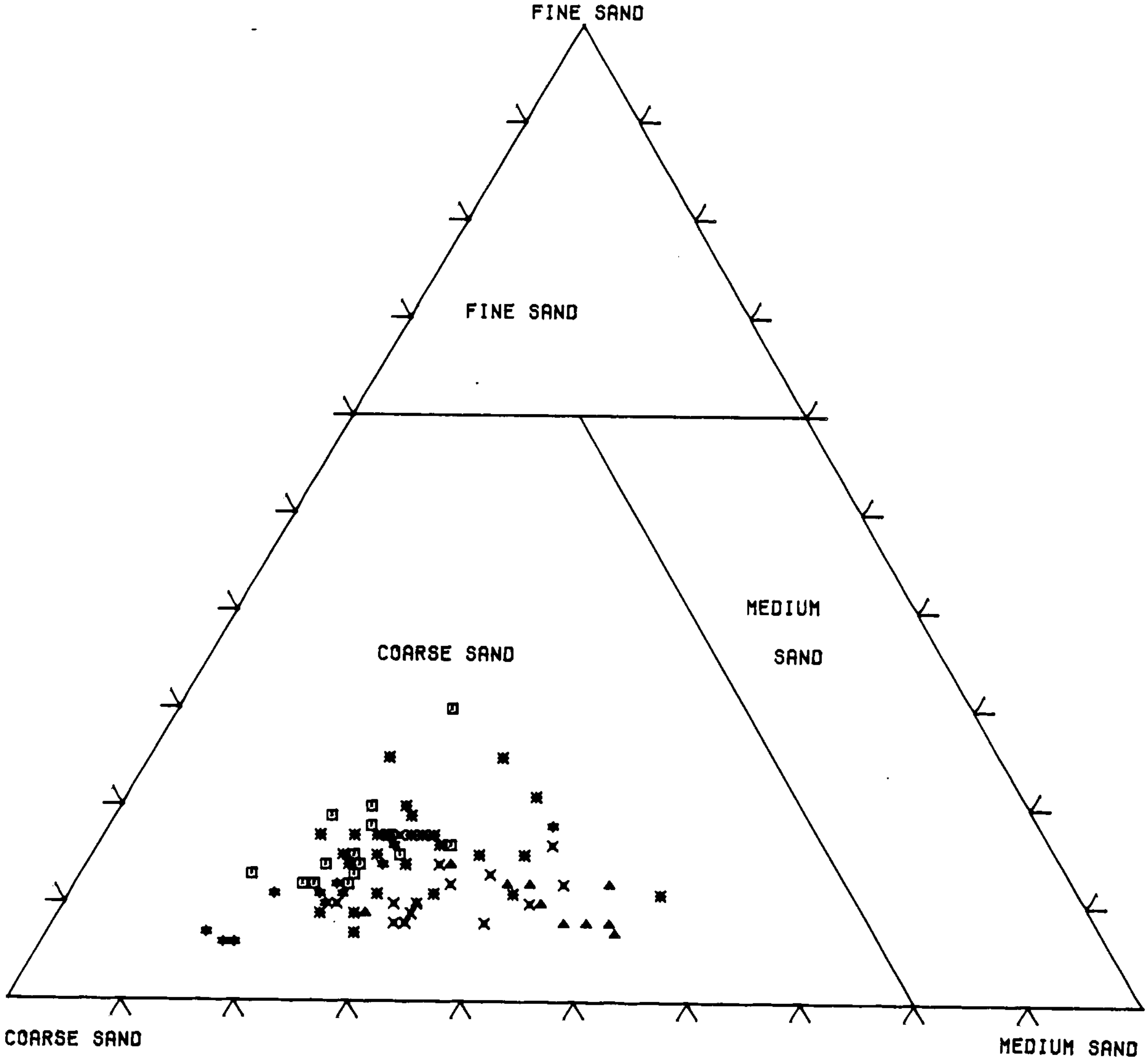
Residual soil (Makhutso Granite)	- ◻
Residual soil (Vlaklaagte granite)	- ✱
Pebble layer	- ✳
Transported soil (Vlaklaagte granite)	- ▲
Transported soil (Makhutso Granite)	- ✕

Figure 5-4: Diagram showing the predominant grain-size distribution patterns in different soil-types overlying the granites.

The above diagram can thus be used to determine whether a residual soil overlies the Makhutso or Vlaklaagte granite. For the determination of the possible source of transported soils this diagram is unreliable due to factors such as grading and the distance of transportation. It furthermore makes it possible to distinguish between residual and transported soils, even when the pebble layer is absent. The grain-size distribution will, however, be different for different source rock-types.

A sand grade chart (Fig. 5-5) indicates the sand grade of the soils to be coarse whilst the texture is loamy sand to sand (Fig. 5-6).

The mineral distribution in the soil fractions ranges from almost only quartz in the gravel and coarse sand fractions to dominantly clay minerals (mainly kaolinite) in the silt-clay fraction. The type of clay mineral depends on the horizon in which it occurs. Flake-shaped secondary minerals such as sericite and illite are concentrated in the sand fractions and in particular in the medium and fine fractions.



LEGEND

Residual soil (Makhutso Granite) - ⊡
Residual soil (Vlaklaagte granite) - ✱
Pebble layer - ✳
Transported soil (Vlaklaagte granite) - ▲
Transported soil (Makhutso Granite) - ✕

Figure 5-5: Sand grade chart (after MacVicar **et al.**, 1977). Values are expressed as percentages of the total sand fraction.

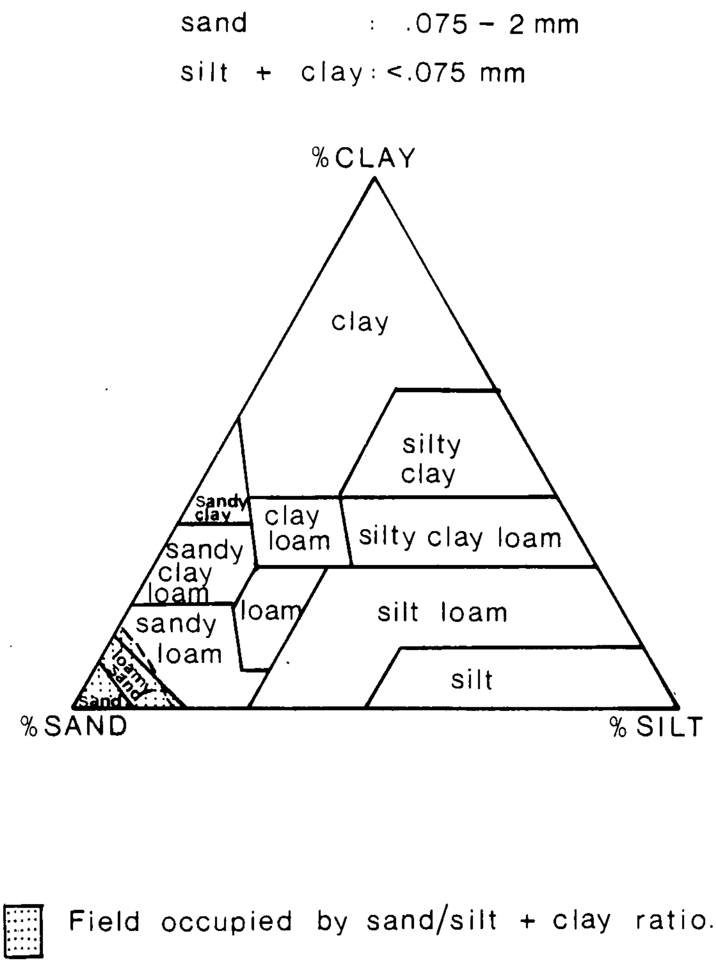


Figure 5-6: Texture chart (after MacVicar **et al.**, 1977). The weight percentages of the sand fraction are plotted against the total weight percentages of the silt plus clay fraction.

6. GEOCHEMISTRY OF THE ROCK-TYPES

The major and trace element data of the 28 rock samples which were analysed, are presented in Appendix B. Four composite quartz-pegmatite samples and one sample of chloritised Makhutso Granite were also analysed for trace elements.

The major and trace element compositions of the principal rock types distinguished in the study area are shown in Table 6-1.

6.1 MAJOR ELEMENTS

Figs. 6-1a and b show the major element data normalised against the Makhutso Granite. Since the Vlaklaagte granite and the granite aplite may be late-stage differentiates of the Makhutso Granite, Fig. 6-1a is used to estimate relative enrichments and depletions in this pre-pegmatitic phases.

In Fig. 6-1b the altered Makhutso Granite and its greisen which formed as a result of metasomatic alteration in the exogenetic zone, are compared with the Makhutso Granite. The alteration products of the Vlaklaagte granite are also compared with the Makhutso Granite in this figure. In Fig. 6-1c the red Vlaklaagte granite and its greisen, which are products of metasomatic alteration in the endogenetic zone, are compared with the Vlaklaagte granite.

SiO_2

The concentration of SiO_2 remains relatively constant in the sequence Makhutso Granite, Vlaklaagte granite and granite aplite. In the alteration products of both granites no appreciable change was observed either, but SiO_2 is depleted in the greisens, especially those associated with the Vlaklaagte granite.

It is possible that the removal of SiO_2 during the greisenisation process contributed to the formation of the quartz pegmatite veins (associated with the greisens) as the last crystallising stage.

TABLE 6-1: MEANS AND STANDARD DEVIATIONS OF THE MAJOR AND TRACE ELEMENT CONCENTRATIONS.

ROCK TYPE	A		B		C		D		E		F		G		H		I		J		K	
ELEMENT	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
SiO_2	76.62	2.35	76.14	0.99	77.49	0.20	72.60	-	73.89	0.69	74.50	0.71	75.48	1.54	62.76	7.57						
TiO_2	0.23	0.01	0.17	0.01	0.10	0.00	0.20	-	0.21	0.01	0.21	0.01	0.13	0.07	0.07	0.05						
Al_2O_3	10.97	0.04	11.77	0.50	11.09	0.41	12.23	-	12.35	0.24	11.94	0.35	11.83	0.66	20.87	5.17						
Fe_2O_3	2.26	0.02	0.43	0.07	0.68	0.33	1.53	-	0.62	0.29	0.40	0.05	1.74	1.00	2.43	0.61						
FeO	1.28	0.10	0.65	0.05	1.22	0.06	5.48	-	1.93	0.31	2.18	0.09	0.80	0.53	2.14	0.33						
MnO	0.02	0.01	0.01	0.01	0.03	0.02	0.02	-	0.01	0.00	0.02	0.00	0.01	0.01	0.01	0.00						
MgO	0.01	0.00	0.12	0.05	0.05	0.05	0.15	-	0.16	0.05	0.13	0.03	0.11	0.06	0.24	0.12						
CaO	0.59	0.69	0.94	0.11	0.32	0.09	0.06	-	0.90	0.15	0.83	0.03	0.28	0.30	0.02	0.00						
Na_2O	3.47	0.07	3.64	0.31	2.74	0.02	0.01	-	3.36	0.25	3.20	0.06	1.32	1.28	0.01	0.00						
K_2O	4.01	2.06	5.26	0.16	5.17	0.19	5.43	-	5.40	0.17	5.42	0.22	6.77	0.97	7.90	1.11						
P_2O_5	0.01	0.00	0.03	0.01	0.01	0.00	0.01	-	0.06	0.09	0.02	0.01	0.22	0.01	0.01	0.00						
Cr_2O_3	0.01	0.00	0.01	0.01	0.02	0.01	0.01	-	0.01	0.00	0.02	0.01	0.01	0.00	0.01	0.00						
H_2O^+	0.40	0.04	0.37	0.02	0.65	0.05	1.85	-	0.74	0.10	0.76	0.08	0.97	0.26	2.82	C.55						
H_2O^-	0.13	0.04	0.20	0.03	0.13	0.01	0.06	-	0.10	0.03	0.12	0.01	0.15	0.07	0.06	0.02						
Li	8.5	9.2	8.3	1.5	8.5	0.7	36	-	29.6	5.3	22.0	1.4	12.6	5.9	32.75	9.21						
Be	2.0	0.0	6.0	0.0	7.5	0.7	10	-	6.5	1.5	8.0	0.0	5.8	2.3	153.5	151.73						
B	ND	ND	16.3	7.6	16.5	19.0	20	-	48.0	18.1	3.0	0.0	73.0	30.1	45.25	40.95						
F	940.0	155.5	320.0	85.4	1265.0	374.4	1090	-	1310.0	255.4	1440.0	127.2	1068.3	634.5	3912.50	1445.32						
V	5.0	0.0	5.0	0.0	6.6	0.6	10	-	5.0	0.0	5.4	0.8	5.0	0.0	22.25	2.22	10.7	7.78	39.0	19.90	5	-
CO	5.0	0.0	5.0	0.0	5.0	0.0	7	-	5.0	0.0	5.0	0.0	5.0	0.0	11.25	3.77	5.0	0.0	49.0	33.94	28.0	-
Ni	11.0	8.5	7.0	3.5	7.5	3.5	28	-	10.1	4.4	12.0	7.1	9.2	3.2	26.00	7.40	5.0	0.0	53.0	25.46	28.0	-
Cu	5.0	0.0	5.0	0.0	251.5	16.3	90	-	23.9	35.9	23.0	25.5	162.7	151.3	12.75	15.50	6.5	2.12	1270.0	410.12	147.0	-
Zn	71.5	64.3	5.0	0.0	164.0	49.5	188	-	6.3	2.2	5.5	0.7	53.7	78.9	9.25	5.31	5.0	0.0	150.0	141.42	1592.0	-
Rb	240.0	15.6	265.7	5.5	344.5	26.2	1179	-	451.0	22.3	466.5	33.2	609.2	130.2	1490.75	566.02	176.5	10.6	201.0	77.78	226.0	-
Sr	59.5	2.1	72.3	1.2	40.5	3.5	31	-	92.1	4.1	58.0	4.2	40.8	28.9	21.75	4.99	24.5	2.12	8.0	4.24	5.0	-
Y	114.5	12.0	119.6	10.8	79.0	5.7	59	-	91.0	27.6	117.0	4.2	101.3	24.9	89.00	26.80	27.5	3.53	15.0	14.14	34.0	-
Zr	509.0	24.0	231.0	8.7	160.0	0.0	240	-	255.9	7.0	327.5	7.8	210.0	45.7	166.50	35.69	38.0	4.24	5.0	0.0	135.0	-
Nb	17.5	0.7	21.7	0.6	21.0	0.0	21	-	22.6	1.3	29.0	1.4	26.2	5.1	15.25	12.18	7.0	2.82	5.5	0.5	19.0	-
Mo	5.0	0.0	5.0	0.0	5.0	0.0	5	-	33.3	48.5	56.5	16.3	22.7	41.3	5.00	0.00	35.0	10.00	5.0	0.0	5	-
Ba	1120.0	63.6	587.0	22.9	394.5	88.4	347	-	503.7	11.2	342.0	84.9	432.0	89.9	282.00	52.90	141.5	14.84	652.5	569.22	33.0	-
Sn	8.5	4.9	18.7	11.8	24.0	7.1	260	-	25.7	8.9	42.5	6.4	52.3	39.4	1006.00	872.19	375.5	118.08	37.5	21.92	20.0	-
W	5.0	0.0	5.0	0.0	18.5	13.4	19	-	5.0	0.0	5.0	0.0	14.8	11.2	5.00	0.00	5.0	0.0	75.0	7.07	21.0	-
Pb	25.0	5.7	27.7	4.0	54.0	0.0	37	-	27.1	2.5	30.5	0.7	56.8	27.5	30.75	11.61	31.0	0.0	150.0	141.42	155.0	-
Th	28.5	2.1	37.7	6.0	45.5	2.1	45	-	29.1	3.2	76.0	2.8	39.7	8.7	45.00	10.30	9.0	2.82	619.5	2.12	43.0	-
U	8.5	2.1	9.3	3.2	13.5	0.7	16	-	12.3	3.7	18.0	4.2	19.2	8.2	10.00	4.69	7.0	2.82	10.5	7.78	18.0	-

LEGEND

A - Stavoren Granophyre
B - Grey Makhutso Granite
C - Red Makhutso Granite
D - Greisen from Makhutso Granite
E - Grey Vlaklaagte granite
F - Granite aplite
G - Red Vlaklaagte granite
H - Greisen from Vlaklaagte granite
I - Quartz-pegmatite veins associated with greisens
J - Quartz-pegmatite veins from sulphide rich zone
K - Epithermal altered Makhutso Granite in sulphide rich zone.

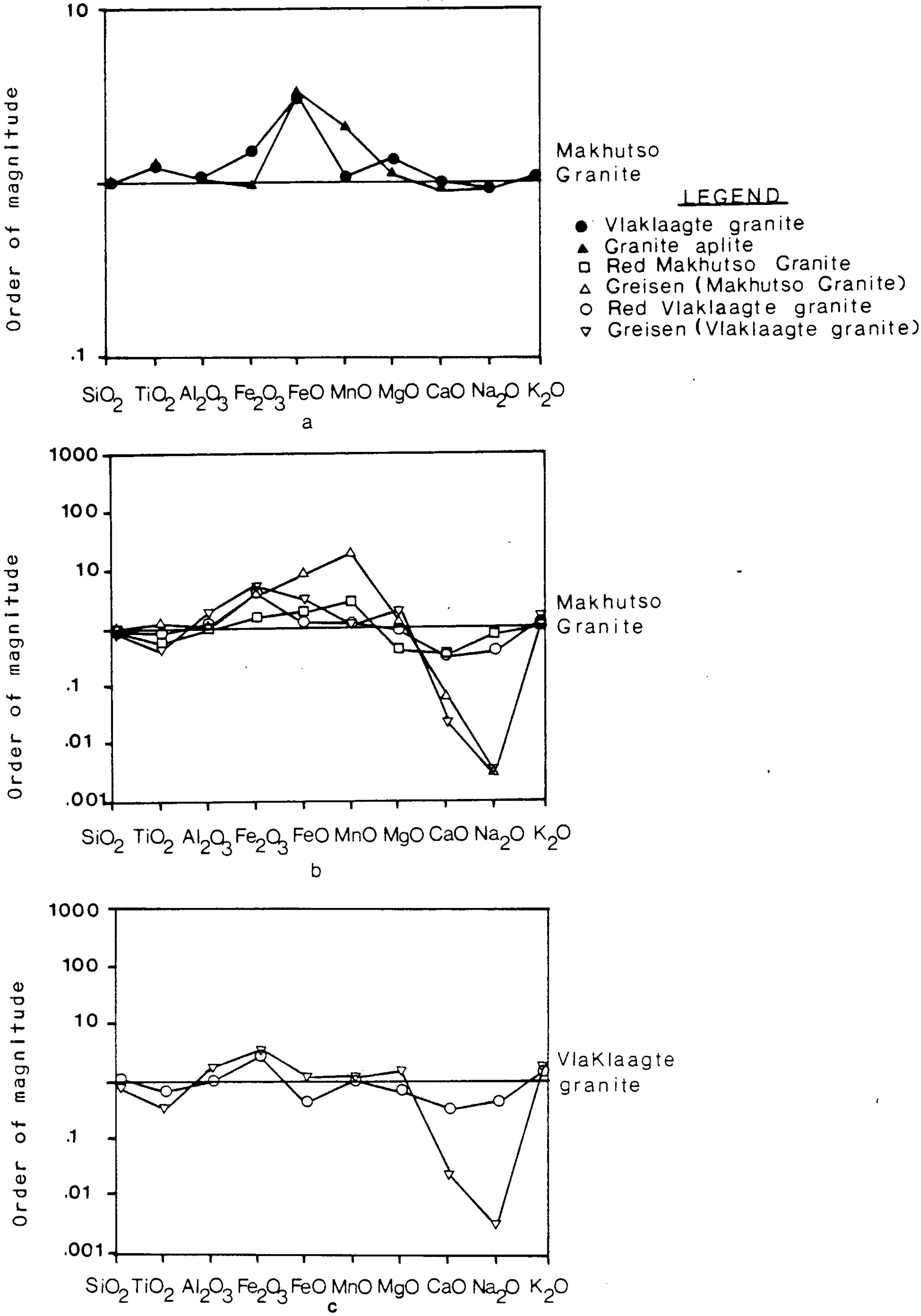


Figure 6-1: Major element compositions of the Vlaklaagte granite and granite aplite normalised against the Makhutso Granite (a), greisen and red granite normalised against the Makhutso Granite (b) and greisen and red granite normalised against the Vlaklaagte granite (c).

TiO_2

An increase of TiO_2 in the Vlaklaagte granite and granite aplite relative to the Makhutso Granite is observed. The gas-liquid phase that caused the greisenisation, however, reduced the TiO_2 in the immediate surrounding wall rocks. This is proved by the fact that the altered Makhutso and Vlaklaagte granite as well as the greisen from the Vlaklaagte granite are all depleted in TiO_2 compared to their respective wall rocks.

Al_2O_3

The concentration of Al_2O_3 remains the same in the Makhutso and Vlaklaagte granite and the granite aplite. In the metasomatic products Al_2O_3 is only enriched in the endo-greisens. Phyllosilicates along with topaz are the most important aluminium bearing minerals in the greisens.

Fe_2O_3 and FeO

Progressive Fe-enrichment was observed in the sequence Makhutso Granite, Vlaklaagte granite and granite aplite. The Fe_2O_3 to FeO ratio is higher in the Vlaklaagte granite than in the granite aplite. This probably reflects the drier magma from which the aplite crystallised. The greisens also reflect strong iron enrichment. In Fig. 6-1b it will be noted that the ratio of Fe_2O_3 to FeO is higher in the endo- than in the exo-intrusional zone. The higher ratio is also observed when comparing the alteration products of the endo-genetic zone with the Vlaklaagte granite (Fig. 6-1c). This suggests that a greater degree of oxidation prevailed in the endo- than in the exo-genetic zone.

MnO

In the pre-pegmatitic phases, MnO is enriched in the granite aplite only. This enrichment is probably a result of the disequilibrium caused by the separation of the gas-liquid phase from the solid phase. The excess Mn^{2+} (0.91A) that remains in the solid phase after the gas-liquid phase was separated, probably replaced either the Ca^{2+} (1.06A) or the Mg^{2+} (0.78A) in the silicates as described by Goldschmidt (1954).

In the altered zones MnO is enriched only in the exo-intrusional zone (red Makhutso granite and the associated greisen). The Mn^{2+} in the gas-liquid phase thus only took part in the late stages of metasomatism in the exogenetic zone.

MgO

The MgO content first increases from the Makhutso to the Vlaklaagte granite and then decreases in the granite aplite. In the zones of metasomatic alteration the greisens are slightly enriched in MgO and the red altered granitic zones depleted in MgO. The depletion of MgO in the red altered granitic zones can be attributed to its leaching from biotites in this zone.

CaO and Na_2O

The Na_2O and CaO decrease in concentration in the sequence Makhutso Granite, Vlaklaagte granite and granite aplite. During the greisenisation process the CaO and Na_2O are removed from the metasomatic products with a maximum depletion in the greisens.

K_2O

A slight increase in the K_2O content is detected in the sequence Makhutso Granite, Vlaklaagte granite and granite aplite. Both the greisens and red altered granites are slightly enriched in K_2O compared to the wall rocks.

6.1.1 Discussion

To accomodate the differences in the elemental behaviour in the pre-pegmatitic (fractional crystallisation) and the pegmatitic stages (metasomatism), the behaviour of the elements are discussed separately for each.

According to Thornton and Tuttle (1960), Wedepohl (1978) and Rankama and Sahama (1950), SiO_2, MnO and K_2O increase as the differentiation index (pre-pegmatitic) increases. Although MnO and K_2O follow this pattern, SiO_2 remains the same in the sequence under consideration. It is possible that some silica may be incorporated into the gas-liquid phase during crystallisation and that it ultimately caused the quartz-pegmatite veins to form.

Thornton and Tuttle, (1960), showed that CaO, MgO and total Fe decrease during differentiation with Na_2O only decreasing when the pegmatitic stage is approached. In the sequence studied,

Na_2O and CaO decrease but MgO and total Fe do not. MgO, however, increases from the Makhutso to the Vlaklaagte granite and then decreases marginally to the granite aplite. The fact that biotite is relatively abundant in the Vlaklaagte granite and granite aplite, reflects the enrichment of MgO and total Fe.

TiO_2 usually concentrates in early crystallates but in this case behaves similar to Fe. This is probably also the result of the formation of biotite when the pegmatitic stage is approached.

In the pegmatitic stage metasomatic alteration of the granites (with which the gas-liquid phase came into contact) took place, causing the formation of the red granites and greisens.

The elements depleted from the metasomatic end products are SiO_2, TiO_2, CaO and Na_2O. Inversely Al_2O_3, total FeO, MgO and K_2O are concentrated in these rocks with MnO only enriched during the very late stages of metasomatism in the upper zones.

6.2 TRACE ELEMENTS

The trace element data for the different rock types are summarised in Table 6-1. Fig. 6-2a shows the mean values for the Vlaklaagte granite and the granite aplite normalised against those of the Makhutso Granite. Fig. 6-2b and c similarly show the mean values of the respective greisens and red granites normalised against the Makhutso and Vlaklaagte granites respectively.

Lithium is enriched in both the Vlaklaagte granite and granite aplite relative to the Makhutso Granite. It is also enriched in the greisens from both the Makhutso Granite and Vlaklaagte granite. No change in the concentration of Li is observed in the red Makhutso Granite, but the red Vlaklaagte granite is marginally depleted relative to the wall rocks. The enrichment in the Vlaklaagte granite and granite aplite is probably due to the substitution of Al by Li in biotite during crystallisation (Goldschmidt, 1954). Similar substitutions also account for the Li enrichment in the biotite-rich greisens where small amounts of lepidolite and/or zinnwaldite are found. The behaviour of Li is, however, erratic in the red granites and this is possibly due to chloritisation.

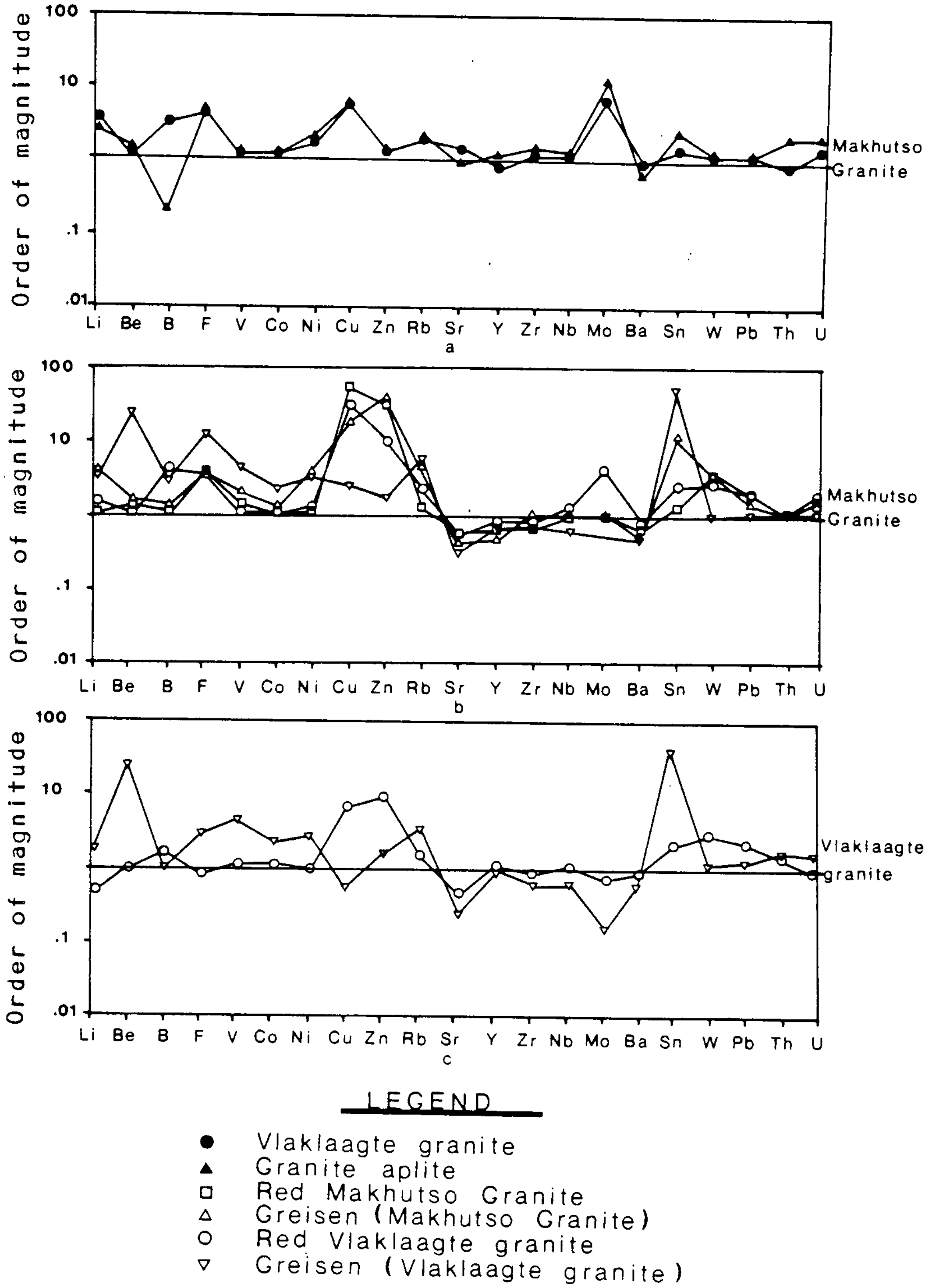


Figure 6-2: Trace element compositions of the Vlaklaagte granite and granite aplite normalised against the Makhutso Granite (a), greisen and red granite normalised against the Makhutso Granite (b) and greisen and red granite normalised against the Vlaklaagte granite (c).

Beryllium is significantly enriched in the Vlaklaagte greisen (endo-greisen) whilst the red Makhutso Granite is only marginally enriched compared to the wall rocks. Beryllium replaces the Si^{4+} ion (0.39A) in the $[SiO_4]$ tetrahedra in late-stage crystallates and hence increases with fractionation (Wedepohl, 1978; Rankama and Sahama, 1950). The Be is furthermore concentrated in the phyllosilicates and topaz of the greisens and especially the endo-greisens during the metasomatic process.

Boron is strongly enriched in the Vlaklaagte granite but strongly depleted in the granite aplite. The red Makhutso and Vlaklaagte granite and the greisen of the Makhutso Granite are marginally enriched compared to the wall rocks. The small ionic radius of B^{3+} (0.20A) and the volatility of its compounds prevent it becoming trapped in the hydroxyl-bearing minerals (Rankama and Sahama, 1950) and probably accounts for its strong depletion in the aplite phase. Boron probably remained in the separated gas-liquid phase. It is, however, not significantly enriched in the pneumatolitic rocks either. This may be due to its high volatility, preventing it being trapped during the formation of alteration products.

Fluorine is enriched in the Vlaklaagte granite and granite aplite. The red Makhutso Granite and both greisens are also enriched in F relative to the respective wall rocks. The distribution of F is attributed to the fact that fluorine enters into structural positions of OH^- in the late stage minerals during differentiation (Wedepohl, 1978). High concentrations of F added to the greisens during the process of metasomatism caused the formation of minerals such as topaz, fluorite and gilbertite.

Vanadium is only enriched in the greisens and red Makhutso Granite where V^{3+} (0.65A) follows Fe^{3+} (0.67A) very closely. This siderophile tendency of V^{3+} in an oxidising environment also accounts for its enrichment in the Fe-arsenides and sulphides in the upper quartz-pegmatitic zone.

Cobalt is strongly enriched in the greisens relative to the respective wall rocks with no appreciable change in the red granites. The enrichment of Co in the greisens and in the upper Fe-arsenide and sulphide-rich quartz-pegmatite zone, reflects both the siderophile and chalcophile tendencies of Co during the pegmatitic stage.

Nickel is enriched in the Vlaklaagte granite and more so in the granite aplite. Both the red Makhutso and the red Vlaklaagte granite and their respective greisens are enriched in Ni compared to the wall rocks. The Ni^{2+} (0.78A) normally follows Mg^{2+} (0.78A) which enters biotite (Goldschmidt, 1954), thus the enrichment of Ni in all the biotite-rich rocks can be explained. The ultimate enrichment of Ni in the Fe-arsenides and sulphide-rich zones reflects its siderophile and chalcophile tendencies.

Copper is strongly enriched in both the Vlaklaagte granite and granite aplite relative to the Makhutso Granite. The red Makhutso and red Vlaklaagte granite are more enriched in Cu than the respective greisens if compared with the wall rocks. The endo-greisens from the Vlaklaagte granite are even marginally depleted in Cu relative to the Vlaklaagte granite. In the absence of S the Cu^{2+} is expected to replace small amounts of Fe^{2+} and/or Mg^{2+} (Rankama and Sahama, 1950) in the biotite-rich rocks. The enrichment of Cu in the red granitic zones, between the greisens and wall rocks, probably formed by release of Cu from the original biotite in the granite, followed by its migration outward and entrapment as chalcopyrite in the red granitic zone. Chalcopyrite and pyrite are the main Cu-bearing minerals in this zone. The chalcophilic tendency of Cu caused Cu-sulphides to form in the late epithermal pegmatite stage where S was available (Table 6-1).

Zinc is only marginally enriched in the Vlaklaagte granite and granite aplite. The red Vlaklaagte granite, is more enriched in Zn than the greisen of this granite. Both the red Makhutso Granite and its greisen are strongly enriched in Zn. The strong chalcophilic tendency of Zn also resulted in its enrichment in the sulphide rich zones.

Rubidium is enriched in both the Vlaklaagte granite and granite aplite relative to the Makhutso Granite. The greisens are strongly enriched in Rb with the red granites less so. Rubidium substitutes for K in biotite and K-feldspar. It also substitutes for K in sericite and biotite formed during alteration of the K-feldspars. It is also enriched in the quartz-pegmatite veins.

Strontium is marginally enriched in the Vlaklaagte granite and depleted in the granite aplite. The greisens show the greatest depletion, with the red granites less depleted in Sr relative to the respective wall rocks.

Yttrium is marginally depleted in the Vlaklaagte granite in the pre-pegmatitic sequence. In the red Vlaklaagte granite and the associated greisens no enrichment or depletion of Y is observed compared to the wall rocks. However, in the red Makhutso Granite and its associated greisens a slight depletion of Y relative to the wall rocks is evident. The fact that Y is not enriched in the late pre-pegmatitic crystallates is probably the result of its relatively large ionic size (0,98 A), causing it to remain in the gas-liquid phase.

Zirconium is marginally enriched in the Vlaklaagte granite but more so in the granite aplite. In the red Vlaklaagte granite and its greisens Zr is slightly depleted compared to its wall rocks. Zirconium often is enriched in the last rocks to crystallise prior to the pegmatitic stage.

Niobium is enriched in the granite aplite but not in the Vlaklaagte granite. No significant change in the concentration of Nb is evident in the metasomatic products except the greisens associated with the Vlaklaagte granite which are slightly depleted.

Molybdenum is strongly enriched in both the Vlaklaagte granite and granite aplite with a maximum in the latter. In the red Vlaklaagte granite and its associated greisen the Mo is depleted compared to the Vlaklaagte granite.

Barium is depleted in the Vlaklaagte granite and more so in the granite aplite. The red granites are less depleted in Ba than the associated greisens compared to the wall rocks.

Tin is enriched in both the Vlaklaagte granite and more so in the granite aplite. The greisens from both the Makhutso Granite and Vlaklaagte granite are strongly enriched in Sn with the red granitic zones less so. Tin is increasingly enriched with increasing metasomatism from the unaltered granites to the red granites and finally the greisens. Pockets of high grade Sn-ore (cassiterite) are occasionally present in the greisens. The late quartz-pegmatite is depleted in Sn due to its earlier deposition in the greisens.

Tungsten is enriched in the red Vlaklaagte granite, red Makhutso Granite and the greisen from the latter relative to the wall rocks. In the pegmatites and especially the quartz-pegmatite veins the W is extraordinally enriched (Table 6-1).

Lead is strongly enriched in the red Makhutso Granite and red Vlaklaagte granite but less enriched in their respective greisens. It is also considerably enriched in the sulphide rich outer quartz-pegmatite veins and the associated altered wall rocks.

Thorium is marginally depleted in the Vlaklaagte granite and enriched in the granite aplite. Both the red Makhutso Granite, the red Vlaklaagte granite and the respective greisens are enriched in Th relative to their wall rocks. It is also strongly enriched in the late pegmatitic stage and more so in the sulphide rich zone (Table 6-1).

Uranium is enriched in the Vlaklaagte granite and more so in the granite aplite. In the pegmatitic stage U shows the strongest enrichment in the red Makhutso Granite and its associated greisen as well as the red Vlaklaagte granite. The greisens associated with the Vlaklaagte granite are depleted rather than enriched. Enrichment of U is also evident in the sulphide-rich late pegmatitic stage (Table 6-1).

6.2.1 Discussion.

The relative concentrations of Rb, Ba and Sr indicates that the Vlaklaagte granite and granite aplite represent late stages of differentiation (Fig. 6-3). The aplite facies is slightly more differentiated and plots along the same differentiation trend, indicating that a fractionation series Makhutso Granite - Vlaklaagte granite - granite aplite may exist.

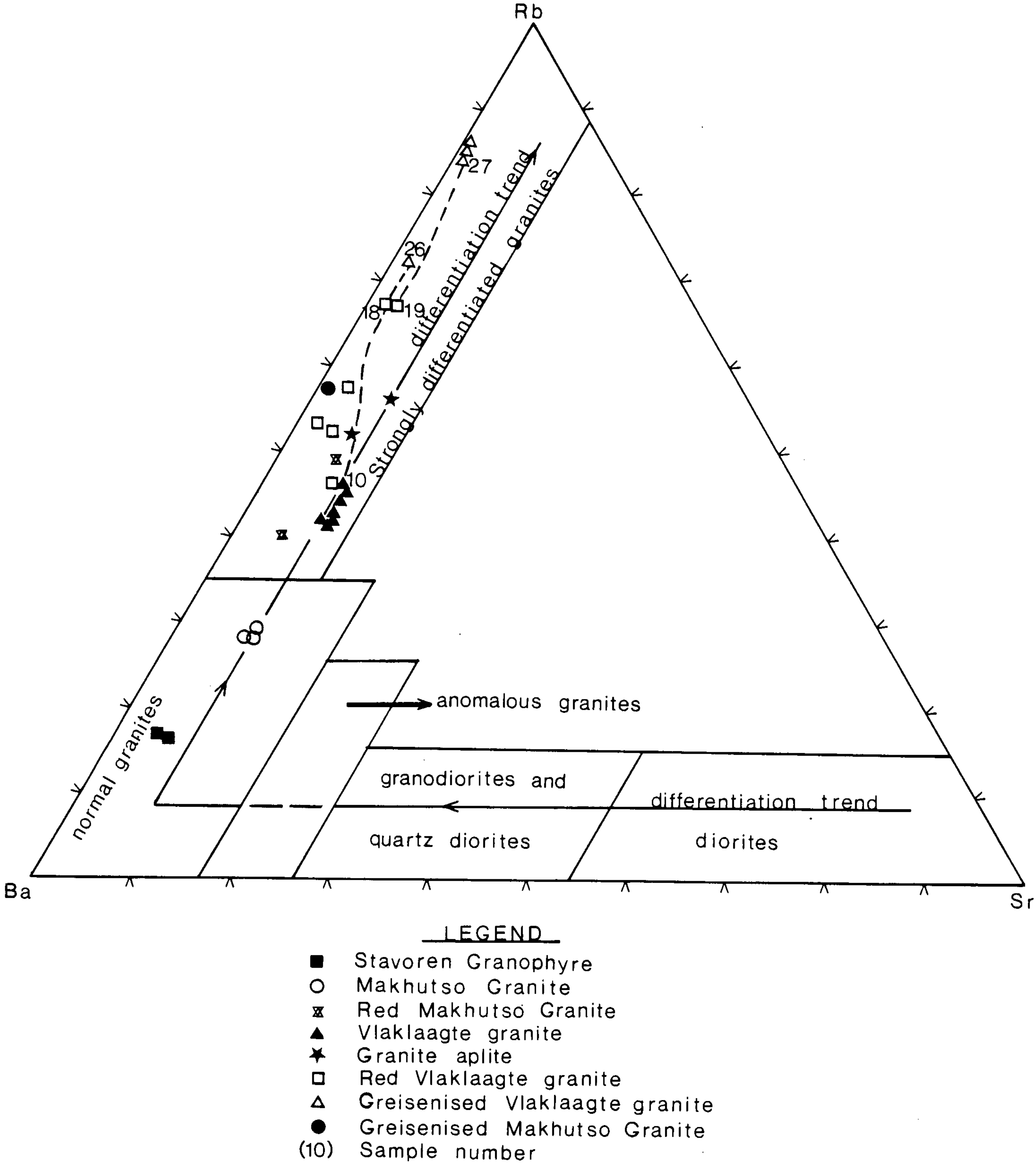


Figure 6-3: Ternary diagram for Rb, Ba and Sr showing the differentiation trends for the rocks in the area (after El Bouseily and El Sokkary, 1975).

Two suites of metasomatic products are also plotted in this diagram. The one can be traced from the grey Vlaklaagte granite (10) via the red granite (18) to the greisen (26). The second is from the red Vlaklaagte granite (19) through to the greisen (27). These trends indicate a decrease in the Ba and Sr content with an increase in Rb with increasing greisenisation, thereby extending the differentiation trends observed in the pre-pegmatitic rocks. However, the fundamental processes, fractional crystallisation in the pre-pegmatitic rocks and metasomatism in the pegmatitic phase, differ and unusual trends could be expected for some elements. On this basis it may be possible to distinguish between pre-pegmatitic and pegmatitic rocks as well as different rock types in each phase.

A higher degree of differentiation (metasomatism) is apparent in the contact metasomatic products of the endo- than the exo-genetic zone. This is due to less Rb and more Sr being present in the country rocks of the exogenetic (Makhutso Granite) than in the endo-genetic zone (Vlaklaagte granite).

The elements showing enrichment with increasing differentiation in the pre-pegmatitic stage are Li, Be, F, Ni, Cu, Zn, Rb, Zr, Nb, Sn, Th and U. Inverse patterns are depicted for Sr and Ba. No definite enrichment or depletion are evident for B, V, Co, Y, W and Pb.

The elements enriched with increasing metasomatism in the telescopic zones from the unaltered granitic wall rocks through the red granites to the greisens are Li, Be, B, F, V, Co, Ni, Rb, Sn and Th. Elements also enriched in the metasomatic products prefering the red epithermal granitic zones rather than the mesothermal greisen zones, are Cu, Zn, Pb, W and U. The elements generally depleted in the metasomatic products are Sr, Mo, Ba and the incompatable elements Y, Zr and Nb which remain in the gas-liquid phase.

In Fig. 6-4 the more important lateral trace element dispersion patterns in the three main temperature zones are shown, i.e hypothermal, mesothermal and epithermal. The elements that are enriched from the early (high temperature) metasomatic products to the late (low temperature) sulphide-rich products in the

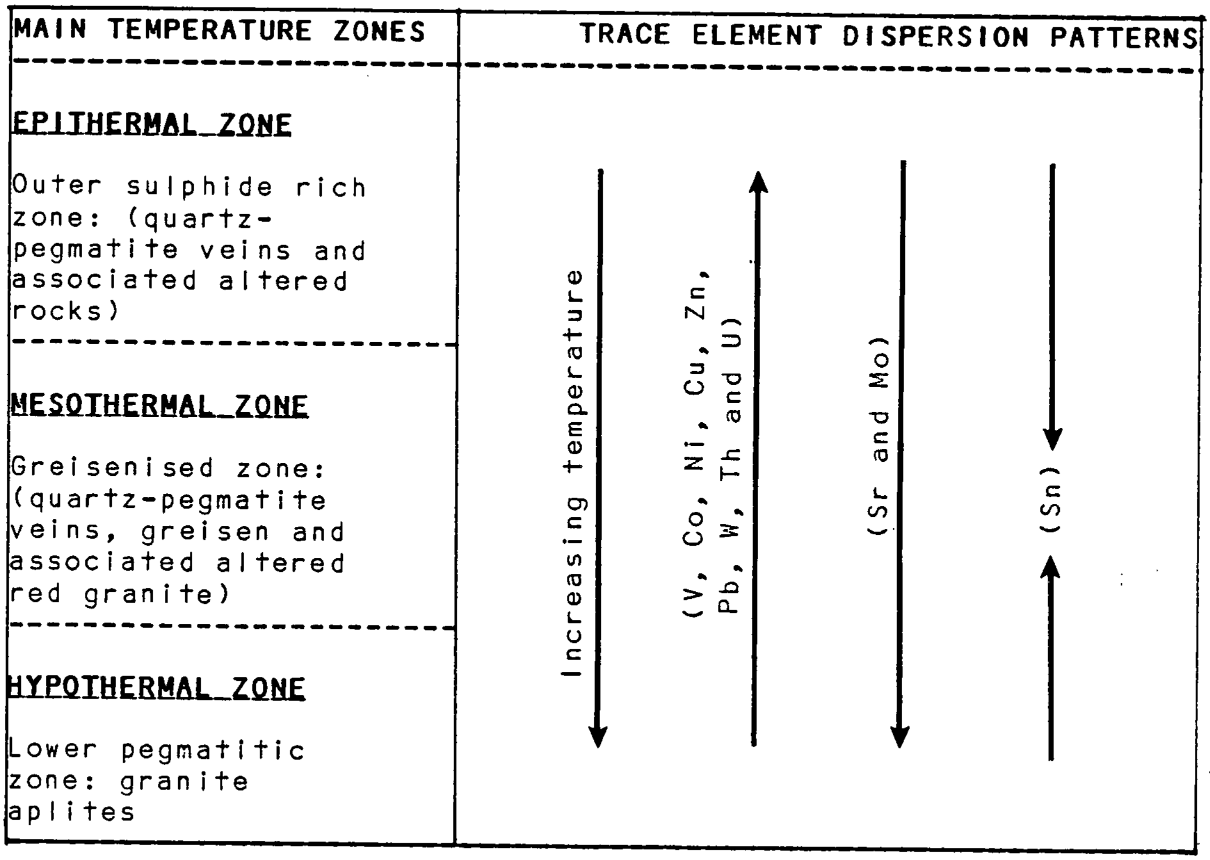


Figure 6-4: Diagram showing the more important trace element dispersion patterns in the three main temparature zones in the pegmatitic stage.

pegmatitic stage are V, Co, Ni, Cu, Zn, Rb, Pb, W, Th and U. All these elements except for Rb possess either siderophile or chalcophile tendencies. Strontium and in particular Mo show inverse patterns. Tin concentrates in the mesothermal stages (greisen).

As a result the hypothermal zone is marked by the enrichment of Mo, the mesothermal zone by Sn and the epithermal zone by siderophile and chalcophile elements, in particular Cu. This is only partly in agreement with the association of sulphides (especially those of Cu and Mo) with Sn deposits in the Bushveld granites and associated rocks (Crocker and Callaghan, 1979).

The data suggest that specific single or multi-element anomalies are associated with different mineralised zones. It is thus evident that primary anomalies for the elements listed could be studied lithogeochemically. Secondary halos in the overlying soils, reflecting differences in the primary environment, may also form.

6.3 EMPLACEMENT SEQUENCE OF THE GRANITES.

The following emplacment history is inferred from the geological, petrological and geochemical data:-

- The Makhutso Granite intruded into the Stavoren Granophyre, which acted as a roof.

- Deformation including the opening of fissures took place during crystallisation of the Makhutso Granite with the Vlaklaagte granite intruding into these fissures. The Vlaklaagte granite represents a late differentiate of the Makhutso Granite.

- During crystallisation of the Vlaklaagte granite another set of fissures formed in it and were exploited by high temperature pneumatolytic-hydrothermal solutions. This caused aplites to form from which the gas-liquid phase was separated.

- These pneumatolitic-hydrothermal solutions caused quartz-pegmatites to form, accompanied by the metasomatic alteration of the wall rocks under a thermal gradient.

7 VERTICAL GEOCHEMICAL WEATHERING AND DISPERSION PATTERNS IN THE SECONDARY ENVIRONMENT.

Weathering of the surrounding rock-types gives rise to the formation of the soils which in turn reflect some of the geochemical characteristics of the parent material. Taking the various soil forming processes as previously discussed into consideration, it is therefore essential that the vertical geochemical dispersion in the soil profile is examined.

The dispersion patterns in the soils (secondary environment) display vertical and horizontal variations influenced by numerous factors.

Because the bedrock material (Fig. 3-6) consists of partly weathered bedrock and the unconsolidated material consists of soils (residual and transported) one expects a marked difference in the geochemical distribution pattern of these two groups. The geochemical behaviour of each element throughout the soil profile is discussed because of the fact that the soil profile as a whole is regarded as an open chemical system which is not restricted to individual horizons.

7.1 BEDROCK MATERIAL

The major, minor and trace element data (Appendix C) for the R1, R2, R3 and R4 zones in a typical profile (6) are summarised in Fig. 7-1. In general the elements (both major and trace) can be subdivided into five distribution patterns:

- Elements showing an increase from the R4 to the R1 zone (TiO_2, K_2O, V, Cu, Zn, Rb, Zr, Nb, Ba, Sn, Pb, Th and U).
  The mode of enrichment differs widely and the most general causes are the following:-
  a). Elements associated with resistant minerals being enriched due to compaction (TiO_2, V, Zr, Nb, Sn, Th and U).
  b). Elements with lithophile tendencies associated with clay minerals (K_2O, Rb and Ba).
  c). Elements with chalcophile tendencies also strongly associated with clay minerals and iron oxides (Cu, Zn and

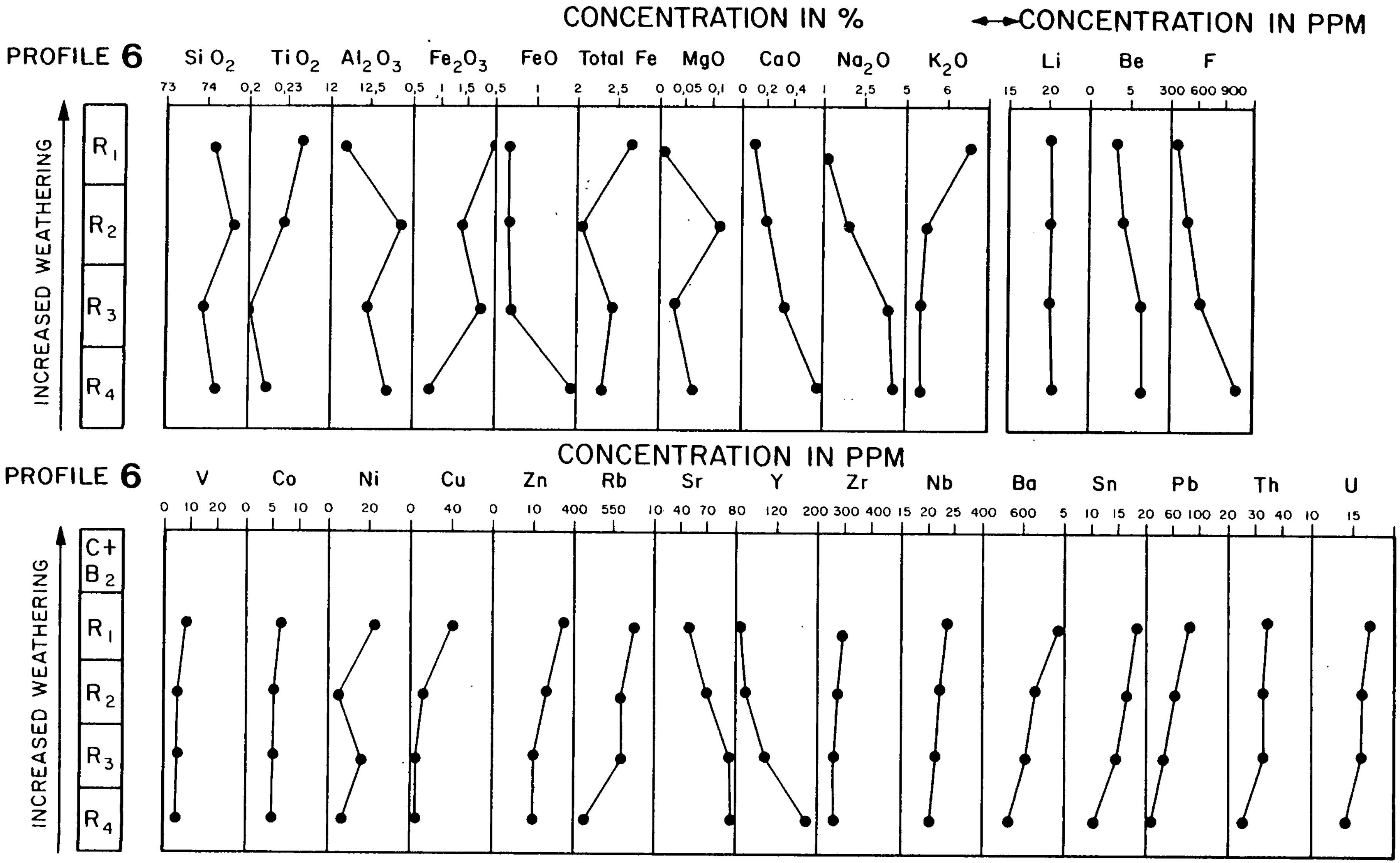


Figure 7-1: Profile diagram showing the distribution patterns for major and trace elements in the bedrock material.

Pb). The relatively low concentrations of Cu and Pb in the rock itself are unlikely to be the source for the high concentrations observed in the higher zones. This enrichment in the weathered zones is possibly the result of the enrichment from an external source. Copper and Pb transported in solution by groundwater is considered to be the reason for enrichment in this bedrock zone. Similar enrichment of Cu and Pb in the soils overlying the bedrock material have also been observed.

- Elements showing a decrease from the R4 to the R1 zone (CaO, Na_2O, Be, F, Sr and Y). These elements are leachable and therefore mobile. Apart from Y the elements are also known to be associated with non-resistant silicate minerals.

- Elements with a strong siderophile tendency following Fe^{3+} closely (Co and Ni). These elements (particularly Ni) are enriched in the highly oxidised R3 and R1 zones where Fe^{2+} is oxidised to Fe^{3+}.

- Elements enriched in the reduced R2 zone (Al_2O_3 and MgO). This could be the result of the reducing nature in the R2 zone, causing higher concentrations of illite and kaolinite to be present with less Fe^{3+}.

- Elements showing no definite variation (SiO_2 and Li).

The mineral in which an element is present together with the redox potential evidently control its solubility. If the element substitutes in a resistant mineral it tends to be enriched with increasing weathering. If an element is present in a non-resistant mineral it could either remain behind when immobile or be leached if mobile. The mobility of the leached elements then depends on the redox potential of the zone through which it is moving.

To a much lesser extent the enrichment and depletion of mobile elements are also dependant on the concentration of the elements in the rock. If the concentration of an element in the percolating groundwater is higher than those in the rock itself, the weathered zones would tend to be enriched in such an element. If the concentration of a mobile element is higher in the rock than in the undersaturated groundwater the inverse is expected. The behaviour of mobile elements in the bedrock weathering zone is therefore unpredictable if the mineral in which the elements occur and the external enrichment is unknown.

Maximum groundwater movement occurs on the contact between the bedrock and unconsolidated weathering zone. Consequently the development of false anomalies for mobile elements are expected at geochemical barriers.

7.2 UNCONSOLIDATED MATERIAL

As discussed in Chapter 3 the unconsolidated material is subdivided into residual and transported soils, which are separated by the pebble layer on the upper slopes and ridge. On the middle and foot slope palaeo-colluvium occurs below the pebble layer.

Chemical analyses of the various whole samples as well as on different mesh size fractions were carried out. The whole sample analyses were used to determine the general distribution pattern whilst the different size fraction analyes were used to evaluate the most sensitive fraction for exploration.

7.2.1 Whole samples

The major and minor element distribution patterns in two typical soil profiles (Appendix D) are illustrated in Fig. 7-2. Distribution patterns for trace elements are shown for all profiles in Appendix E. Although major elements can be used for exploration purposes, attention is mainly given to those minor and trace elements that can be analysed routinely on a X-ray fluorescence spectrometer.

Mottling is a common feature and because of the heterogeneous nature thereof, the chemical dispersion between the different types of mottles are discussed in this section.

7.2.1.1 Major element distribution

The major element distribution in soil profiles is a direct consequence of the breakdown of rock-forming minerals with resistates

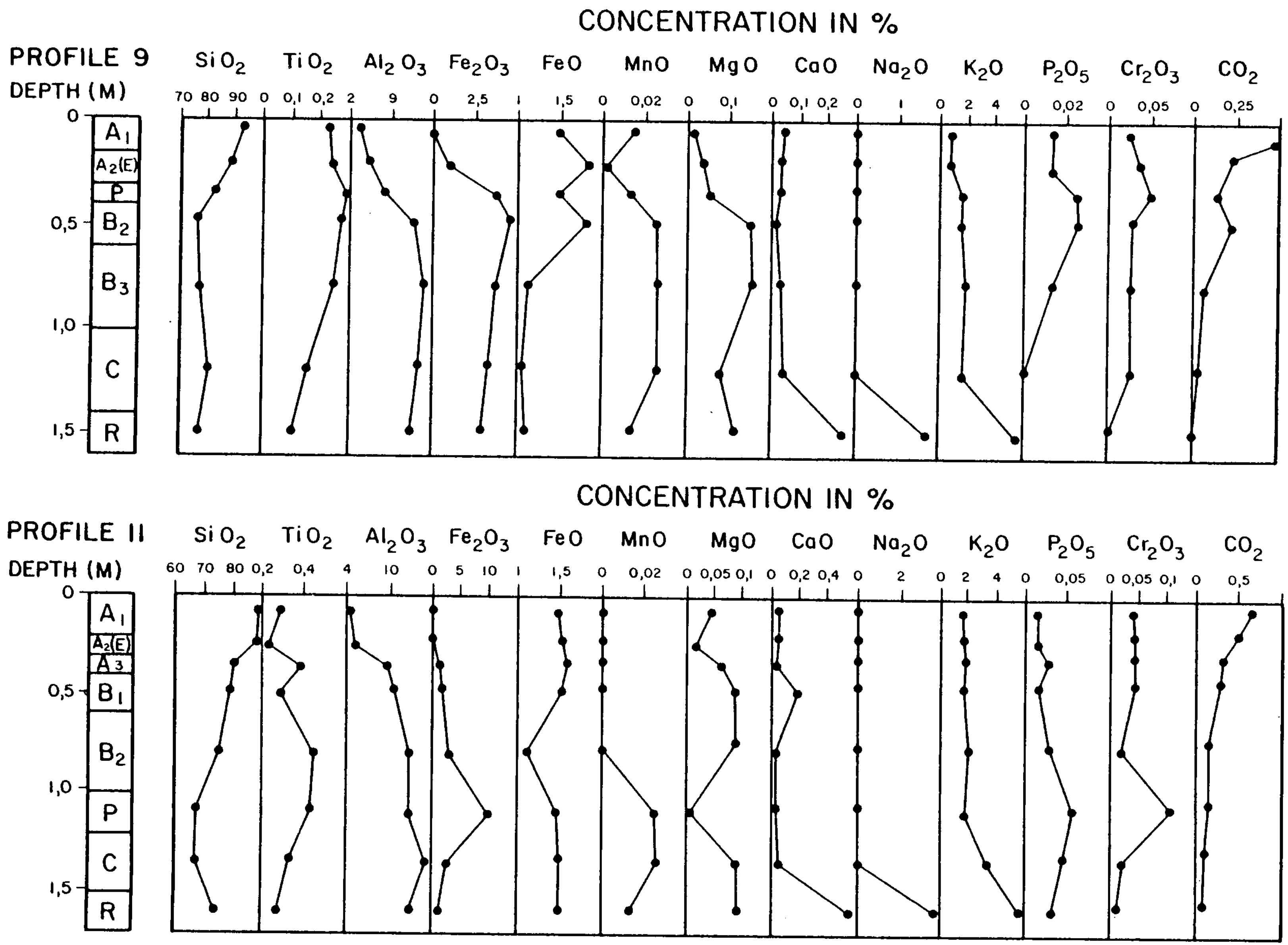


Figure 7-2: Major element distribution patterns in profiles 9 and 11.

and clay minerals forming the residual end products. The elemental oxide distribution in typical soil profiles on the ridge and upperslopes with the B horizon developed in residual (profile 9) and transported soil (profile 11) respectively are shown in Fig. 7-2.

SiO_2

The SiO_2 content in the residual soils is fairly low in the B horizon of profile 9 with the C horizon enriched relative to the bedrock, whilst in profile 11 the C horizon has the lowest concentration. In the transported soils the SiO_2 is enriched in the A horizon of both profiles and less so in the B horizon relative to the residual soils (profile 11). The pebble layer in the residual soil profile (9) is enriched in SiO_2 whilst the pebble layer and C horizon in the transported soil profile (11) are depleted.

It is evident that the proportion of resistant quartz increases in zones of eluviation (A horizon) while the inverse is true as the accumulation (illuviation) of clay minerals increases in the B horizon. Eluviation and illuviation are therefore also the main controlling factors in the enrichment or depletion of SiO_2 in the pebble layer. In the C horizon the concentration of SiO_2 in respect to the bedrock is controlled by the same influences.

TiO_2

The TiO_2 is enriched in the upper parts of the residual soils (Appendix A). The B_2(R) horizon forming the top part in the residual soils, usually shows the maximum enrichment. Distribution patterns of TiO_2 are very irregular in the transported soils but a slight enrichment in the B_2(T) horizon is usually present (profile 11). The pebble layer is strongly enriched in TiO_2 when compared with the residual and transported soils.

Enrichment of TiO_2 in the upper parts of the residual soils and in the pebble layer is the result of compaction and the concentration of resistates such as ilmenite and sphene. The irregular distribution patterns in the transported soils are due to the fact that TiO_2 is present in resistates. The enrichment of TiO_2 in the B_2 horizon of the transported soils could be the result of the adsorption of some Ti^{2+} on clay minerals or the formation of rutile needless (Goldschmidt, 1954). Should this enrichment have been the result of heavy mineral concentrations then an enrichment in the other transported horizons would be expected.

Al_2O_3

In residual soils Al_2O_3 shows a strong enrichment in the B horizon and more specifically the B_3 horizon of profile 9. Compared to the bedrock, the C horizon is also enriched in both profiles 9 and 11. In transported soils Al_2O_3 is depleted in the A horizon of both profiles 9 and 11. The B horizon of profile 11 is situated in the transported soils and also shows an enrichment in Al_2O_3 compared to the A horizon. The Al_2O_3 is depleted in the pebble layers of both profiles 9 and 11 compared to the residual soils. This depletion is greater in profile 9.

Al_2O_3 shows a strong enrichment in the illuvial zones while the zone of eluviation is depleted. The same pattern is observed in the pebble layer. It is thus clear that Al_2O_3 and SiO_2 show a strong inverse distribution in the zones of eluviation and illuviation, resulting from the fact that quartz and clay minerals are the dominant soil forming constituents.

FeO and Fe_2O_3

In residual soils Fe_2O_3 and FeO are enriched in the oxidised illuvial horizon i.e., the B_2(R) horizon. The reduced illuvial horizon (B_3 horizon) is less enriched than the B_2(R) horizon relative to the bedrock. Only the Fe_2O_3 is enriched in the C horizon whilst the FeO remains the same as in the bedrock. The A horizon in transported soils is completely depleted of Fe_2O_3 with the B horizon enriched as illuviation increases. Irregular distribution patterns are obtained for FeO in the transported soils, indicating that Fe^{2+} could be captured in resistates. The pebble layer is more enriched in Fe_2O_3 than either the residual or transported soils.

Goethite and hematite cause enrichment of Fe_2O_3 in the intermediate zones. Accumulation of iron and aluminium oxides in the illuviated B horizon is very characteristic and depletion of these in the eluviated A horizon is common (Levinson, 1980).

Goethite pellets cause the high Fe_2O_3 concentrations in the pebble layer.

Most of the ferrous iron which oxidises to ferric iron originates from the ferro-magnesian silicate minerals whilst that present in resistant minerals such as magnetite and ilmenite, remains longer in the Fe^{2+} state.

MnO

The MnO is slightly enriched in the B and C horizons in the residual soils relative to its concentration in the bedrock. In the transported soils MnO is generally depleted compared to the residual soils, showing an irregular distribution pattern. The behaviour of MnO in the pebble layer is unpredictable with Mn showing an affinity for the iron oxides.

Depletion of MnO in the transported soils could be due to differences in source areas or stronger leaching conditions than in the residual soils.

MgO

In residual soils MgO is enriched in the B horizon compared to the bedrock. In transported soils MgO is depleted in the A horizon and enriched in the B horizon. The pebble layer is also depleted of MgO compared to the residual soils.

MgO is thus leached in the eluvial zone (i.e. the A horizon) and accumulated in the illuvial zones (i.e. the B horizon). MgO furthermore correlates positively with the clay minerals and especially the chlorite content of the soil. The high mobility of Mg^{2+} is a result of its low ionic potential (Gordon **et al.**, 1958).

CaO and Na_2O

Both the CaO and Na_2O are almost totally depleted in the residual soils relative to the bedrock. In the transported soils and pebble layer CaO and Na_2O are totally depleted.

The depletion indicates that both these elements have a greater mobility during the prevailing weathering conditions than any of the other major elements. The low ionic potential

($Z/r < 3.0$) of these elements is the reason for their high mobility (Gordon **et al.**, 1958).

K_2O

The residual soils are depleted of K_2O compared to the bedrock. The C horizon is most depleted whilst the B horizons, (especially the B_3 horizon) are enriched (profile 9). The transported soils are more depleted in K_2O than the residual soils with the A horizon showing the greatest depletion. Some enrichment was observed in the B horizon of profile 9. The K_2O concentration in the pebble layer depends on the ratio between residual and transported soils and is therefore unpredictable.

The K_2O which shows a slight increase in the consolidated zone decreases with increasing weathering due to pottassium feldspar decomposition. This behaviour is also ascribed to the low ionic potential of K_2O. An increase of K_2O in the B horizon could also be a result of its association with clay minerals.

P_2O_5

Phosphorus is enriched in the upper zones of the residual soils and the highest concentration is in the zone below the pebble layer (Appendix A). An irregular distribution pattern is common in the transported soils. The highest concentration in the profile as a whole, is often present in the pebble layer.

Enrichment of P_2O_5 in the residual zones and the pebble layer is a result of the accumulation of resistates (monazite and apatite). Irregular distribution patterns in the transported soils can be expected due to different sources and energy conditions during deposition.

Cr_2O_3

The Cr_2O_3 is enriched in the residual soils, but in transported soils it has an irregular distribution. Chromium is most enriched in the pebble layer.

Enrichment of Cr_2O_3 in the pebble layer may be due to the precipitation of the chromate ion by the cations of heavy metals such as Pb and Mo which are associated with the iron oxides in both profiles (Goldschmidt, 1954).

CO_2

Carbon measured as CO_2 is depleted in the residual zones except for the B_2(R) horizon in profile 9 where it is enriched. It is enriched in the A horizon and depleted in the other horizons of the transported soils. The CO_2 is also depleted in the pebble zone.

Enrichment of CO_2 in the upper horizons is caused by organic carbon resulting from the breakdown of organic matter. Percolating groundwater can transport the organic carbon downwards causing enrichment of the lower horizons. Enrichment in the B_2(R) horizon of profile 9 could be due to organic debris present in the palaeo-surface. The C horizon in profile 11, however, does not show any enrichment.

7.2.1.2 Trace element distribution

The trace element distribution patterns in the soil profiles, are plotted for all 32 profiles and are illustrated in Appendix E. Elements with very similar behaviour patterns are grouped together in the subsequent discussion and the generalised trace element dispersion patterns in the two most typical soil profiles in the area are shown in Fig. 7-3.

The most consistant variations are seen in those elements displaying a siderophile tendency upon weathering (Co, Ni, Cu, Zn, Pb and Mo). In the residual soils the elements are enriched in the oxidised B horizon (especially the B_2(R)) relative to the bedrock. Enrichment is also present in the B_3 and C horizons of some profiles. They are depleted in the transported soils (particularly the A horizon) but marginally enriched in the B_2(T) horizon. The pebble layer shows the greatest enrichment of all the zones in the profile.

The above elements are coprecipitated and adsorbed on iron oxides rather than clay minerals in the B2 horizon and the pebble layer. Sporadic enrichment in the B_3 and C horizon can be attributed to enrichment by lateral-moving groundwater. A close relationship between the distribution patterns of Pb and Th exists in the transported soils, suggesting that both co-exist in resistant minerals (eg. monazite, sphene and allanite) or that anglesite

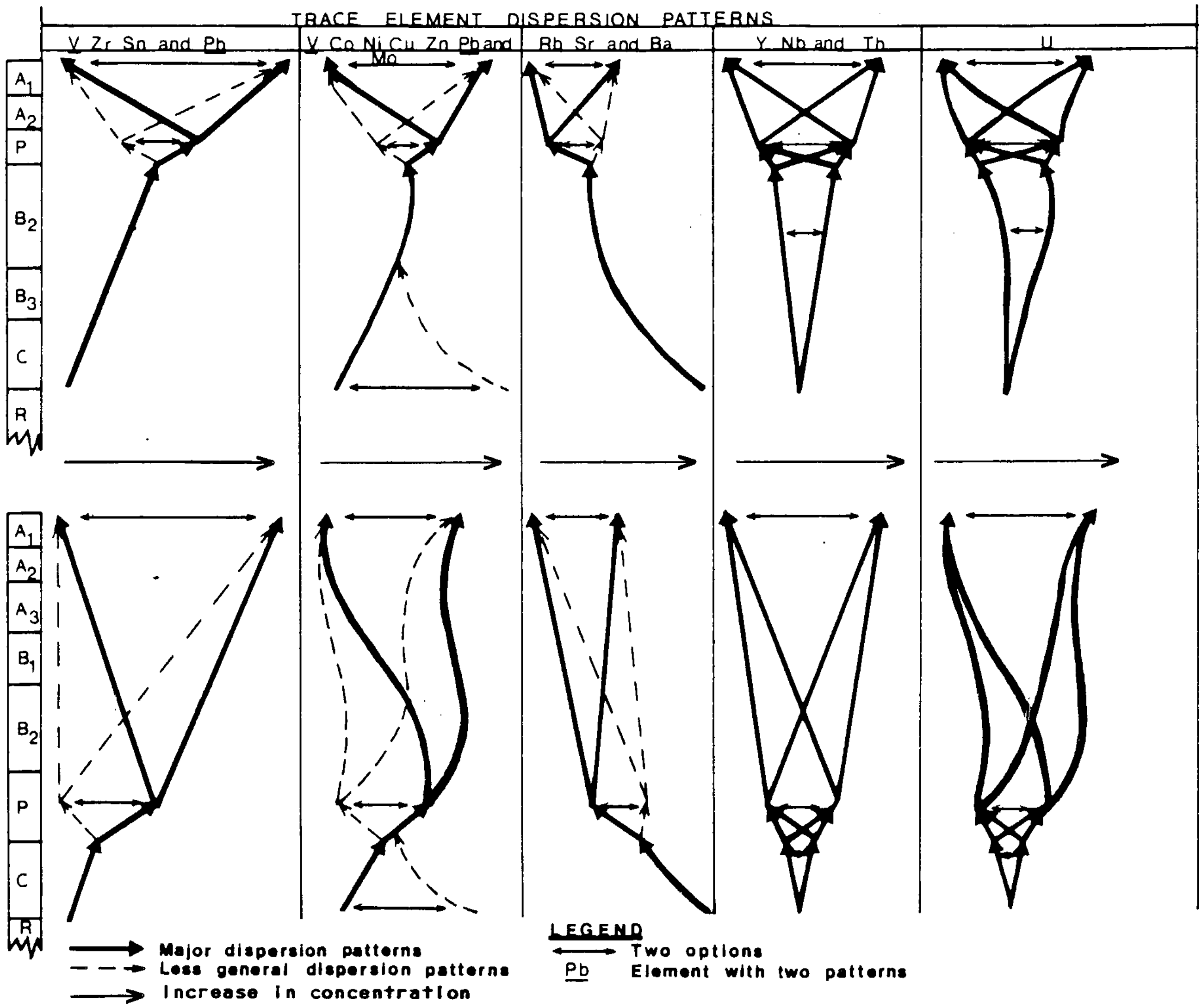


Figure 7-3: Generalised trace element dispersion patterns in the two most typical soil profiles in the area representing a) a partly stripped palaeo-profile and b) a completely stripped palaeo-profile.

or cerussite are present.

Rubidium, Sr and Ba display a lithophile tendency upon weathering in the profiles. These elements are depleted in the residual soils compared to the bedrock with their concentrations decreasing to the top zones. The transported soils are marked by low, variable concentrations. Very low concentrations are also present in the pebble layer.

Both Rb, Sr and Ba have low ionic potentials ($Z/r < 3.0$, Gordon **et al.**, (1958), causing their high mobility. Their concentrations in the soil profiles depend on the leaching conditions of feldspar only. The percentage clay minerals is a minor controlling factor in this case.

Those elements controlled by resistant minerals are Zr and to a lesser extent V and Sn. In the residual soils these elements show enrichment toward the upper parts (either the B or C horizon) compared to the bedrock. In the transported soil they show a variable distribution pattern, with some enrichment of V and Sn occuring in the B_2 horizons of some profiles. Vanadium is the most enriched in the pebble zone whilst extremely high Sn concentrations are encountered in some profiles. In other profiles the Sn concentration in the pebble layer seems to be a function of its concentration in either the transported or residual soils. Zirconium is generally depleted in the pebble layer although enriched in a few profiles.

Eluviation coupled with compaction results in the concentration of the resistates which explains the enrichment of the above elements towards the upper parts of the residual soils. In the transported soils and pebble layer differences in the grain size of the resistates and the chemical tendencies of these elements upon weathering require separate discussion.

Vanadium enrichment in the pebble layer (especially in the goethite pellets) and the B_2(T) horizon would be due to sorbtion on Fe-oxides. Hydromorphic enrichment of V in addition to eluvial enrichment in the Fe-rich residual zones (B horizon) is also recognised in one profile. The variable distribution of V in the transported soils could result from variations in the resistate concentrations.

Erratic Zr distribution in transported soils may be due to variations in sources or energy conditions during deposition. Coarse material consisting of quartz pebbles and goethite pellets is the reason for the low Zr concentrations in the pebble layer. The finer grained zircon is concentrated in the silt-clay fraction.

Tin is enriched in transported soils derived from Sn-rich sources. Lateral eluvial enrichment of cassiterite in transported soils causes the higher concentrations in this zone. Enrichment in the pebble layer can be ascribed to the concentration of coarser cassiterite grains in the predominant coarser fractions, or to the siderophile enrichment of Sn. Due to its high S.G., cassiterite could be deposited in hydraulic equilibrium with coarse quartz pebbles, which will cause an inverse relationship between grain size and Sn-contents. The concentration of Sn in the pebble layer is thus controlled by the ratio of transported to relict material and the concentration of Sn in the transported and residual soils.

Enrichment of Sn in the B_2 horizon is a result of hydromorphic enrichment of Sn leached from silicates such as biotite on weathering.

Thorium, U, Y and Nb have confusing distribution patterns. These elements are often enriched in the upper zones of the residual soil profiles whilst depleted in others relative to the bedrock. In the transported soils they behave erratic and are nearly always depleted (especially in the A horizon). Both Y and U are enriched in the pebble layer. The enrichment of Y in this zone is due to the concentration of resistates and that of U due to its siderophile enrichment in the goethite pellets. Nb is generally depleted in the pebble layer with Th showing no consistant behaviour.

Enrichment towards the upper parts of the residual soils is due to the accumulation of resistates. Depletion in the top parts of some profiles can result from the association of these elements with nonresistant silicate minerals.

When the above elements are released upon weathering Y, Nb, and Th behave lithophilic and U siderophilic.

Yttrium, Nb and Th preferentially concentrate in the gleyed horizons for the same reasons as Rb, Sr and Ba. When leached from silicates Y like Rb, Sr and Ba, is very mobile.

Uranium has a strong affinity for highly oxidised zones (B_2 horizon and pebble layer). As a result enrichment in the B_2 horizon of some profiles is also evident. This affinity can be attributed to the fact that the uranium is adsorbed by the hydrous ferric oxides.

7.2.1.3 Mottling and the formation of the gleyed horizons.

Mottles are absent in the lower part of the C horizon and thus exclude geogenic mottling in these soils (Brink and Williams, 1977). Hydromorphic mottling is present, indicating intermittent wet and dry conditions. In Fig. 7-4 the pH values obtained for the different horizons in profiles 9, 26 and 27 (Table 7-1) are plotted on a pH-Eh diagram. Most reactions in the zone of weathering take place within the shaded area (Fig. 7-4) and the dashed curve represents the oxidation-reduction potential for ferrous and ferric iron in solution. The portion of the curve with the steepest negative slope represents (Fe^{+2}) in solution in equilibrium with (Fe_2O_3, $FeO(OH_3)$) as solids.

At a pH of 5 or higher the oxidation potential of ferrous hydroxide lies far below the potential available in the weathering environment and therefore all the horizons with a pH in the dotted area are marked by red, brown or yellow iron oxides.

Relatively low pH values (4.2 - 4.8) were obtained in the B_3 horizons (5.1 -5.3) and in the B_2(R) horizons (Table 7-1). During intermittent wet periods the oxidation potential of the water-saturated and poorly aerated gleyed horizon will decrease (the pH-Eh state of the soils will move into the black area in Fig. 7-4) and reduction of ferric oxides and hydroxides will take place resulting in mobile ferrous compounds that can be leached from the soils.

Strong depletion of iron causes the gleyed B_3 horizon in

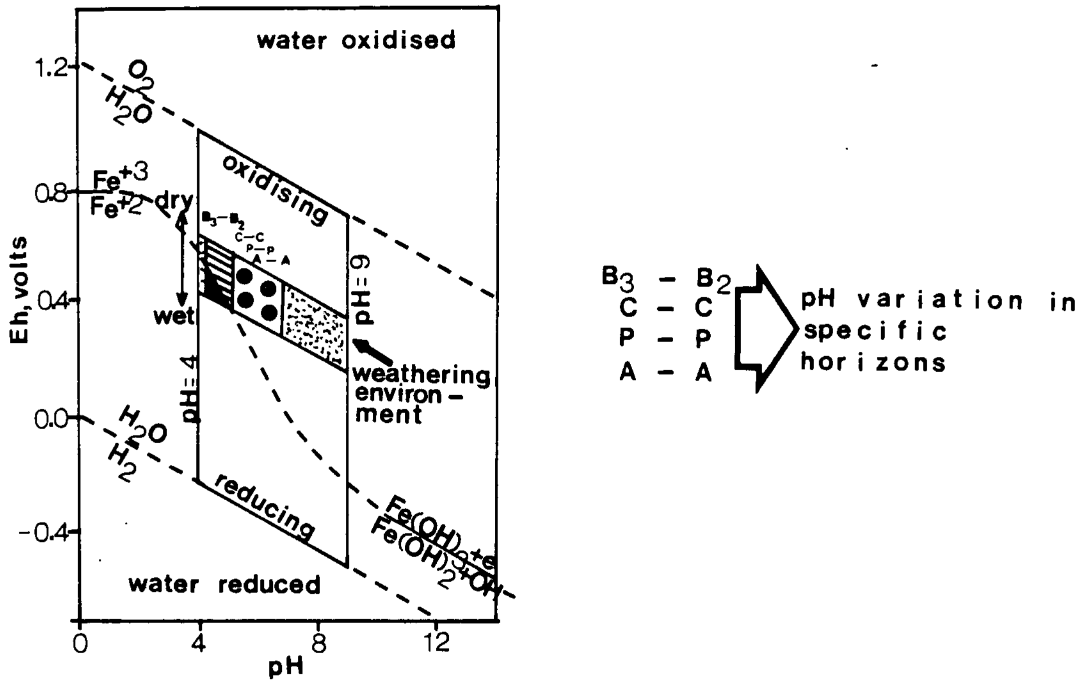


Figure 7-4: Eh-pH diagram (after Levinson, 1980) in which the pH values for the various horizons in profiles 9, 26 and 27 are plotted.

TABLE 7-1: THE pH VALUES FOR ALL HORIZONS IN PROFILES 9, 26 AND 27.

HORIZONS	pH VALUES OF SOILS		
	PROFILE 9	PROFILE 26	PROFILE 27
A_1	5.5	6.0	6.5
A_2	5.5	5.7	6.1
P	5.3	5.5	5.7
B_2	5.1	5.2	5.3
B_3	4.8	4.2	4.5
C	5.2	5.3	5.4

most of the profiles. When iron is not completely leached the ferrous oxides are oxidised and precipitated around nuclei of existing iron minerals during drier conditions when oxygen enters the soil. The pH-Eh state of the soils will then move back into the striped area (Fig. 7-4). The precipitation of ferric oxides then causes the mottled structures in the B_2(R) horizon or B_3 horizon. In the B_3 horizon white mottling is predominant whereas in the B_2(R) horizon the mottling is predominantly red.

Major element analysis on such mottles from profile 9 (Table 7-2) shows that Fe_2O_3 is dominant in the red mottles whilst Al_2O_3 and K_2O are dominant in the white mottles. In the reddish B_2(R) horizons from profiles 26 and 27, Fe_2O_3, Al_2O_3 and K_2O are enriched whilst Fe_2O_3 is depleted in the gleyed B_3 horizons.

The gleyed and mottled horizons therefore resulted from alternating acid reducing to oxidizing environments. This could be due to a fluctuating water table or lateral moving groundwater, containing H^+-ions, during intermittent wet and dry periods. The H^+ is then preferably adsorbed on the clay minerals of the lower illuvial horizons (hydrolysis), causing the clay to behave like weak acids and lowering the pH value to between 4 and 5. An increase in the H^+-ion concentration then causes a decrease in the solubility of lateral and vertically moving SiO_2 and Al_2O_3 and promotes the formation of clay minerals (Harmse, 1974).

The fact that no water table was observed during the sampling of the profiles in the rainy season and the fact that the lower part of the present C horizon is not similarly affected by the lateral movement of groundwater, excludes both these possibilities for the present. It is, however, possible that the gleyed horizon represents a palaeo-marker for a zone of maximum groundwater movement. The low pH observed in this study would therefore have developed in the gleyed zones at a much earlier stage and would have remained to the present.

Minor and trace element analysis on mottles from profile 9 as well as on kaolinitic feldspars and goethite pellets from profiles 9, 10, 12 and 14 (Table 7-2) indicates that V, Co, Ni, Cu, Zn, Mo, Sn, Pb and U are preferentially fixed with iron oxides whilst Rb, Sr, Y, Ba and Th rather prefer the clay minerals.

TABLE 7-2: THE MAJOR AND TRACE ELEMENT CONCENTRATIONS IN THE B_2 AND GLEYED HORIZONS, THE RED AND WHITE MOTTLES AND THE GOETHITE PELLETS AND WEATHERED FELDSPARS.

	B_3 AND B_2 HORIZONS				MOTTLES		PEBBLE				LAYER			
	PROFILE 26		PROFILE 27		PROFILE 9		PROFILE 9		PROFILE 10		PROFILE 12		PROFILE 14	
	B_3	B_2	B_3	B_2	B_3(W)	B_3(R)	KAO	GOE	KAO	GOE	KAO	GOE	KAO	GOE
SiO_2	78.05	80.10	78.47	80.63	75.96	80.58								
TiO_2	0.30	0.30	0.31	0.30	0.25	0.17								
Al_2O_3	13.05	10.21	12.42	9.31	14.72	5.64								
Fe_2O_3	1.31	3.40	1.62	2.74	1.31	8.47								
FeO	1.21	1.72	1.17	1.51	0.90	1.52								
MnO	0.03	0.04	0.02	0.02	0.01	0.03								
MgO	0.17	0.16	0.16	0.17	0.17	0.16								
CaO	0.03	0.03	0.02	0.02	0.02	0.03								
Na_2O	0.01	0.01	0.01	0.01	0.01	0.01								
K_2O	3.04	1.51	2.88	1.67	4.06	1.48								
P_2O_5	0.02	0.02	0.03	0.03	0.01	0.01								
Cr_2O_3	0.03	0.02	0.03	0.02	0.02	0.03								
H_2O+	1.56	1.84	2.33	2.16	1.31	1.11								
H_2O-	0.48	0.21	0.37	0.16	0.50	0.12								
CO_2	0.06	0.12	0.05	0.10	0.10	0.03								
TOTAL	99.35	99.69	99.89	98.85	99.35	99.39								
V	14	19	16	21	24	48	53	310	16	217	32	347	23	272
Co	10	14	6	5	15	28	5	311	5	203	7	278	5	174
Ni	5	5	10	5	9	15	5	75	5	57	5	64	5	57
Cu	5	8	12	6	20	30	34	166	23	247	18	427	71	831
Zn	5	8	10	5	20	30	31	82	9	85	8	49	33	100
Rb	168	97	126	61	414	278	300	97	200	46	247	40	158	30
Sr	14	11	10	6	17	7	14	5	17	5	14	5	10	5
Y	65	60	38	39	92	68	111	45	75	45	81	33	60	34
Zr	401	422	342	396	305	287	327	335	324	348	256	263	341	334
Nb	21	21	17	14	24	18	25	23	12	17	11	11	22	6
Mo	5	5	5	5	5	5	5	35	5	55	35	75	3	57
Ba	280	119	138	69	222	60	178	5	166	5	106	5	115	5
Sn	30	31	29	36	985	1165	1061	1867	60	115	11	45	22	174
W	5	5	5	5	5	5	5	5	5	5	5	5	5	20
Pb	50	33	24	7	76	103	136	184	46	306	24	85	5	140
Th	21	23	23	14	32	34	41	25	19	18	11	6	33	34
U	5	5	5	5	8	9	6	30	7	33	5	25	5	40

B_3W - WHITE MOTTLE
B_3R - RED MOTTLE
KAO - KAOLINITE (ALTERED FELDSPAR)
GOE - GOETHITE PELLETS

This explains the enrichment of the former group of elements in the pebble layer (goethite pellets) and the B_2 horizon.

7.2.1.4 Discussion.

The major constituents in the soils (SiO_2 and Al_2O_3) represent respectively the quartz and clay fractions which are the dominant mineral phases. The quartz to clay ratio together with the Fe_2O_3 content are the main factors controlling the distribution of all the other elements in the soil profiles.

Quartz always increases relative to clay minerals as eluviation increases and the reverse applies to illuviation. Since quartz is mono-elemental an increase in its concentration dilutes the concentration of all the other elements.

Some of the minor and trace elements (eg. Co, Ni, Cu, Zn, Rb, Sr and Ba) accumulate in the clay fraction which is the second most dominant constituent in soils. These elements are enriched in the illuvial zones where clay accumulates. Their concentration is therefore also influenced by the quartz to clay ratio of the sample.

The Fe_2O_3 in each zone fixes chalcophile and siderophile elements in the secondary environment and is associated with the oxidation zones (B_2 horizon and the pebble layer).

The element behaviour patterns in the soil profiles can be subdivided into three groups:-

Elements mainly present in resistates (P, Si, Zr, V and Sn): The distribution of these elements in the secondary environment is controlled by the distribution of the resistates with which they are associated. In the upper parts of the residual soils enrichment of these elements is due to compaction. In the transported soils they could behave erratic due to differences in sources and conditions of deposition.

When leached upon weathering, V and Sn are also enriched in the oxidised zones (especially in goethite pellets associated with the pebble layer) reflecting their siderophile character.

Elements associated with non-resistant minerals (Mg, Ca, Na, K, Co, Ni, Cu, Zn, Pb, Mo, Rb, Sr and Ba): These elements are leached upon weathering but differences in their chemical affinity cause different distribution patterns. Two groups are distinguished:

- Siderophile and chalcophile elements (Co, Ni, Cu, Zn, Pb and Mo) which are enriched in the oxidised zones due to adsorption onto or coprecipitation with the iron oxides. This is evident in the B_2 horizon and the pebble layer.

- Lithophile elements (Mg, Ca, Na, K, Rb, Sr and Ba) are very mobile and the clay minerals are the controlling factor in fixing them (Table 7-2). Calcium, Na, Rb, Sr and Ba, however, show no remarkable preference for the clay rich horizons because of their high mobility.

Elements associated with both resistant and non-resistant minerals (Ti, Mn, Y, Nb, Th and U): The behaviour of the elements depends on their original host minerals and could cause either enrichment or depletion in the upper residual soils. This causes a confusing distribution pattern. Further distribution of these elements when leached, is controlled by their chemical affinity which makes distribution patterns even more unpredictable. These elements can be subdivided into:

- Manganese and U which are enriched in the oxidised zones (i.e. the B_2 horizon and the pebble layer) when released upon weathering.

- Lithophile elements (Ti, Y, Nb and Th) which are preferentially adsorbed on the clay minerals. Enrichment of these elements in the B_3 horizon or pallid zone is therefore common. Yttrium, however, is more mobile and not that strongly associated with the clay minerals.

It is clear that an understanding of the host mineral phase for each element is a prerequisite for understanding its distribution in soil. In addition the use of SiO_2/Al_2O_3, Al_2O_3/Fe_2O_3 and SiO_2/Fe_2O_3 ratios, in conjunction with the mineralogical and chemical parameters, is imparitive in understanding the geochemistry of the secondary environment.

7.2.2 Size fractions

Tin, Mo and Cu are considered to be three of the most sensitive pathfinders in the exploration for tin and associated deposits. A study of the behaviour of these elements in the different soil size fractions was therefore attempted.

The parameters evaluated, include the optimum size-fraction and horizon to sample during an exploration programme. As a result of the differences in the composition and formation of the residual soils, the transported soils and the pebble layer, each one is evaluated separately in order to establish the best size fraction and horizon to sample for exploration.

7.2.2.1 Tin

In the soils under consideration Sn is predominantly present as cassiterite. The grain size of cassiterite is thus the most important factor in the determination of the size fraction to be used in exploration.

Figures 7-5 and 7-6 indicate that the grain size of cassiterite in the three soil types and in different profiles varies considerably. This results from differences in the sources from which the cassiterite was derived, which in turn reflects the depositional environment of the primary deposit. Coarse-grained cassiterite and nodules are restricted to soils derived from greisens and pegmatite veins, whilst finer grained cassiterite is derived from altered and unaltered granites.

In the **residual soils** (Fig. 7-6) the sand fractions give the most consistant distribution patterns. This reflects the grain-size of the primary cassiterite. The gravel (eg. profiles 2, 12, 26, 27, 29 and 31) and the silt-clay fractions (eg. profiles 2 and 12) are thus not always representative sampling media.

Due to the grain-size of cassiterite in the greisens, the gravel fraction could well be the optimal size fraction for soils overlying the massive greisens. In this case, however,

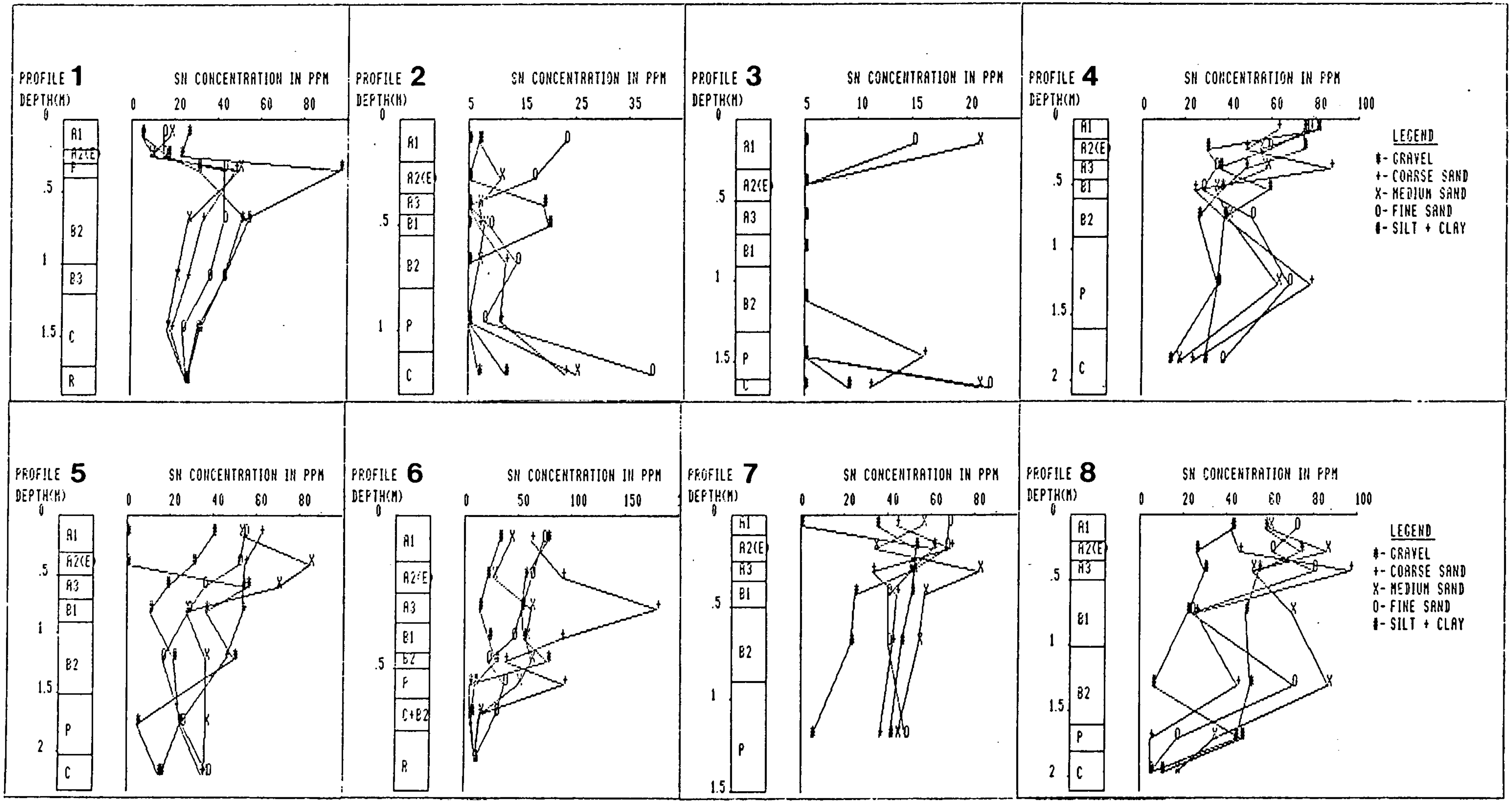


Figure 7-5: Distribution of Sn in size fractions in all 32 soil profiles.

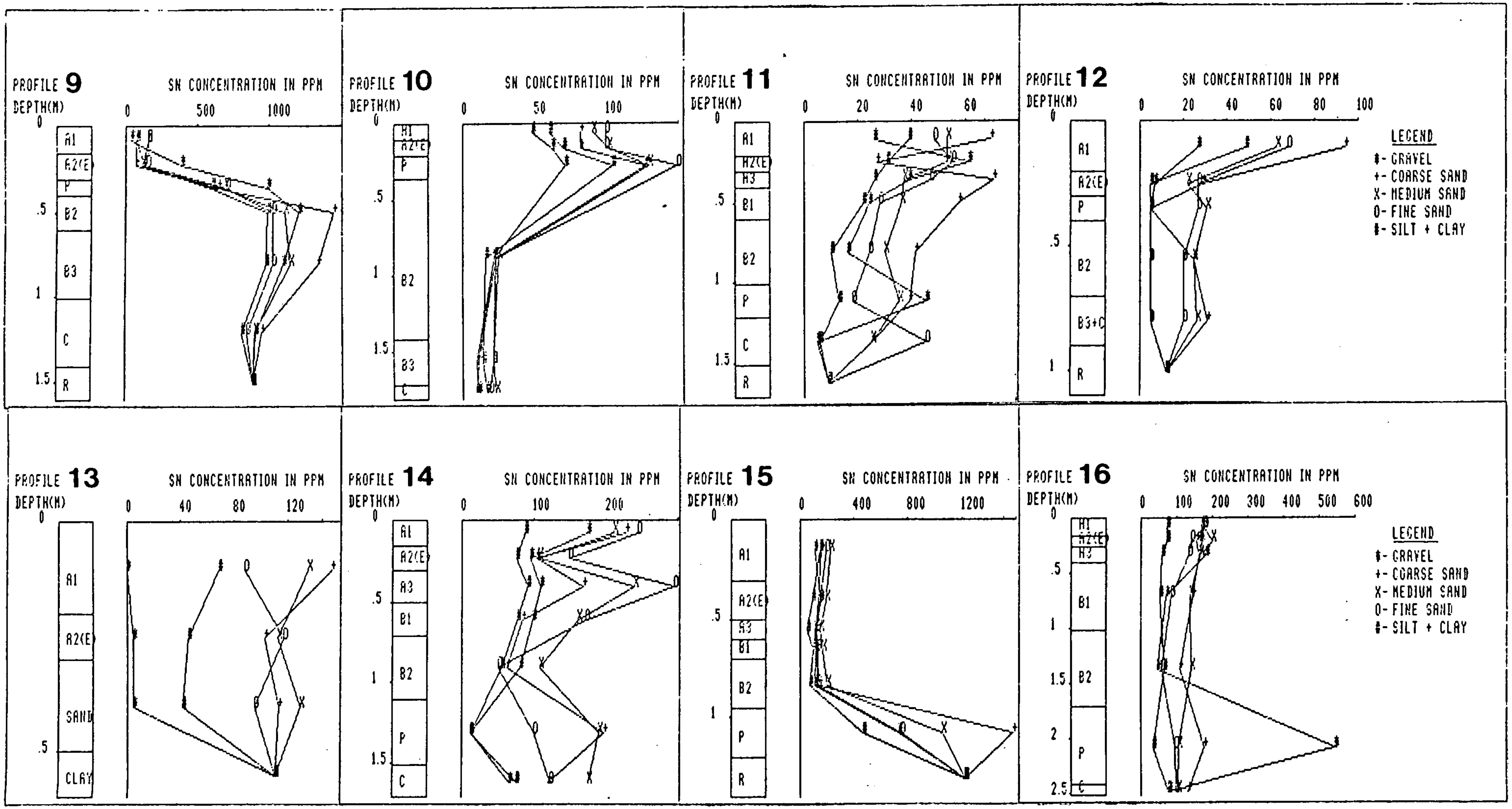


Fig. 7-5: (Continued)

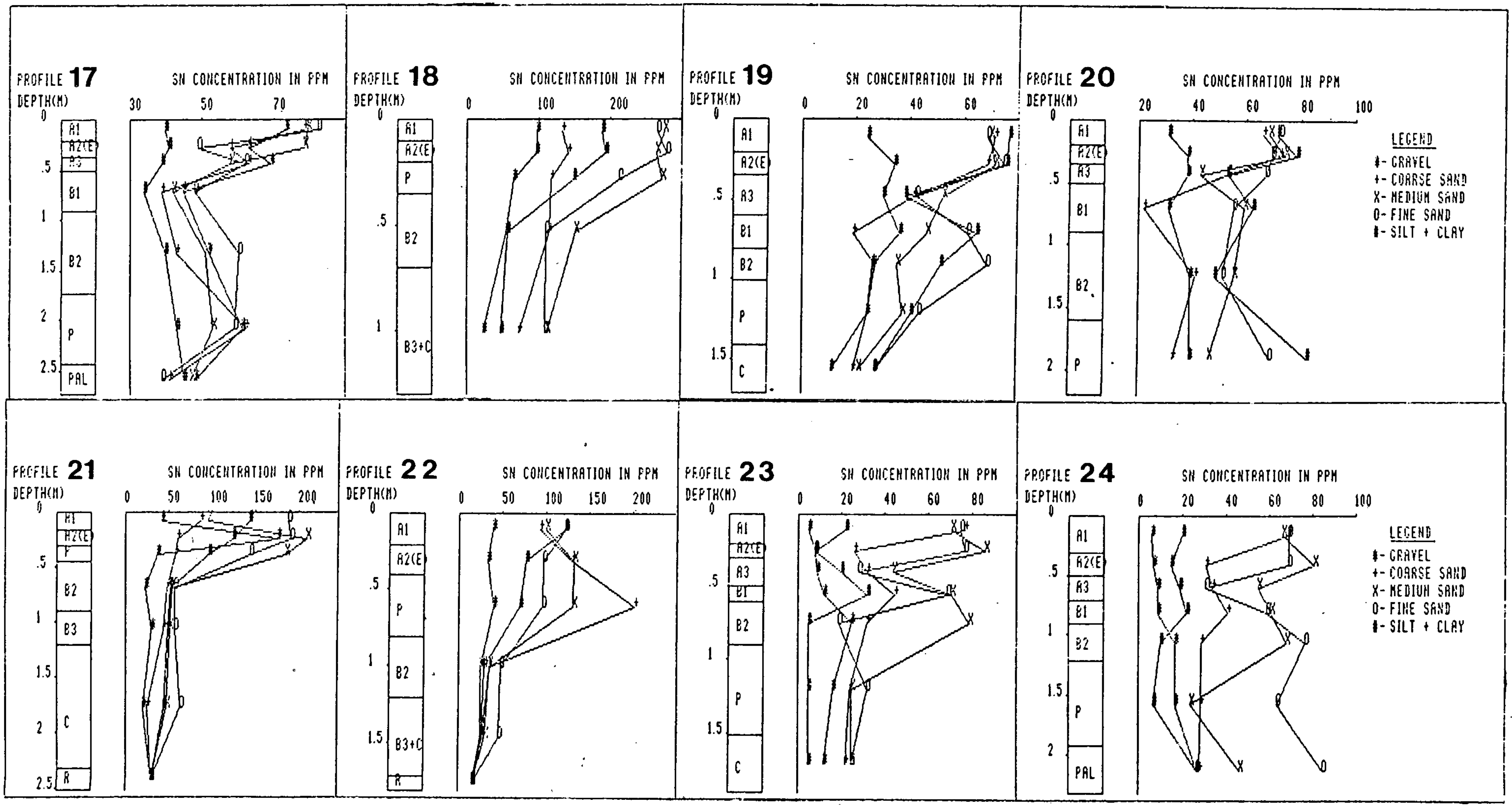
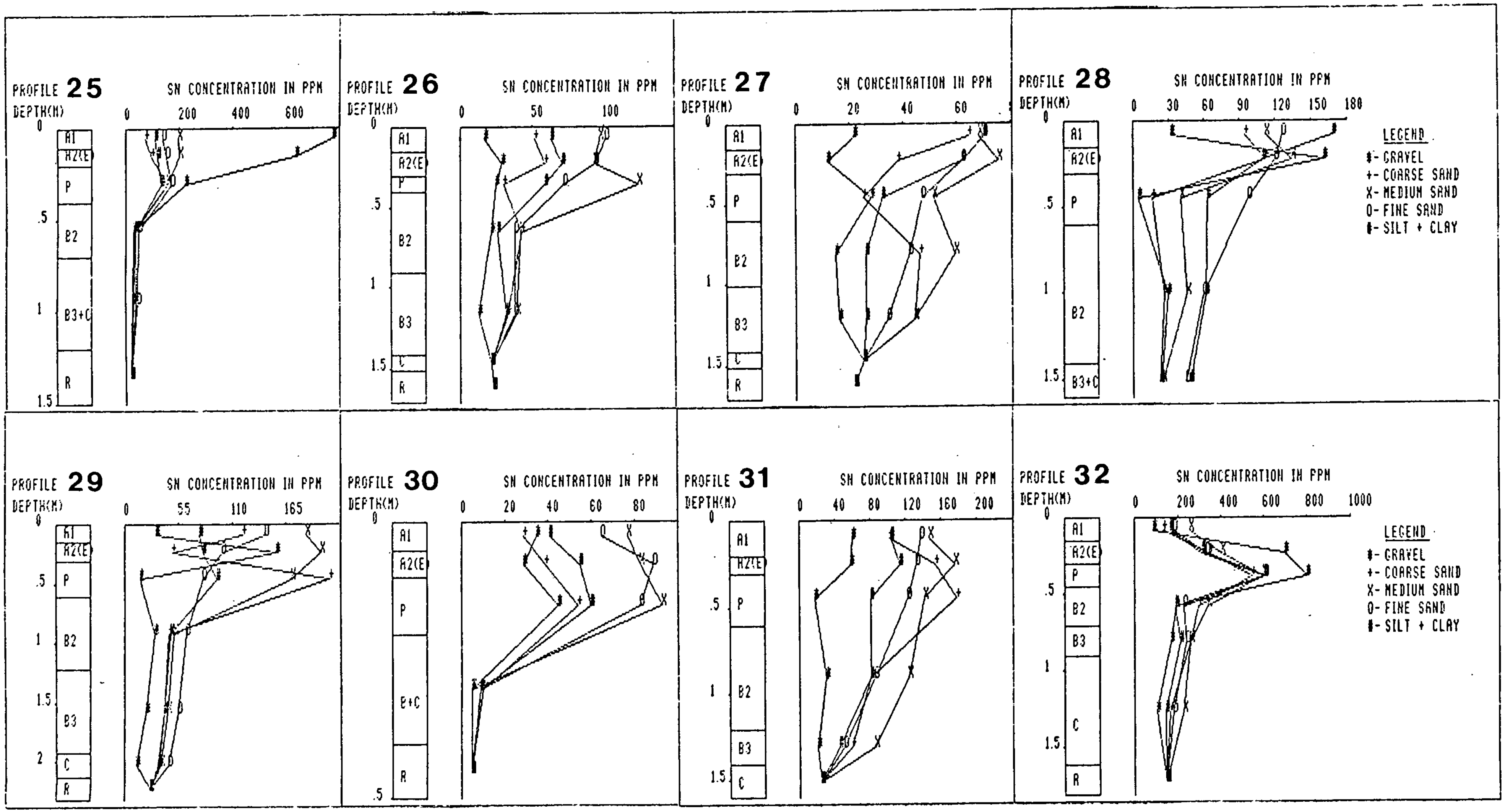


Fig. 7-5: (Continued)



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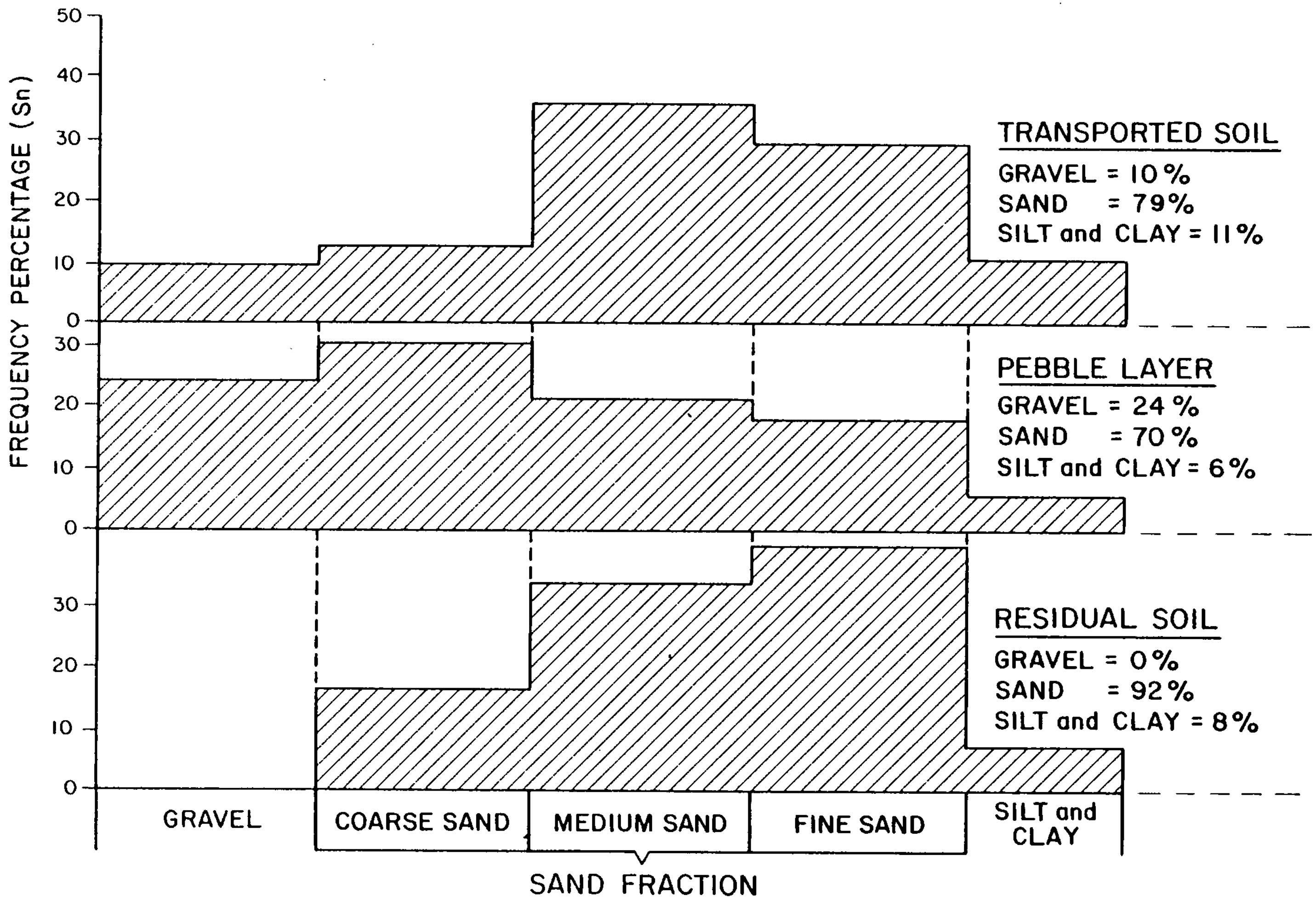


Figure 7-6: Grain-size distribution of cassiterite between fractions in the residual soil, pebble layer and transported soil (only the predominant size fraction for each zone is plotted).

the sand fraction may also be enriched in cassiterite.

The silt-clay fraction was the most sensitive in only two profiles and resulted from fine-grained cassiterite or sorbtion onto iron oxides and clay minerals. As a result the sand and silt-clay fraction together, should give a total coverage of all possible cassiterite deposits and are therefore recommended. Exclusion of the gravel fraction would minimise dilution and therefore overcome the analytical sensitivity problem in the determination of Sn.

Residual soils should be able to localise a mineralised zone accurately since it is still **"in situ"**. During a broad pilot study the horizon sampled would not make any serious difference in determining mineralised areas but in a detail programme it would. For cassiterite the eluvial zones will be more optimal, but mixing of eluvial and illuvial horizons will have disasterous consequences.

The lower part of the C horizon which is the most continuous and in which eluvial enrichment of cassiterite has taken place and illuviation is minimal, would obviously be the best choice.

The **transported soil** above the pebble layer is marked by lower energy conditions causing size grading. This results in a large variation in the grain-size of cassiterite with the mode in the medium fractions (Fig. 7-6). The variation in the grain-size results from differences in sources, changes in energy conditions and comminution of cassiterite grains during transportation.

The minus 2 mm fraction includes approximately 90% of the predominant cassiterite fractions (Fig. 7-6). Fragments of greisen cause Sn enrichment in the gravel fraction (profile 25). A bulk sample of transported soils would include all cassiterite but might not show small anomalies well because of dilution.

Transported soils indicate regional geochemical anomalies but not localised ore. Distribution patterns in this case are extremely difficult to interpret because depositional conditions, directions of movement etc. have to be considered as well.

in restricted drainage areas the soil unit as a whole could be used to find directions of transportation depending on the cassiterite grain-size.

The **pebble layer** shows a variation in the depositional energy which is controlled by the topography. This causes a large variation in the grain-size distribution of cassiterite and is even more restrictive due to different sources, the depositional energy and the degree of comminution. The transported to residual soil ratio and the concentration of Sn in the transported and residual fractions respectively are just as important. More residual material is expected in the lower part of the pebble layer which would therefore give a better indication of the underlying rocks. Cassiterite is thus evenly distributed in all of the size fractions (Fig. 7-6).

A bulk sample from the lower part of the pebble layer would thus reflect all variations, but quartz dilution will cause poor results. The ratios of Sn concentrations between the lower part of the pebble layer and the residual soils could also be used for lateral tracing. When tracing against the direction of soil transportation, a >1 ratio indicates that the source is still further upstream whilst a <1 ratio means that the source has been passed. A cut-off point is expected above the source.

The gravel fraction in the pebble layer can contain large amounts of cassiterite (profiles 1, 16 and 25) mainly as coarse cassiterite which on the upper palaeo-slopes reflects the mineralised zone accurately and in some cases is the optimum sampling medium. The outwashed cassiterite which is redeposited on the lower palaeo-slopes reflects increased distances of transportation (Fig. 7-7) and a study of the grain-size distribution (population) of cassiterite on the palaeo-slope presents an exellent exploration technique. Every size fraction with its respective Sn concentration should thus be plotted on a histogram where cassiterite added from a new source would be recognised due to a different population trend. The size of the goethite pellets, containing sorbed Sn may influence the result to a lesser extent.

The pebble layer and especially the lower part is considered to be the most effective sone for lateral tracing of cassiterite,

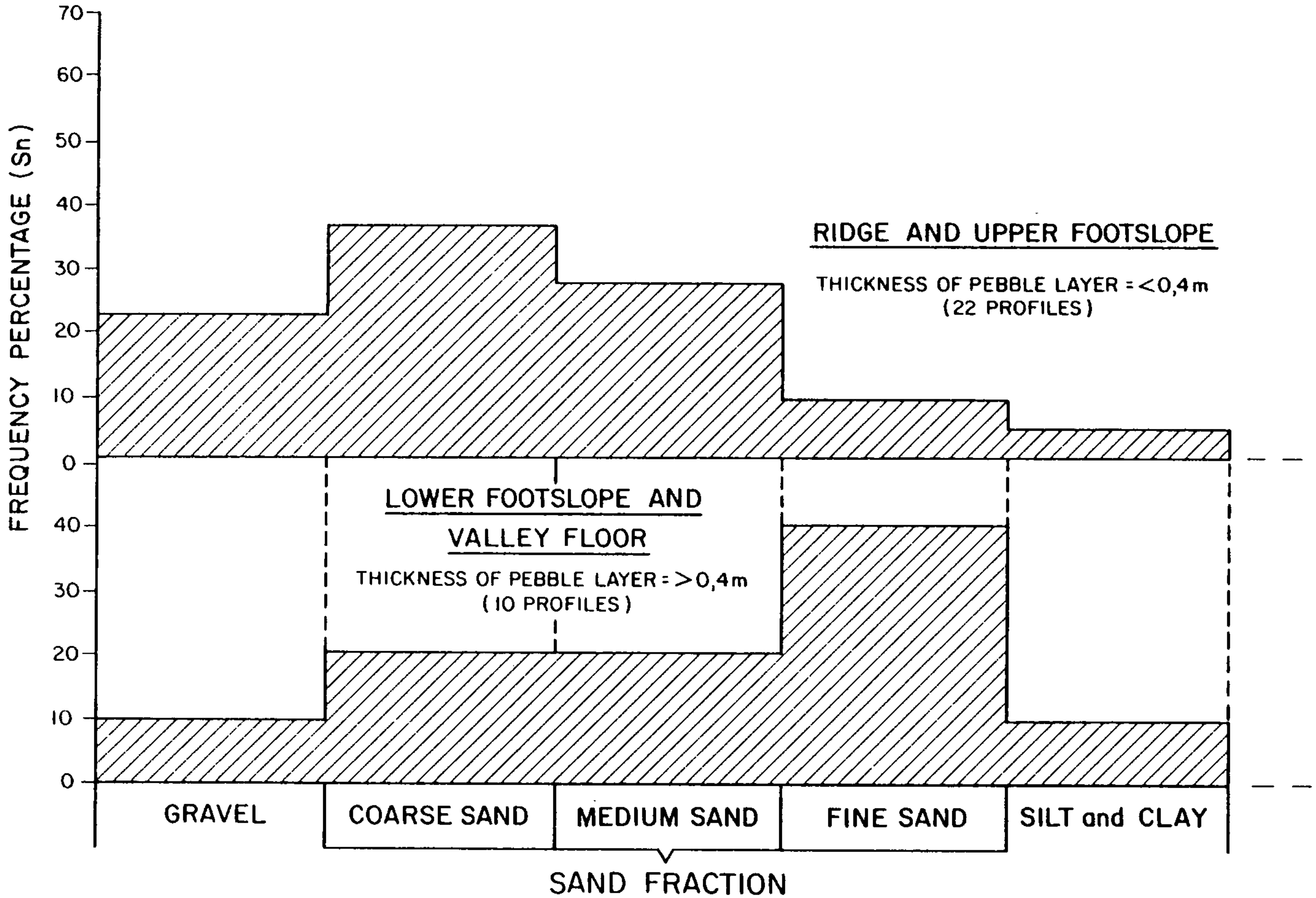


Figure 7-7: A comparison of the grain-size of cassiterite on the ridge and upper slopes with that on the foot slopes in the pebble layer (only the predominant size fraction is plotted).

provided that it is not underlain by palaeo-colluvium.

7.2.2.2 Copper

Because of the coherence of Cu with Fe in the oxidised zones (Fig. 7-8), it is expected that Cu-enrichment always takes place in Fe-rich zones. This type of enrichment could be non-significant or significant depending on the relative sorptive capacity of the Fe-oxides. The latter obviously depends on the type of Fe-oxide phase, its size, shape and genesis.

The raw data (Appendix A) shows that Cu and Fe are strongly enriched in the silt-clay fraction in most horizons and occasionally in the gravel fraction. In the gravel fraction, enrichment is due to goethite pellets on which Cu is sorbed (Table 7-2). Correlation diagrams in Appendix F, show that a linear correlation between Cu and Fe^{+3} (total Fe as Fe_2O_3) exists in the sand and silt-clay fractions, indicating that the Cu content in a specific soil fraction under oxidising conditions is a function of the Fe^{3+} content.

It is thus clear that the use of Cu in any size fraction of any horizon is dependent on the ability to distinguish significant and non-significant anomalies. One approach could be to assume that Fe-oxides have a constant sorptive capacity for Cu. By correcting the Cu concentration for the Fe_2O_3 (total Fe as Fe_2O_3) content after an emperical Cu-sorbtion factor has been calculated, a residual Cu anomaly would then indicate true Cu enrichment above background.

The correlation diagrams (Appendix F) show that the Fe/Cu ratio and therefore also the Cu-sorptive capacity of total iron as Fe_2O_3 varies in different zones and also between soil fractions in a specific zone. The higher cut-off value (background) for Fe_2O_3 in the fines (Appendix F) causes a lower Fe/Cu ratio and a higher Cu-sorptive capacity and vice versa in the coarse fractions.

In Fig. 7-9 the amount of Fe_2O_3 (total Fe as Fe_2O_3) associated with a specific amount of Cu (e.g. 10, 20 and 35 ppm) in the different size fractions of different soil horizons are plotted.

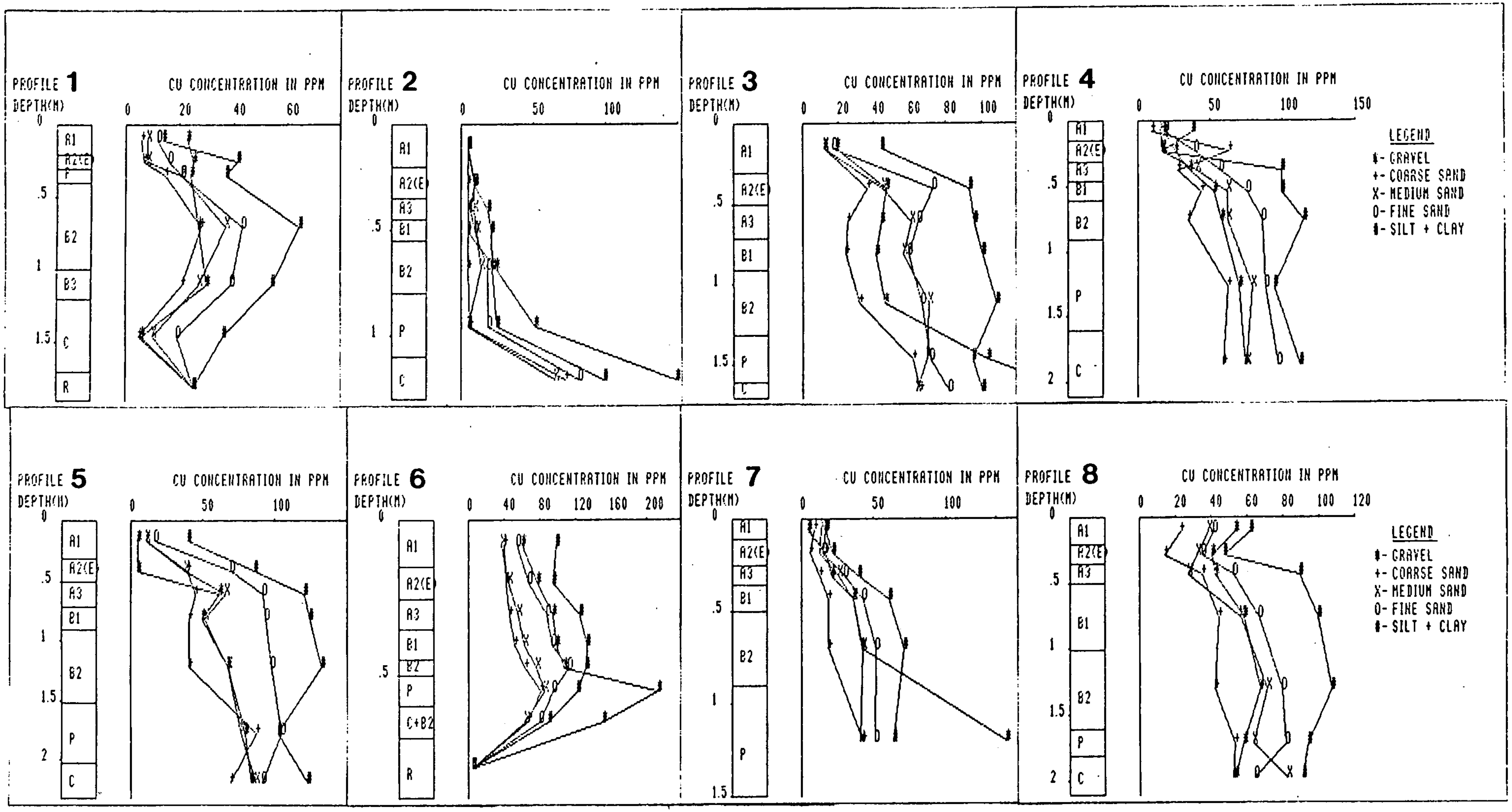


Figure 7-8: Distribution of Cu in size fractions in all 32 soil profiles.

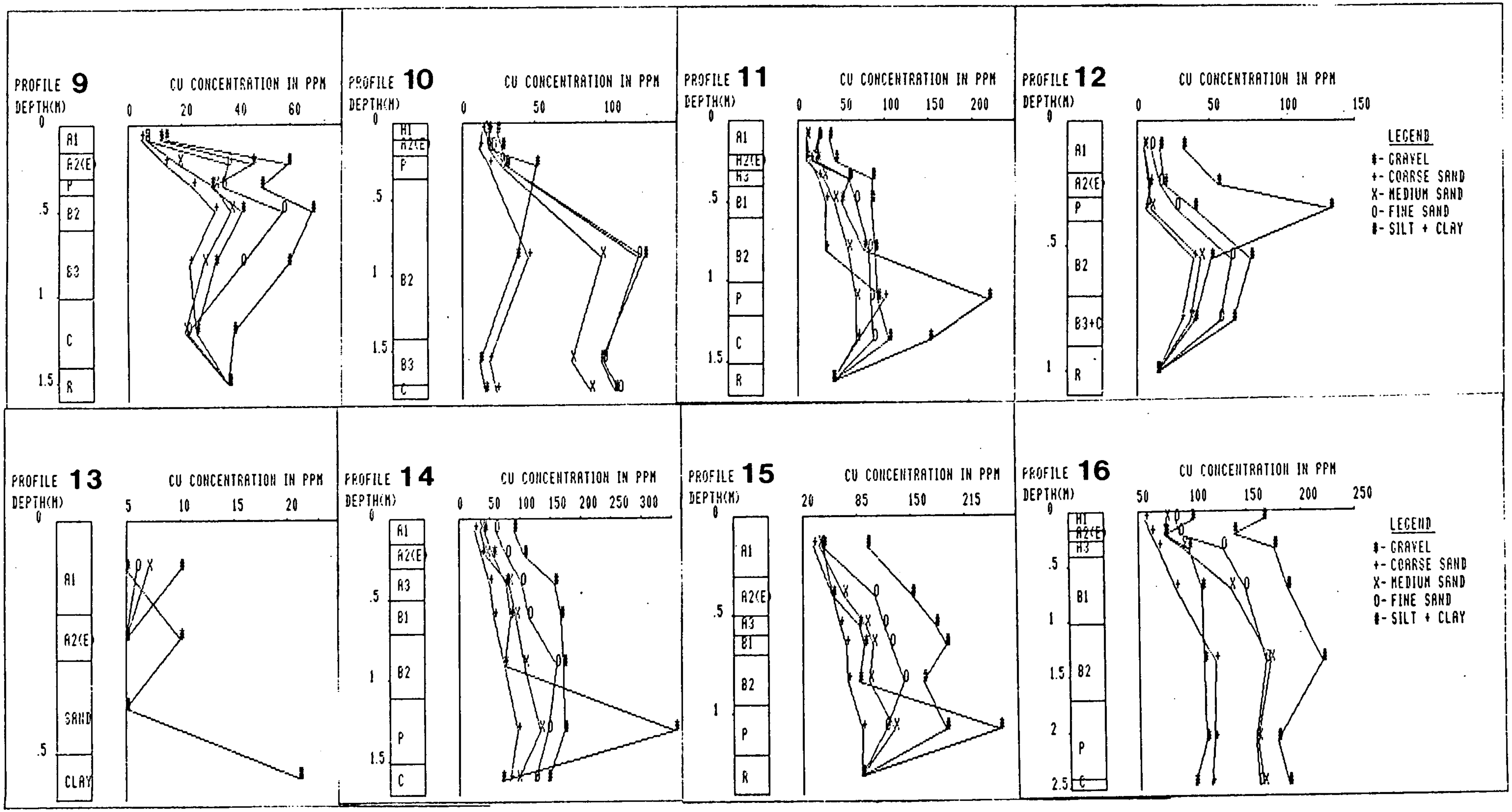


Fig. 7-8: (Continued)

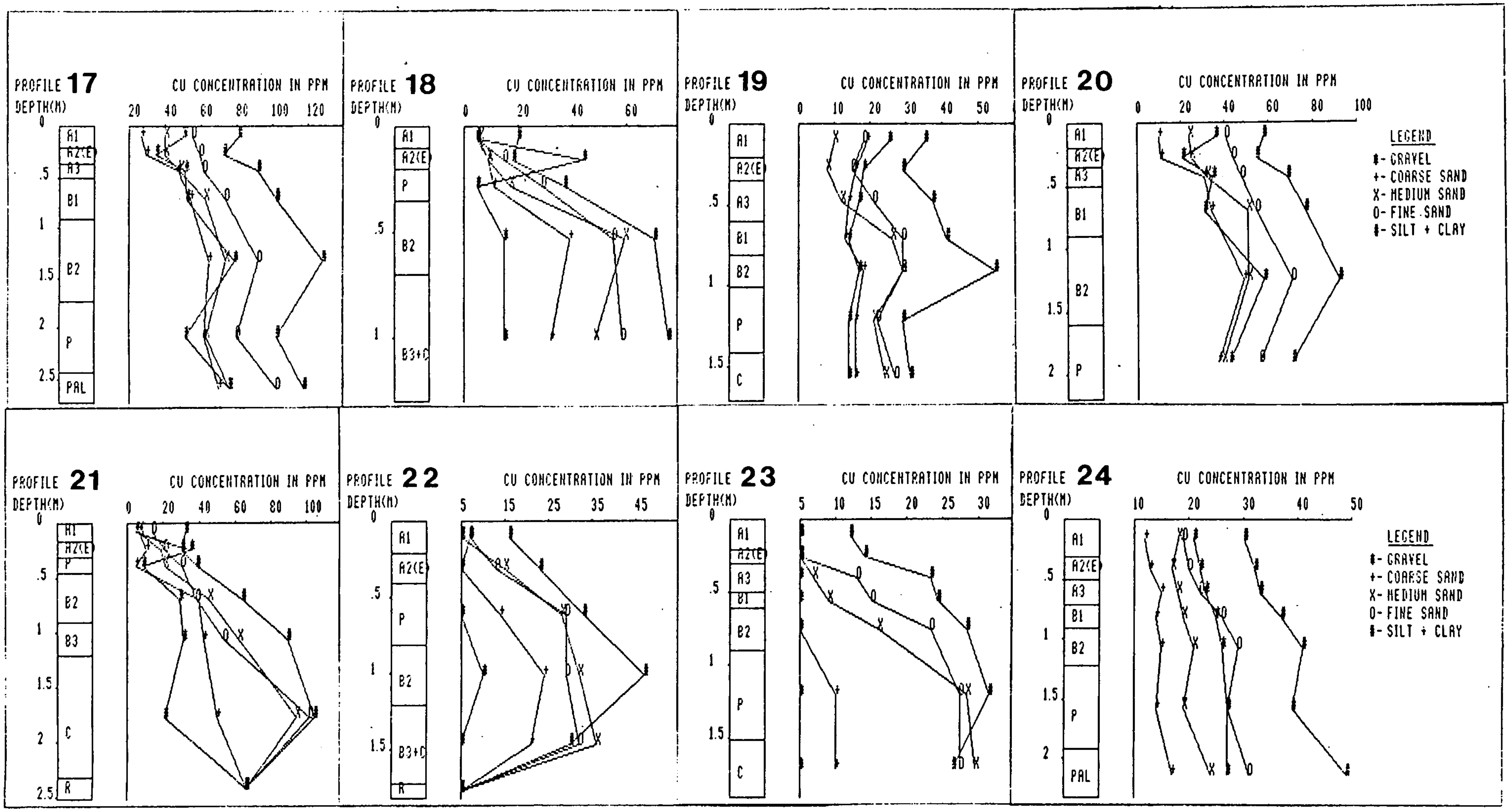


Fig. 7-8: (Continued)

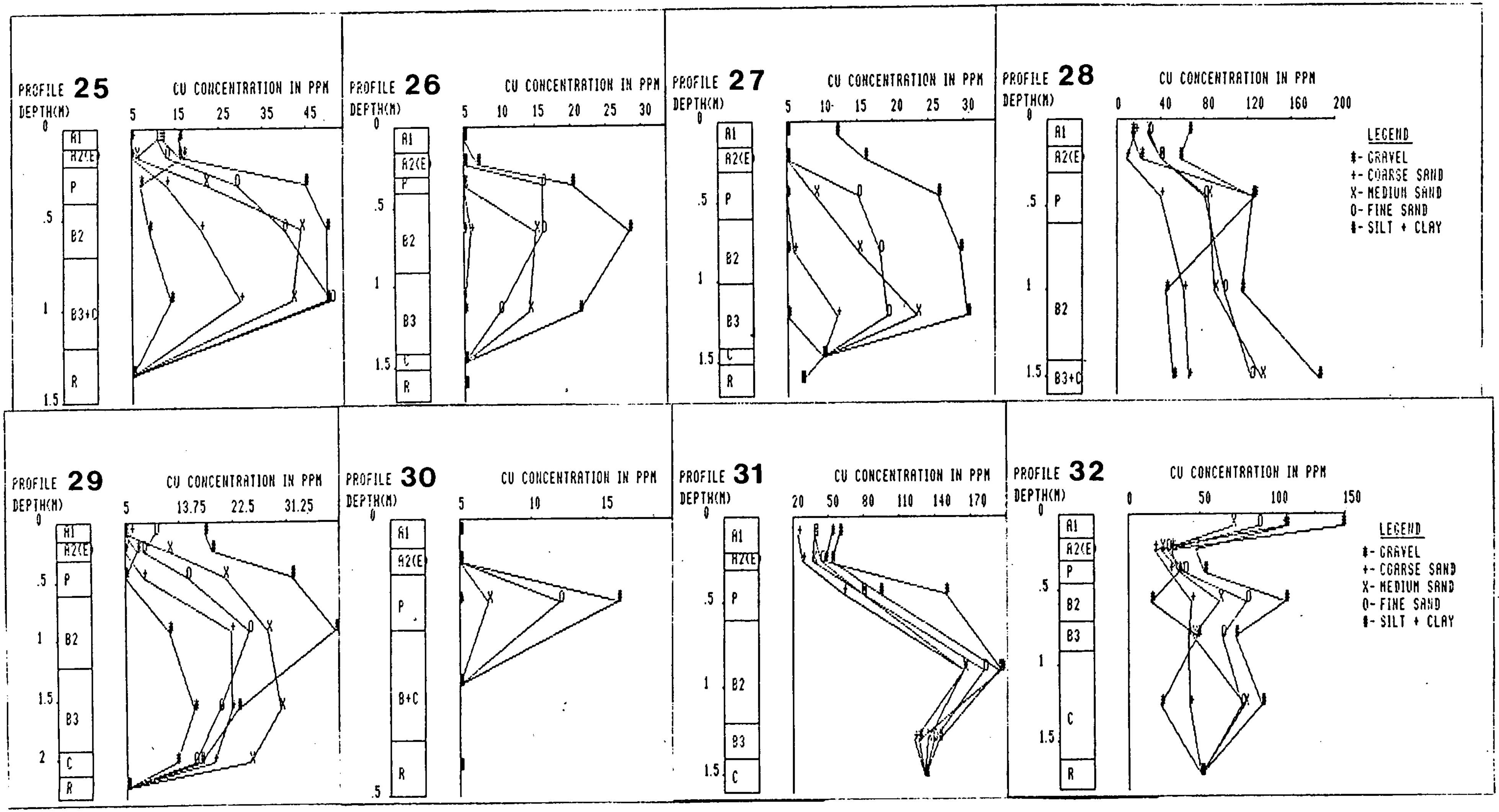


Fig. 7-8: (Continued)

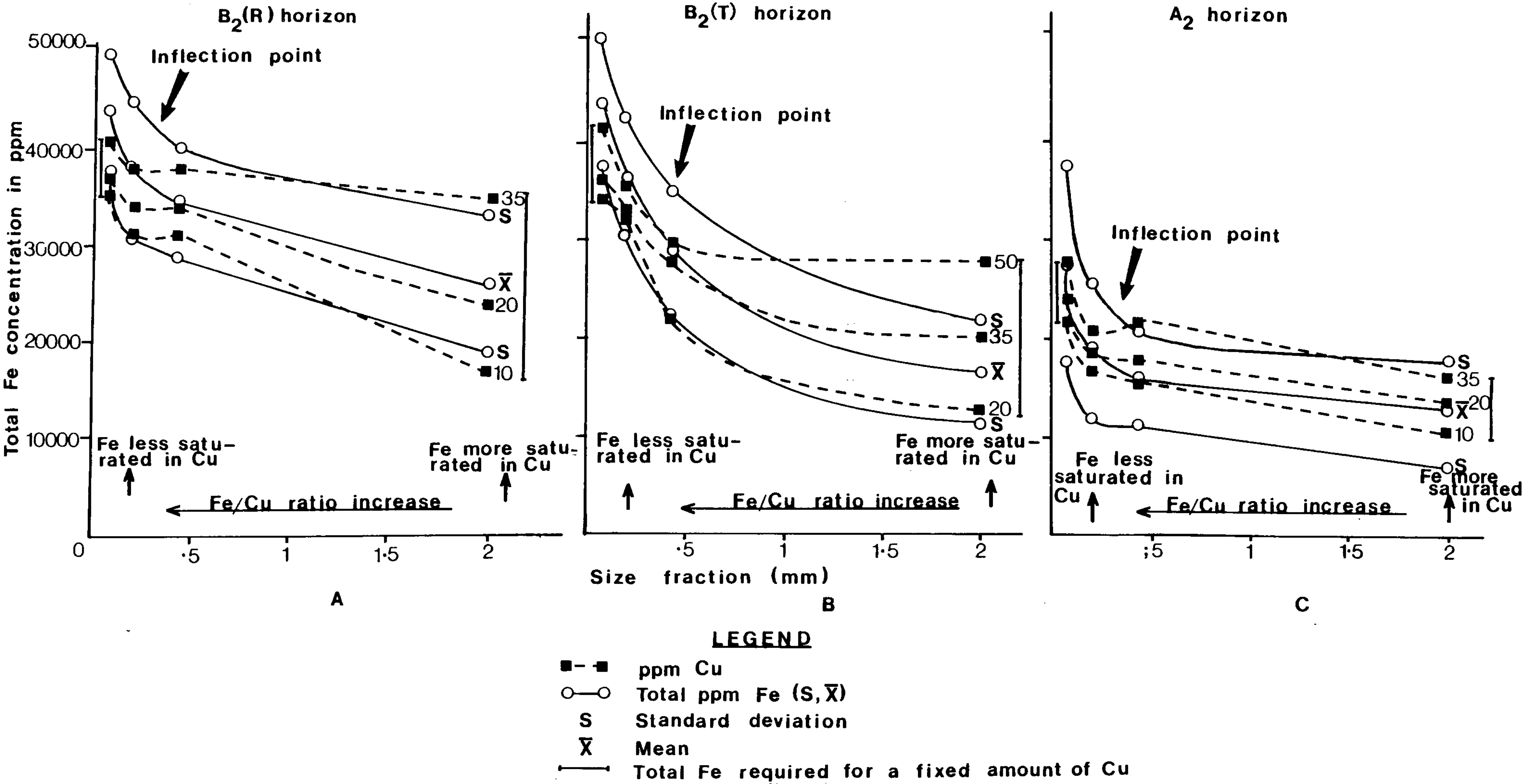


Figure 7-9: Diagram showing the varying relationship between available Fe (total Fe as Fe_2O_3) and fixed amounts of Cu between fractions in A) the B_2(R) horizon, B) the B_2(T) horizon and C) the A_2 horizon.

Simultaneously the mean and standard deviation of the Fe_2O_3 concentration in each size fraction are also plotted indicating the expected field of Fe_2O_3 variation. The increase in Fe_2O_3 relative to the Cu content in the finer fractions is evident, suggesting saturation of Cu in the coarse fractions and under-saturation in the finer fractions.

According to these diagrams it is clear that the Fe-sorptive capacity for Cu is lower in the coarse than in the fine fractions. This could be due to the finer partical size of the Fe_2O_3 particles in the finer fractions (Mason, 1966) or the Fe-oxide phase, its shape and genesis. The Fe-oxides in the coarser sand fractions therefore have lower sorptive capacities and are more Cu-saturated than in the finer fractions. The inflection points representing a change in the sorptive capacity in the finer fractions is probably the result of such a major change in the Fe oxide phase.

The Fe_2O_3 distribution pattern in the different size fractions of the three selected horizons varies markedly, showing a more intense inflection in the finer grained material of the eluviated A_2 horizon than in the illuviated B_2 horizon (Fig. 7-9). In particularly the coarser fractions of the three horizons a decrease in the Fe_2O_3 content is noticed from the B_2 horizon to the A_2 horizon which justifies some discussion.

Zones of illuviation show a gentle logarithmic increase in the Fe_2O_3 content from the coarse to the finer fractions. The extremes in the B_2(T) horizon (i.e. Fe_2O_3 strongly enriched in the silt-clay fraction but also strongly depleted in the coarse fraction) is the result of strong leaching conditions followed by the reprecipitation of iron oxides and clay minerals at a later stage. In the B_2(R) horizon strong leaching conditions were absent and therefore the coarse fraction still contains high concentrations of Fe_2O_3.

In the eluvial zone Fe_2O_3 increases very slightly from the coarse to the fine sand fractions, whilst the increase is considerable to the silt-clay fraction, especially at low concentrations. This results from the strong leaching in this part of the soil profile.

An investigation of the size fractions showed the following:

In the gravel fraction of the transported soils and the pebble layer, Fe-oxides are mainly present as goethite pellets and as coatings on the surfaces of mineral grains. In the residual soils the weathered feldspar contains iron oxides as coatings whilst goethite pellets are scarce.

In the sand fractions in the illuvial zones of transported soils the Fe-oxides form oolitic Fe-nodules and Fe_2O_3 coatings on mineral grains. The residual soils contain less Fe-coatings on minerals and more Fe-bearing weathered silicate minerals. Oolitic Fe-bearing nodules and ferruginised clay minerals increase from the coarse to the finer sand fractions, but are dependent on the effects of eluviation and illuviation in a specific zone.

In the silt-clay fraction Fe-oolitic nodules and encrustations on clay minerals are common. Coatings of Fe-oxide on resistant minerals were also observed.

Under leaching conditions Fe-encrustations are scarce whilst the available Fe concentrates in oolitic nodules and clay in the silt-clay fraction. This explains why less Fe_2O_3 is available in the sand fractions of the highly leached zones.

It is clear that both the concentration and manner in which the Fe-oxides occur, influence the Cu-sorption between fractions, although within the same fraction in the same zone it is fairly constant. By plotting the $(\overline{X}+S)$, $\overline{X}$ and $(\overline{X}-S)$ of the Fe_2O_3 (total Fe as Fe_2O_3) concentration against those of the Cu concentrations in the sand and silt-clay fractions in all the soil horizons (Fig. 7-10), the approximate sorptive capacity for Cu for each zone can be determined, reflecting the weathering conditions.

Both Fe and Cu are depleted in the eluviated zones but enrichment of Cu relative to the Fe_2O_3 in the A_1 horizon (especially in the coarser fractions) may also result from the sorption of Cu on organic constituents (Boyle and Dass, 1967).

The increase in the Cu-sorption from the coarse to the fine fractions, is pronounced in the eluvial zones and less

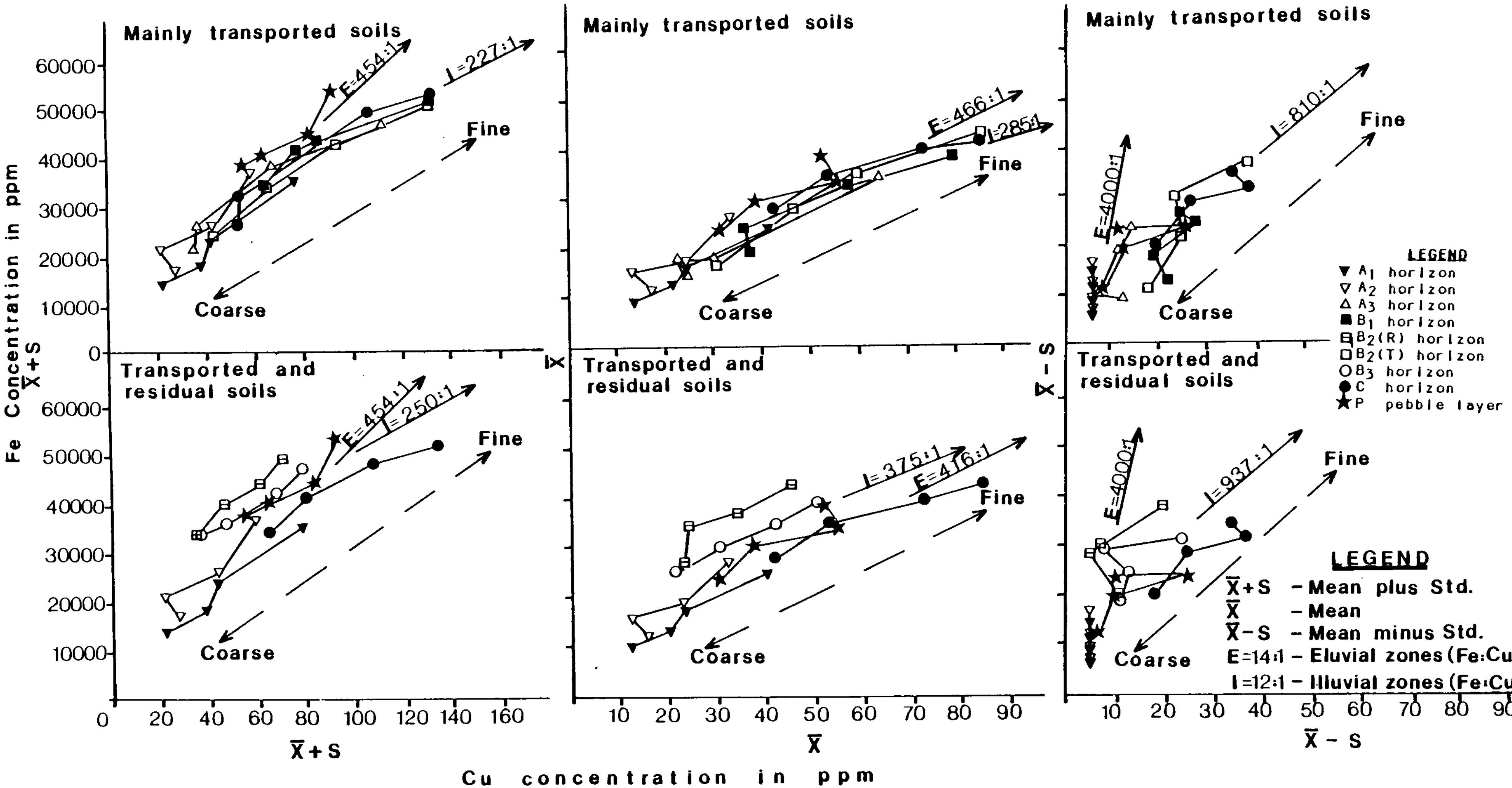


Figure 7-10: Diagram showing the varying Fe_2O_3/Cu relationship (sorptive capacity) between fractions for each horizon and eluvial and illuvial zones in general, using the mean and standard deviations (total Fe as Fe_2O_3).

so in the illuvial zones (Fig. 7-10). Leaching in the eluvial zones therefore caused more Cu enrichment with respect to Fe_2O_3 due to the fact that Fe_2O_3-coated mineral grains in the coarser fractions are more Cu-saturated, especially at low Fe_2O_3 concentrations. The higher the Fe_2O_3 content in a zone the more Cu-undersaturated the soils become.

The Cu is also enriched relative to the Fe_2O_3 in the illuvial zones of the transported soils compared to those of the residual soils (Fig. 7-10). The sorptive capacity is also higher in the illuvial zones of the transported soils than of the residual soils. This is probably a result of the fact that more Cu is available in the transported than in the residual material.

It is evident from the discussion above that a better understanding of the Fe_2O_3 and Cu relationships and the factors controlling them are essential to enable an accurate evaluation of the data. After correcting the Cu concentrations against the relative sorptive capacities of Fe_2O_3 for Cu, the excess Cu concentrations were plotted for the different size fractions against the individual horizons of 6 selected profiles in which Cu enrichment was expected (Fig. 7-11).

From the plots it is obvious that the gravel fraction shows strong but variable enrichment patterns in the transported soils and particularly in the pebble layer. The amount of goethite pellets could thus have influenced the excess amounts of Cu.

In order to minimise the effect of the sorptive capacity of Fe for Cu, individual goethite pellets can be selected from a specific horizon for Cu analysis. The sensitivity of these pellets for chalcophile and siderophile elements have been observed by Mazzuchelli and James (1966) and could thus provide an exellent sampling medium.

Of the other soil fractions, the silt-clay fraction is the most sensitive indicator of anomalous enrichment, but in the B_2 horizon in the transported soils the silt-clay fraction is strongly depleted and hence not a suitable horizon. Leaching followed by precipitation in the B_2(T) horizon is expected to be the reason for the latter.

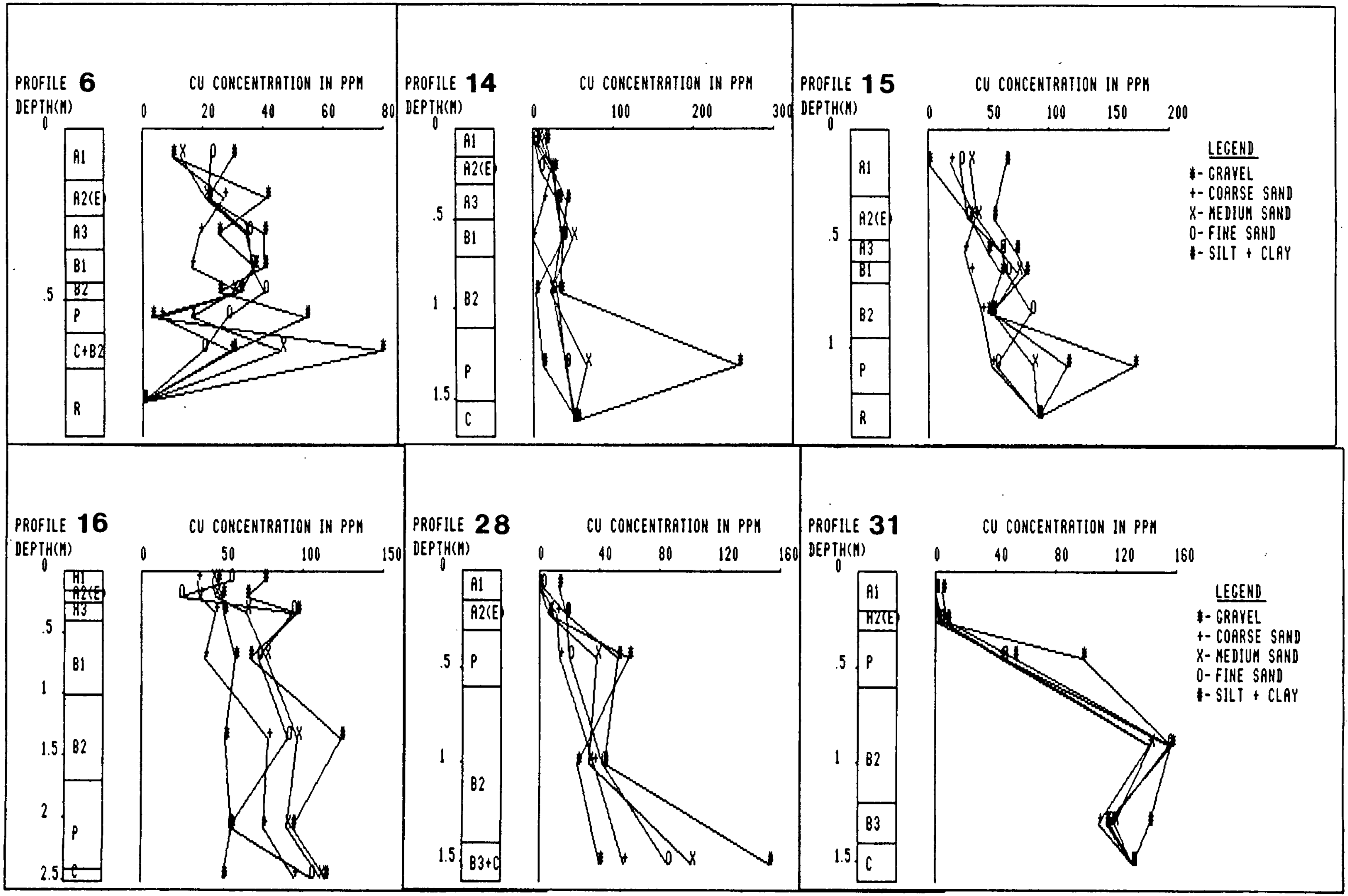


Figure 7-11: Diagram showing the distribution of Cu corrected for Fe_2O_3 (total Fe as Fe_2O_3) in the size fractions of 6 profiles.

The actual Fe-concentrations for each fraction in the horizons of profile 14 plotted against the calculated mean and standard deviations for total Fe as Fe_2O_3 in that horizon (Fig. 7-12) prove the latter. Fig. 7-12 shows that the deviation is a result of Fe_2O_3 ratios between fractions that deviate from the calculated. The more Cu-undersaturated fine fractions (especially in the illuvial zones) are, the more vulnerable they are to over or under compensation which then results in abnormalities.

The more Cu-saturated coarser fractions are less affected by enrichments due to redeposition. The expected Fe-concentrations for the finer fractions in a specific horizon can thus be interpolated from the coarse fractions, parallel to the calculated ratios used for Fe_2O_3 compensation. If the over or under compensation is then corrected, using the interpolated Fe_2O_3 value, the silt-clay fraction is also the most sensitive parameter in the B_2(T) horizon (Fig.7-12). Such over and under compensations in the silt-clay fraction is, however, only expected in the zones where strong irregular Fe_2O_3 enrichment took place between fractions after leaching, such as the illuvial zones occurring in the transported soils.

Depletion of Cu in the fine sand fraction of the eluvial zones also results from irregular leaching conditions causing disequilibrium in the Fe_2O_3 ratios. Under leaching conditions the oolitic Fe-nodules and the Fe_2O_3 rich clay particles are concentrated in the silt-clay fraction. When the fine sand fraction is enriched in chemically precipitated Fe_2O_3, due to weaker leaching conditions, disequilibrium is reached resulting in similar deviations. If Cu is then normalised for Fe_2O_3, assuming the latter to be due to coatings, whilst oolitic nodules and ferruginised clay particles occur, over compensation results. The fine fraction is thus the easiest effected by eluviation and illuviation, causing disequilibrium.

Corrections for all the zones in profiles 14 and 31 (Fig. 7-13) indicate that the silt-clay fraction is always the most sensitive soil sampling parameter, if the Fe_2O_3 is absolutely compensated for. This will apply in the **residual** and **transported soil** as well as the **pebble layer.**

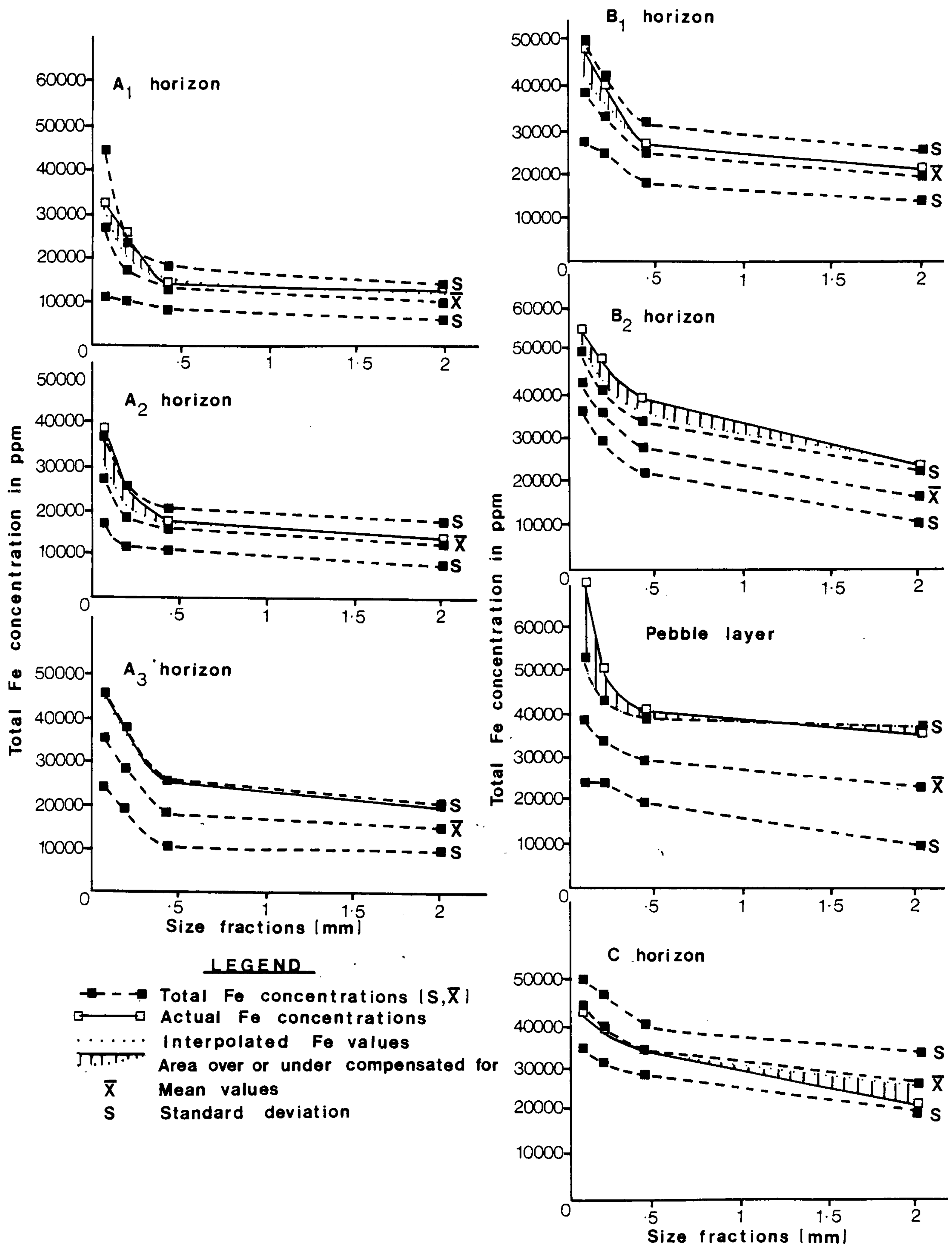


Figure 7-12: Diagram showing some over and under compensations for Fe_2O_3 in the horizons of profile 14 using the calculated sorptive capacities(total Fe as Fe_2O_3).

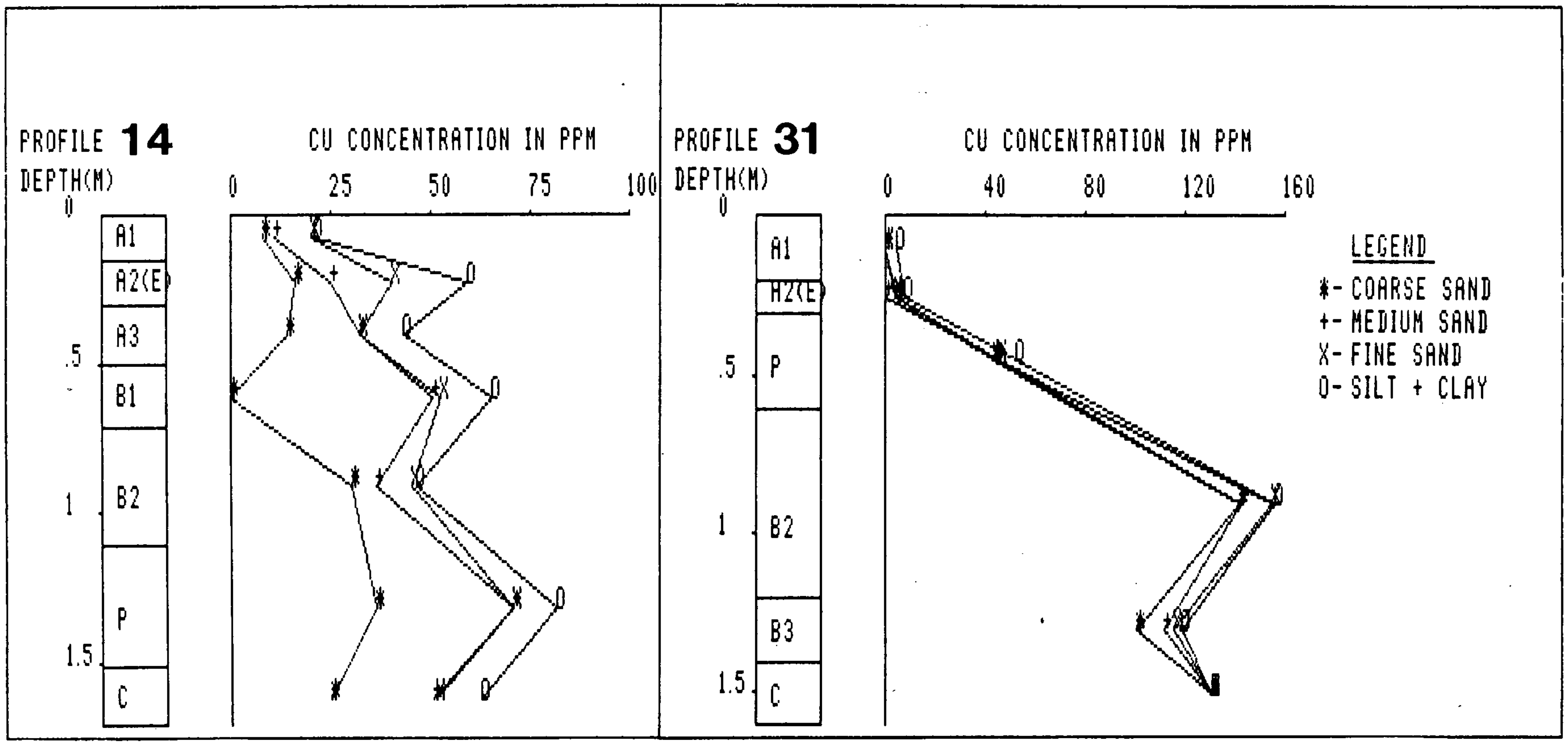


Figure 7-13: Diagram showing the distribution of Cu absolutely corrected for Fe_2O_3 (total Fe as Fe_2O_3) in the size fractions of profiles 14 and 31.

Whilst it is possible to use the silt-clay fraction in an exploration programme, Fe-rich oolites could also be used effectively, especially in the pebble layer but possibly also in all other zones. Since Fe accretion in oolites is controlled by rather restricted chemical and mineralogical parameters, it is expected that the sorptive capacity for Cu would vary within rather strict limits.

In the residual soils overlying Cu-mineralisation (profile 31), the B_2(R) horizon is the most sensitive with the C horizon the second best. Enrichments of Cu in the B_3 and C horizon of profile 28 could result from lateral Cu enrichment due to the lateral moving groundwater from the Cu-bearing pegmatite veins, slightly upstream at profile 31. Lateral enrichment is the most confusing and difficult factor to evaluate if Cu is used in exploration. In profile 6 a false Cu anomaly is obtained due to these influences.

Therefore, if Cu is used laterally, a continuous zone in the residual soils is preferred. The zone of maximum lateral movement of groundwater (lower part of the C horizon) appears to be a useful parameter in tracing an ore-body on a lateral scale and also for locating the ore. The C horizon is usually the only continuous zone and allows anomalous Cu values to be traced upstream. It is essential to use the lower part of the C horizon because relicts of the mottled and pallid zones are still expected in the upper parts of the C horizon on the middle and footslopes (Fig. 3-12).

In transported soils Cu-enrichment is almost purely a result of lateral redistribution (profile 31). The irregular Cu-enrichment between fractions in transported soils complicates the interpretation of data considerably. The A_1 horizon gives the most consistent results, even if it is not the most sensitive. This is probably due to Cu adsorbed on organic material (Boyle and Dass, 1967).

In the pebble layer the goethite pellets offer the best alternative as a lateral tracer but the silt-clay fraction could also be used from this zone.

7.2.2.3 Molybdenum

Molybdenum is chalcophile or siderophile (Levinson, 1980) and mobile as the $MoO_4^{=}$-ion in oxidising, alkaline environments. It also correlates positively with Fe in the same fractions from the individual horizons. It is enriched in the gravel fraction showing an affinity for goethite. Ferrimolybdite is the likely host mineral phase in the goethite pellets, where the Fe^{3+} is inclined to restrict its mobility (Levinson, 1980). The concentration levels of Mo are so small that no correction for Fe_2O_3 is necessary and any Mo value obtained is anomalous.

The silt-clay fraction is a sensitive parameter for Mo-enrichment (Fig. 7-14), but if goethite pellets are present in the gravel fraction (profiles 9 and 11), this is the most sensitive fraction. A disadvantage is, however, the irregular distribution of the goethite pellets. The silt-clay fraction which is always present, is therefore the most universaly applied.

The ferrugenous B_2 horizons appear to be the most sensitive ones to use in the residual soils (profile 12). In most of the profiles, however, a B horizon is not present, making it less applicable. Enrichment of Mo in the C horizon of profile 9 is probably the result of lateral enrichment due to the movement of groundwater. For both lateral tracing and positional determination of mineralised zones, the lower part of the C horizon therefore is the most reliable sampling medium.

Transported soil is a poor sampling medium for Mo exploration. Enrichment is only present in the gravel fraction of profile 12. In the pebble layer (particularly the lower part) the sampling of goethite pellets allows a sensitive means of tracing mineralisation. This is the only zone in which goethite pellets are always present and consequently a reliable sampling medium.

7.2.2.4 Cobalt, nickel, zinc and lead

Cobalt, Ni, Zn and Pb behave the same as Cu and Mo in the soil profiles (Appendix G). It is thus expected that the parameters used for Cu and Mo should be applicable in the same horizons and fractions for these elements.

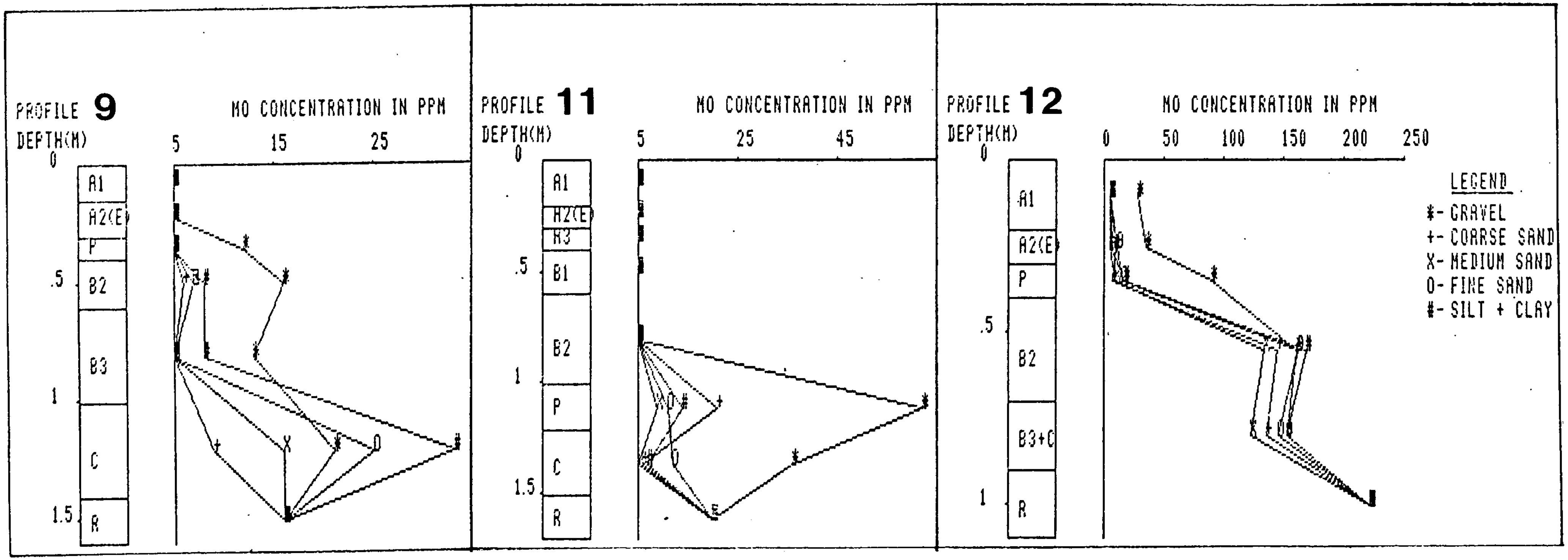


Figure 7-14: Diagram showing the distribution of Mo in the size fractions in profiles 9, 11 and 12.

Enrichment of Pb in the medium and fine sand fractions (profile 27) is probably the result of relatively stable cerussite or anglesite, in the soils. A sand plus silt-clay fraction can thus be considered in this case.

7.2.2.5 Lithophile elements

Rubidium, Sr and Ba which occur in nonresistant silicate minerals exhibit high mobilities during weathering and the clay minerals control the fixation of these elements. The highest concentrations are thus obtained in the silt-clay fraction where these elements are adsorbed on the clay minerals (Appendix G).

Since Rb is known to increase while Ba and Sr decrease with differentiation, the Rb/Sr or Rb/Ba ratios could be applied to establish the degree of differentiation of the bedrock. The Sr/Rb ratios show that Sr is more mobile than Rb and almost completely leached from the soils (Appendix G). The Sr/Rb ratio increases to the upper residual horizons. This is due to the fact that leaching of Rb is still active in these zones whereas Sr has been completely leached.

The Ba/Rb ratios (Appendix G) indicate that Ba and Rb are more in equilibrium, with the Ba being more mobile than Rb in the lower residual horizons, especially at high Ba concentrations (profiles 12, 21 and 26).

Considering the extremely high mobilities achieved by these elements, the lower part of the C horizon may give an indication of the differentiated zone in the bedrock. Comparing Rb, Sr and Ba values in a profile above the Makhutso Granite (profile 19) with one above highly differentiated granite (profile 9), the silt-clay fraction proved to be sensitive to enrichment and depletion (Fig. 7-15). The silt-clay fraction is enriched in Rb and depleted in Sr and Ba in the C horizon over the highly differentiated granite, compared to the less differentiated rocks. Optimum results for both Rb, Sr and Ba can therefore be obtained by using the silt-clay fraction in the lower part of the C horizon.

Similar behaviour patterns are shown by Y, Nb and Th. However,

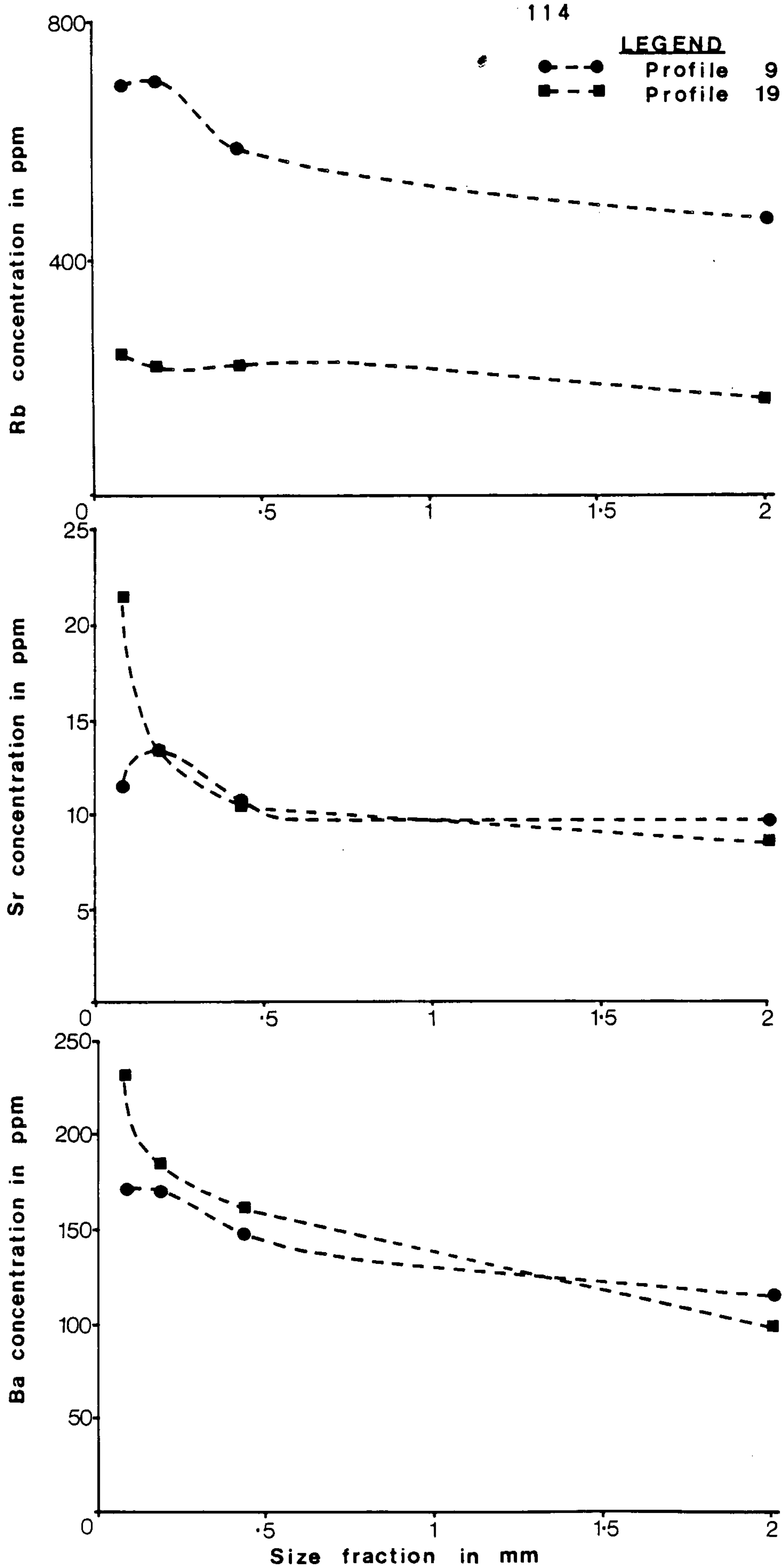


Figure 7-15: Diagram showing the relative enrichments and depletions for Rb, Sr and Ba in each size fraction between mineralised (profile 9) and unmineralised (profile 19) areas.

where these elements are also captured in resistant minerals, different distribution patterns are observed. Because of their inconsistant behaviour these elements are ignored for any further exploration purposes.

7.2.2.6 Elements associated with resistant minerals

Zirconium and Ti predominantly remain in resistant minerals (mainly zircon and ilmenite) and are enriched in the silt-clay fraction (Appendix G). Because cassiterite tends to be coarser than the zircon and ilmenite, it is inclined to be concentrated in any fraction.

Both Zr and Ti behave exactly the same as Sn in the profiles, except for the fact that they are concentrated in the silt-clay fraction. Lateral distribution of these elements are therefore not affected as seriously by variations in the energy conditions during redistribution.

The recommended horizons for sampling these elements are the lower part of the C horizon for positional determination and the pebble layer and possibly the A_1 horizon for lateral tracing. Fig. 7-16 shows that a general enrichment of both Zr and Ti occurs in the C horizon of a soil profile (11) above aplitic granites, compared to a profile (6) above a greisen lode which is generally depleted of these elements. The maximum enrichment is observed in the silt-clay fraction.

Because the C horizon shows the maximum enrichment pattern, it is recommended that this horizon be considered when investigating the distribution of the above elements.

Leachable P, V, Mn and U which are often associated with resistant minerals are also preferably fixed to iron oxides when leached. The inconsistent relationships of these elements with Fe_2O_3 in the profiles studied, excludes them for use in exploration even after corrections for Fe_2O_3 are made.

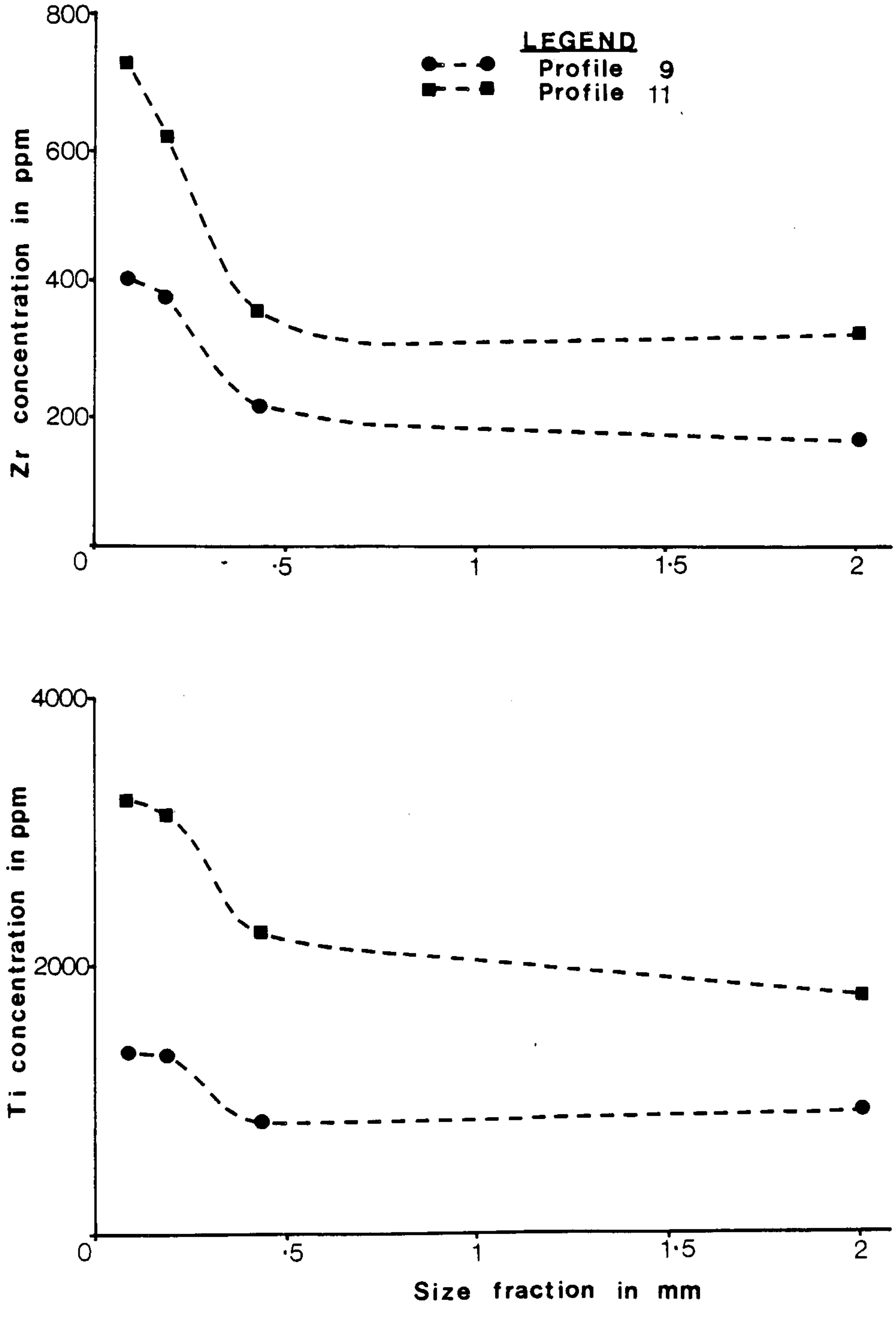


Figure 7-16: Diagram showing the relative enrichments and depletions for Ti and Zr in each size fraction between anomalous (profile 11) and depleted (profile 9) areas.

8 LATERAL GEOCHEMICAL WEATHERING AND DISPERSION PATTERNS IN THE SECONDARY ENVIRONMENT

The lateral dispersion patterns for Sn, Cu, Mo, Rb, Sr and Ba are evaluated by using the optimum horizons and fractions as determined in the previous chapter. Corrections due to the sorptive capacity of Fe_2O_3 have been made for Cu.

Concentration intervals as portrayed on the geochemical maps were determined by using the method of Sinclair (1974). The obtained populations should reflect either different rock-types or mineralised zones or both. Large populations are sudivided for optimum results.

For the pebble layer and C horizon, only values obtained from the prospecting pits were used, whilst for the A_1 horizon values obtained from the lateral traverses (Appendix H) were also included.

8.1 TIN

Residual soil: C horizon (sand + silt-clay fraction).
Three populations were distinguished (Fig. 8-1):

- Population C represents the background for Sn on unaltered and weakly altered granites.
- Population B shows altered zones enriched in Sn.
- Population A indicates intensively greisenised zones.

Pebble layer: (bulk sample).
Five populations were distinguished (Fig 8-2a) with:

- Populations D and E representing the background.
- Population C slightly enriched.
- Populations A and B enriched zones.

Grain-size distribution patterns.

The grain-size distribution of cassiterite is shown on a map using histograms (Fig. 8-2b). Enrichment of coarse cassiterite is evident in all the profiles in the mineralised zones. If the direction of soil movement is taken into account, definite enrichments of coarse cassiterite from known sources are perceived between profiles 27 and 31, 26 and 25, 15 and 32, 15 and 16,

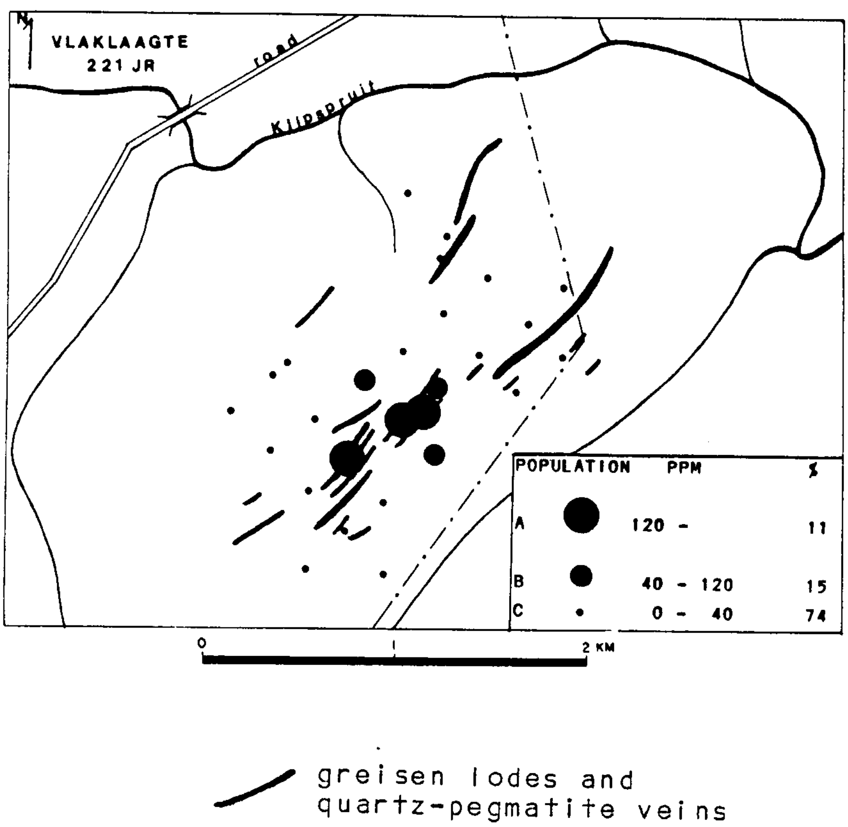
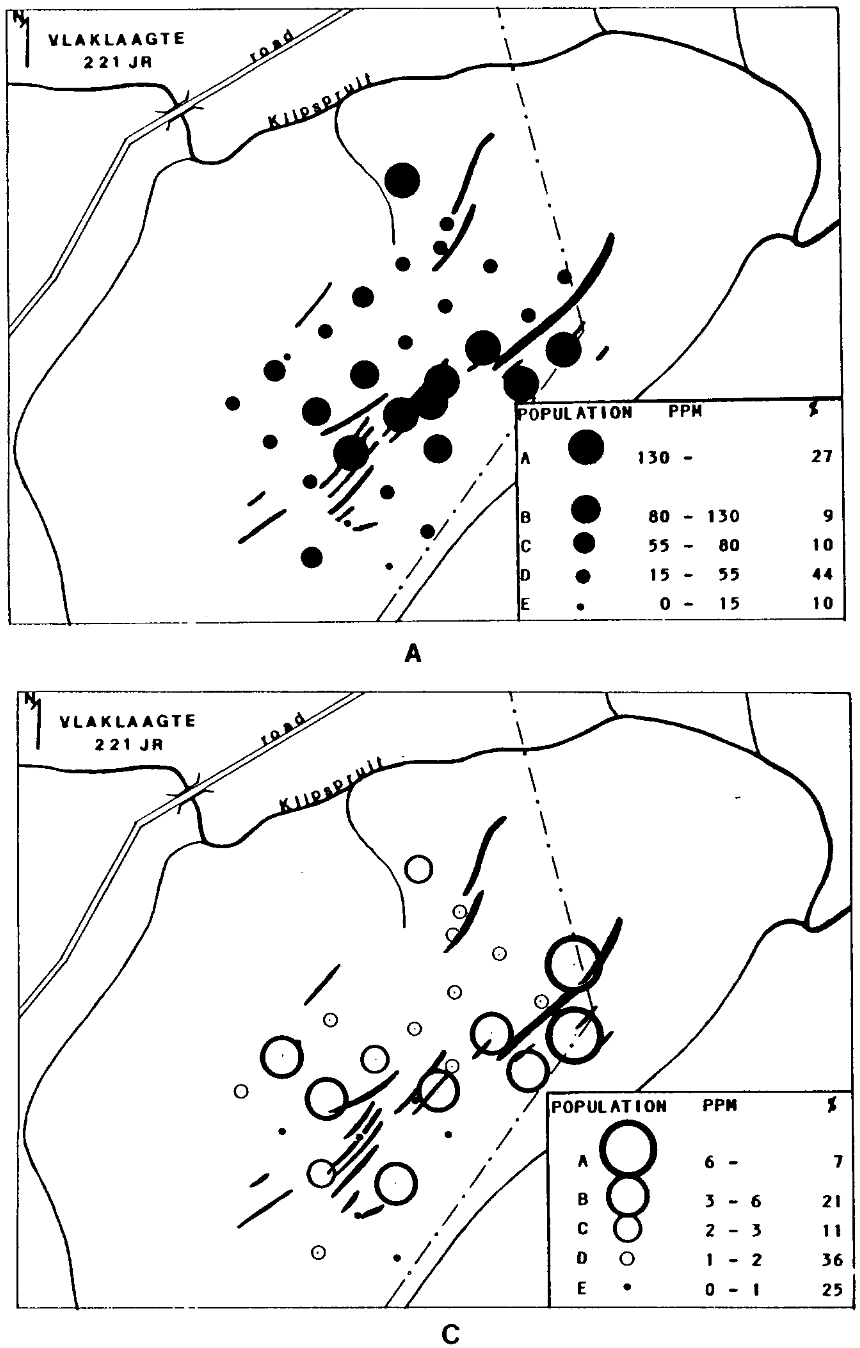


Figure 8-1: Geochemical map showing the Sn distribution in the C horizon (sand plus silt-clay fraction).



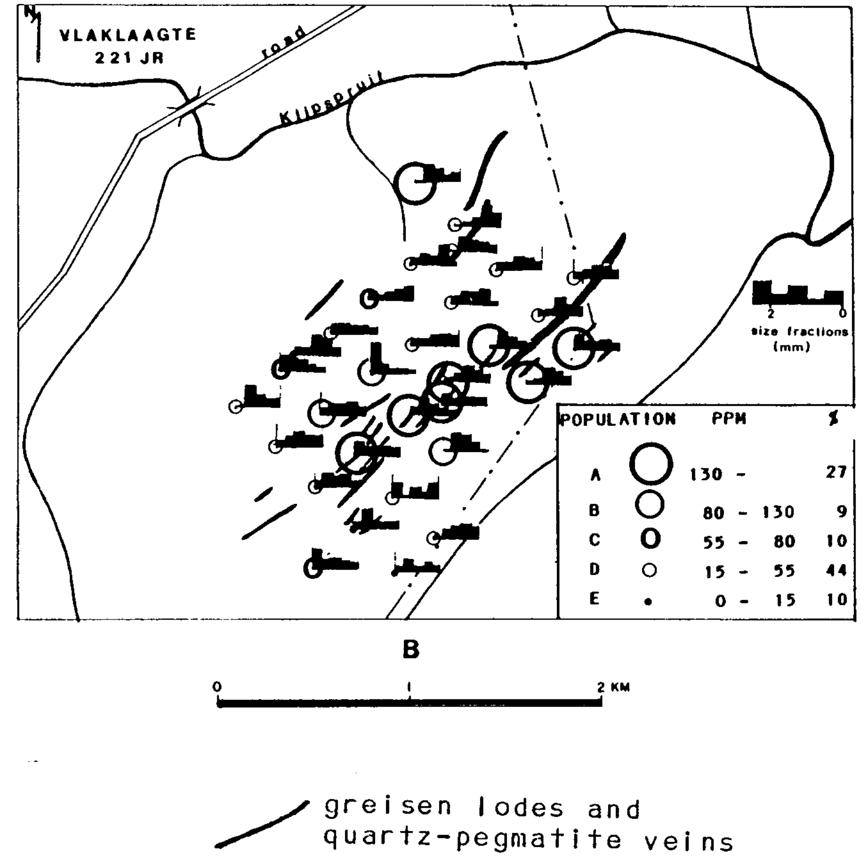


Figure 8-2:

Geochemical maps showing A) the Sn distribution in the pebble layer (bulk sample), B) the grain-size distribution patterns (grain-size populations) in the pebble layer and C) the Sn-ratio between the pebble layer and the top residual soils (bulk sample).

9 and 16 and also at profile 8. Enrichments from unknown sources are observed between profiles 5 and 6, 10 and 11 and also at profile 1. These results are even more meaningful when the concentration of Sn at each sample point is compared.

Ratio of Sn content between the pebble layer and the top residual zone : (bulk sample)

These ratios (Fig. 8-2c) give unsatisfactory results when not compared with the actual Sn concentration. If the concentrations in the zones are considered together with the ratios, mineralised zones can be identified.

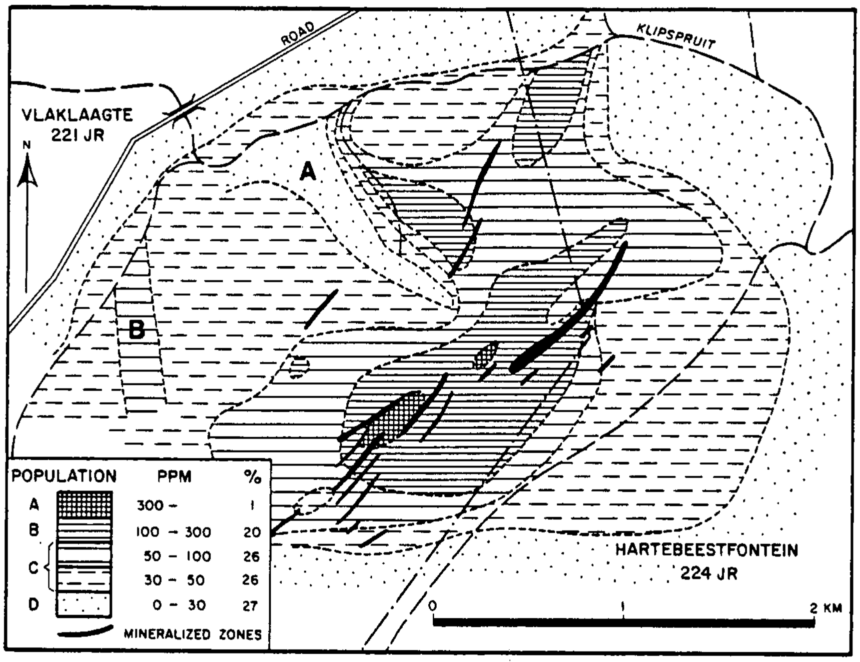
Taking the direction of soil movement into account, the same enrichment patterns than those obtained for grain-sizes are evident, although less significant.

Transported soil: A_1 horizon (bulk sample).
Four populations were distinguished (Fig. 8-3) with:

- Population D representing completely unmineralised zones in the granophyre and Makhutso Granite.
- Population C comprising the background in the mineralised area.
- Population B defining haloes around the mineralised zones for the greisens and quartz pegmatites.
- Population A defining the greisenised zones on the hill crest accurately.

8.1.1 Discussion

The distribution patterns in the A_1 horizon and the pebble layer give a broad definition of mineralised areas on the hill crest where the transported soils are thin and outcrops exist. Downslope, the patterns seem to be due to mechanical redistribution of cassiterite, causing a gradual decrease in both the concentration and the grain size, due to abrassion and dilution. The strip marked (A) in Fig. 8-3 is sandy with quartz the dominant mineral which dilutes the concentration of all other minerals including cassiterite. The anomaly at point (B) in Fig. 8-3 is expected to be the result of a source higher up on the slopes.



greisen lodes and
quartz-pegmatite veins

Figure 8-3: Geochemical map showing the Sn distribution in the A_1 horizon (bulk sample).

The A_1 horizon and pebble layer therefore cause false anomalies in the middle and lower slopes and terraces where thick layers of transported soils occur. The pebble layer is, however, regarded to be the most sensitive zone for lateral tracing, especially the lower part of the layer. Tin ratios between the pebble layer and residual soils present an even better lateral tracing medium, also enabling the positional determination of the source. Grain-size distribution patterns within the pebble layer give optimum results for lateral tracing and would also allow the detection of the source. A combination of these parameters ensure an exellent exploration technique using the pebble layer as illustrated in Fig. 8-4. Care should be exercised to ensure that the pebble layer is in direct contact with the residual soils and that the lower part of the pebble layer is sampled. If palaeo-colluvium occurs below the pebble layer, the zone in direct contact with the residual material should be used instead.

The C horizon reveals anomalous concentrations at profiles 9 and 15 where it is shielded by the transported soil. This horizon is regarded as the only zone that can be used to locate the exact position of a mineralised zone. Usage of the C horizon (particularly the lower part) in conjunction with the pebble layer is recommended for tracing and finding a mineralised zone.

8.2 COPPER

Residual soil: C horizon (silt-clay fraction).

Original values (unnormalised for Fe_2O_3).

Five populations were discerned (Fig. 8-5a) with:

- Population E confined to the unmineralised zones in the Makhutso Granite and granophyre.
- Population D restricted to latterally enriched unmineralised zones in the Makhutso Granite and the Vlaklaagte granite.
- Populations B and C confined to the Vlaklaagte granite and profiles in the Makhutso Granite which are enriched in Cu.
- Population A confined to greisenised zones and the sulphide rich quartz-pegmatite veins.

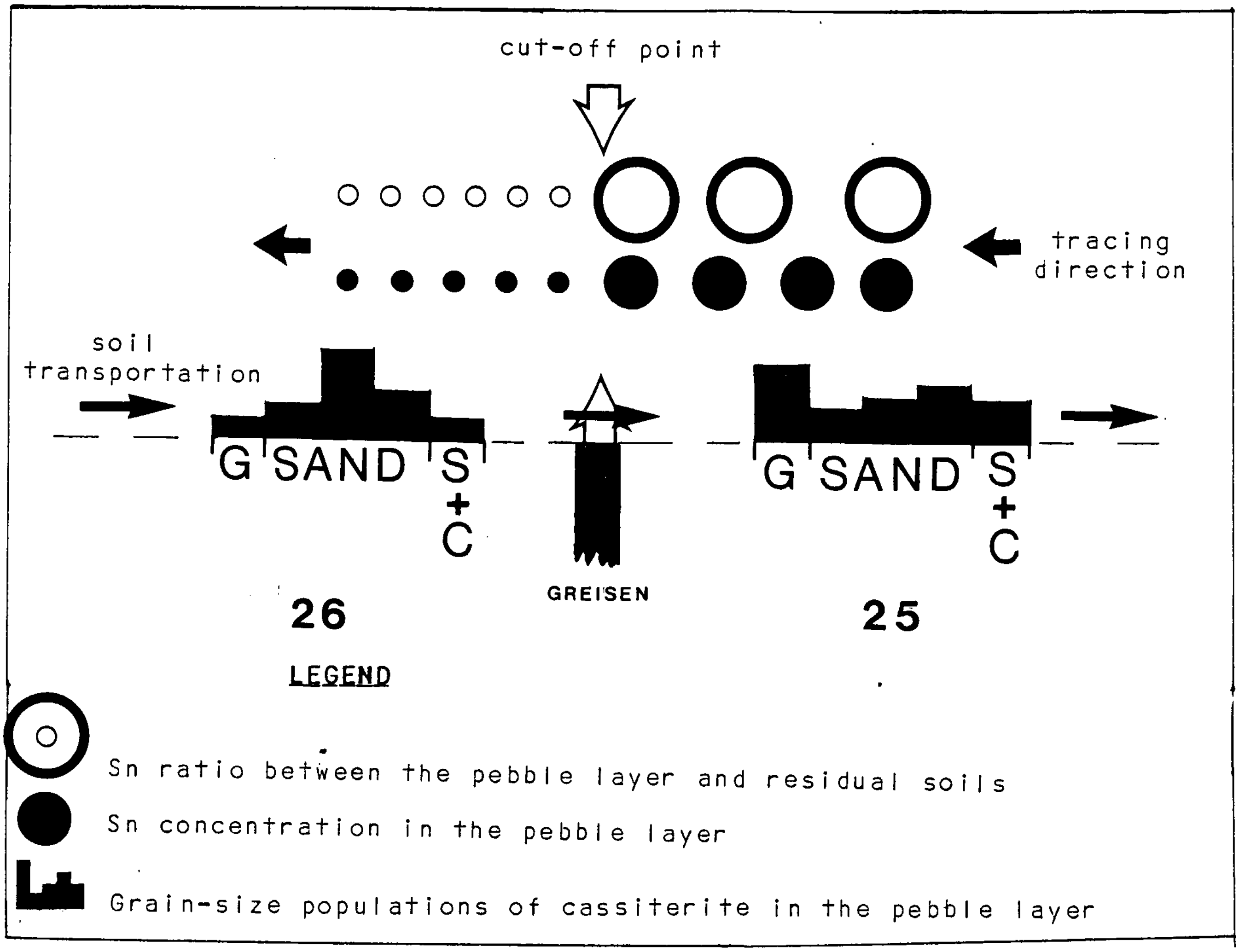


Figure 8-4: Model showing how a combination of the total Sn concentration (bulk sample) in the pebble layer, the grain-size populations of cassiterite in the pebble layer and the Sn ratio between the pebble layer and residual soils could be used for lateral tracing.

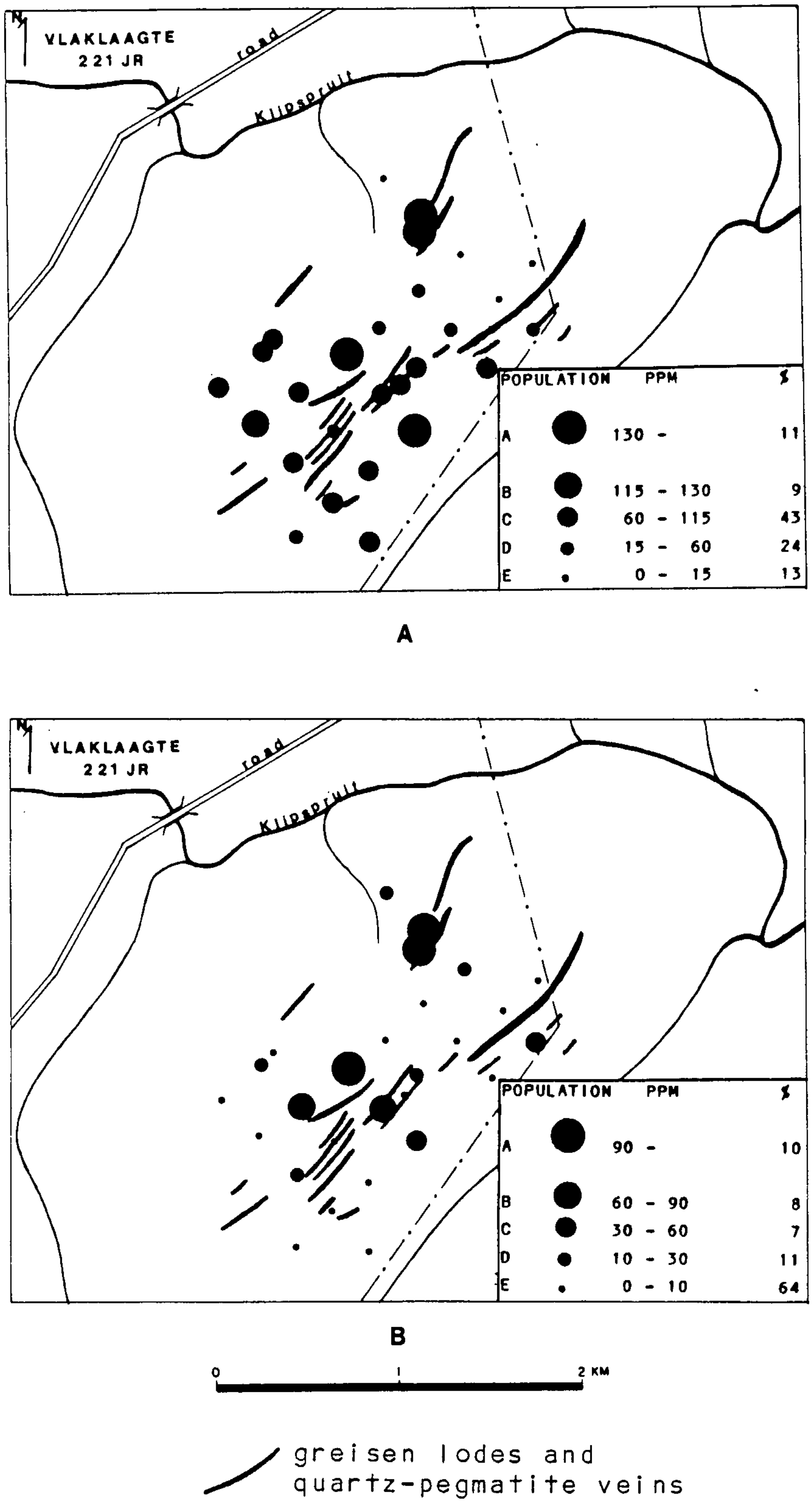


Figure 8-5: Geochemical maps showing the Cu distribution in the C horizon in the silt-clay fraction A) unnormalised for Fe_2O_3 and B) normalised for Fe_2O_3.

Cu values normalised for Fe_2O_3

Five populations were discerned (Fig. 8-5b) with:

- Population E representing the unmineralised zones on both the granophyre, Makhutso Granite and Vlaklaagte granite.
- Population D representing zones slightly enriched.
- Populations B and C representing zones with relatively high concentrations of Cu.
- Population A confined to enriched zones.

Pebble layer: (silt-clay fraction)

Original values (unnormalised for Fe_2O_3).

Four populations were distinquished (Fig. 8-6a) with:

- Populations C and D representing the unmineralised zones.
- Population B showing zones slightly enriched in Cu.
- Population A confined to the mineralised contact zone between the Makhutso and Vlaklaagte granite.

Cu values normalised for Fe_2O_3

Four populations were recognised (Fig. 8-6b) with:

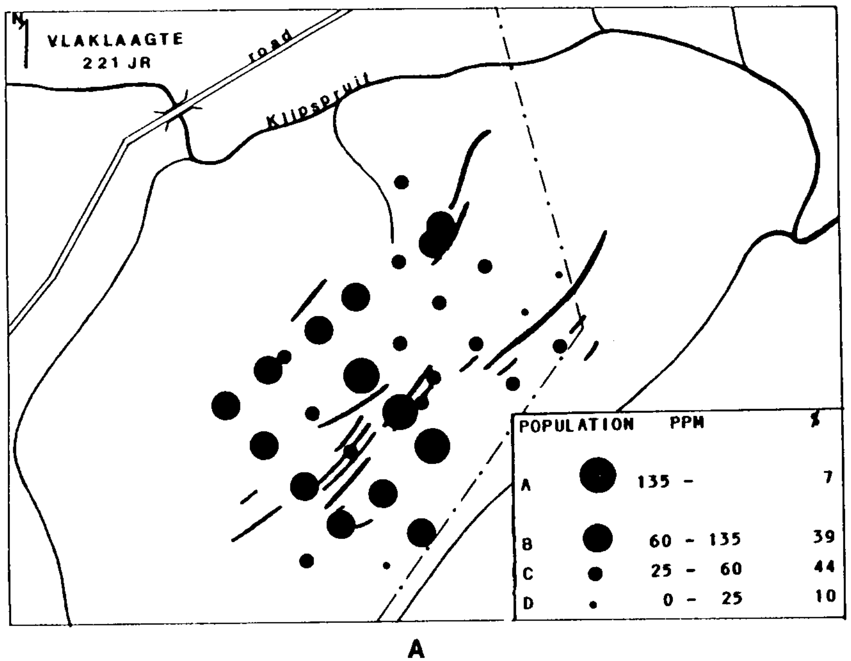
- Population D confined to the unmineralised zones.
- Population C confined to zones slightly enriched.
- Population B confined to stronger enriched zones.
- Population A confined to strongly enriched zones.

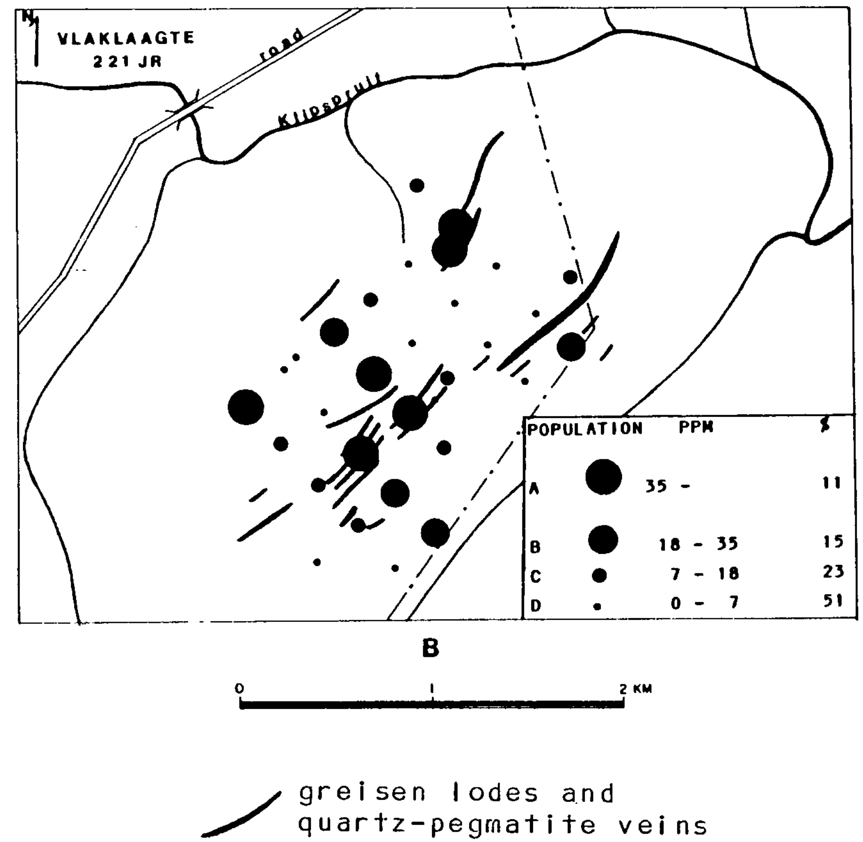
Goethite pellets (original values).

Goethite pellets were also selected for each profile and analysed for Fe and Cu (Table 8-1). The results indicate that no relationship between the Fe and Cu contents exist. No correction for Fe was thus necessary.

Four populations were identified (Fig. 8-6c) with:

- Population D mainly reflecting the background on Makhutso Granite.
- Population C representing background on the Vlaklaagte granite and slight enrichments in the Makhutso Granite.
- Population B restricted to mineralised and lateral enriched zones.
- Population A restricted to the mineralised zones on the





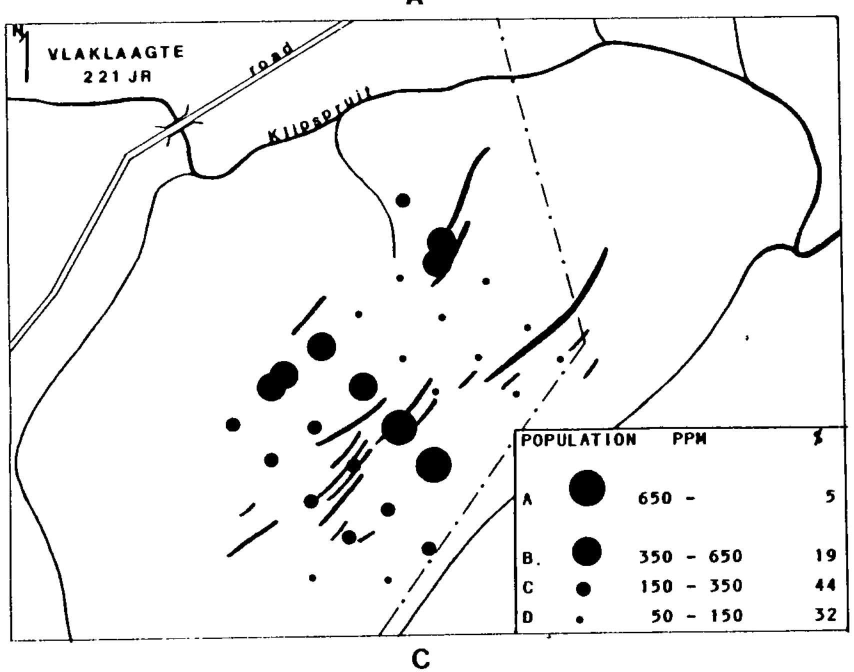


Figure 8-6:
Geochemical maps showing the Cu distribution in the pebble layer A) unnormalised for Fe_2O_3 in the silt-clay fraction, B) normalised for Fe_2O_3 in the silt-clay fraction and C) in the goethite pellets.

TABLE 8-1: TOTAL Fe AS Fe_2O_3, Cu AND Mo CONCENTRATIONS IN GOETHITE PELLETS FROM THE PEBBLE LAYER FOR ALL 32 PROFILES.

PROFILE	ELEMENTS		
	Fe_2O_3	Cu	Mo
1	14.9	100	<5
2	15.8	87	8
3	16.9	324	11
4	17.8	184	11
5	17.6	288	11
6	16.5	297	20
7	16.0	167	14
8	15.6	244	22
9	18.8	166	75
10	16.9	247	55
11	16.0	494	106
12	18.2	427	75
13	---	---	---
14	16.6	831	57
15	15.8	695	25
16	16.0	525	18
17	15.8	362	36
18	14.6	94	15
19	14.8	101	12
20	15.2	96	10
21	14.7	121	9
22	14.6	94	15
23	12.0	119	10
24	14.1	114	11
25	16.1	91	<5
26	17.3	73	8
27	16.3	131	16
28	14.9	443	16
29	17.3	181	17
30	---	---	---
31	16.8	561	16
32	---	---	---

contact between the Makhutso and Vlaklaagte granite.

Transported soil: A_1 horizon (silt-clay fraction)

Original values (unnormalised for Fe_2O_3).
Four populations were obtained (Fig. 8-7a) with:

- Population D restricted to the more sandy part of the first order stream.
- The lower part of population C restricted to the sandy valley floor, the lower slopes and completely unmineralised parts of the Makhutso Granite and granophyre.
- The upper part of population C restricted to the middle and upper slopes in the mineralised area.
- Population B broadly defining the Cu haloes around mineralised zones.
- Population A broadly defining the greisenised contact zone between the Makhutso and Vlaklaagte granite, the sulphide rich quartz-pegmatite, a mineralised zone anomalous in Sn and Mo and a mineralised zone not coinciding with either Sn or Mo.

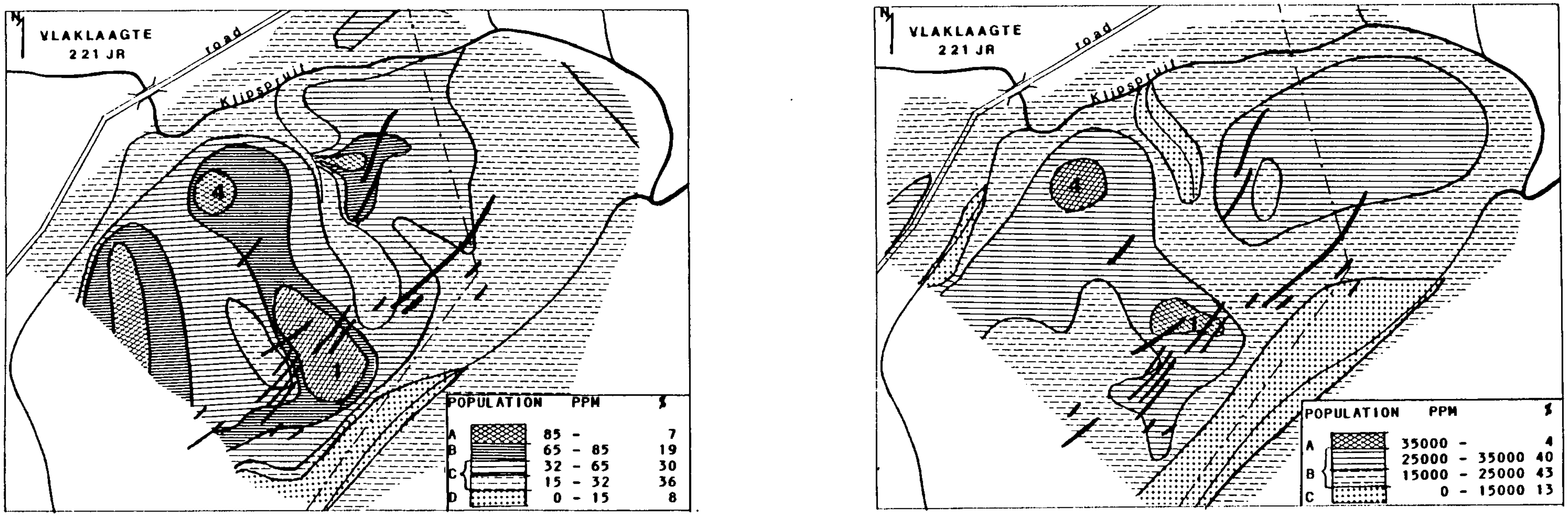
A distribution map for Fe_2O_3 using the silt-clay fraction shows that three populations can be distinguished (Fig. 8-7b) with:

- Population C confined to first order streams.
- Population B representing drainage anomalies from both mineralised and unmineralised zones.
- Population A indicating two highly anomalous zones which both coincide with Cu anomalies.

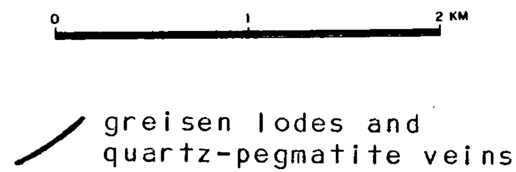
The distribution patterns for both the Fe and Cu from the top of the ridge where anomaly 1 is situated, form a fan to the north west along the slopes to where anomaly 4 is situated. This indicates that the Cu and Fe anomalies are secondary at (4) due to the redistribution of Fe and Cu leached from the greisenised zones on the hill crest.

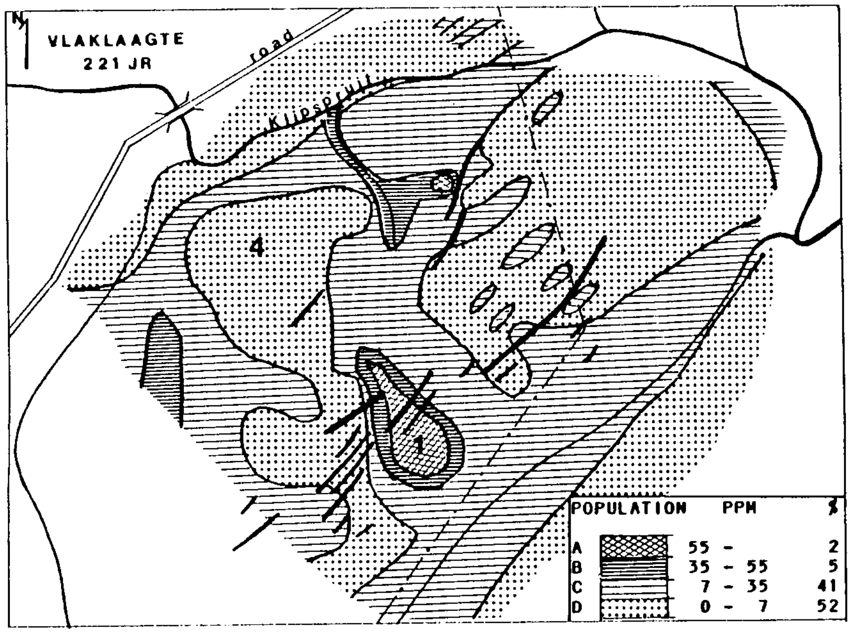
Cu values normalised for Fe_2O_3
Four populations are recognised (Fig. 8-7c) with:

- Population D representing unmineralised zones.
- Population C restricted to the lower slopes and areas



A B





C

Figure 8-7:
Geochemical maps showing A) the Cu (unnormalised for Fe_2O_3) distribution in the A_1 horizon in the silt-clay fraction, B) the Fe distribution in the A_1 horizon in the silt-clay fraction and C) the Cu (normalised for Fe_2O_3) distribution in the A_1 horizon in the silt-clay fraction.

around mineralised zones.

- Population B representing haloes around mineralised zones.
- Population A only restricted to three mineralised zones.

8.2.1 Discussion

The distribution patterns of Cu are relatively broad and are controlled by Fe-oxides. The A_1 horizon shows anomalous distribution patterns for both the Fe-corrected and uncorrected Cu in the vicinity of mineralised zones where the transported soil cover is thin. At the lower slopes mineralised zones are shielded by the thick layer of transported soils. The false anomalies can be separated by comparing both maps.

As a result the anomaly at point 4 (Fig. 8-7a) proved to be only the result of Fe accumulation from a mineralised zone higher up on the ridge. The three other anomalies are associated with mineralised zones. Most of the thicker soils, especially on the terraces, create an iron oxide trap for elements.

In the pebble layer the anomalies for both Fe-corrected and uncorrected Cu values are still broad but more confined to mineralised zones than in the A_1 horizon. Copper mineralisation underlying profiles 10, 18 and 21 and to a lesser extent profile 14 (Fig. 8-6b), are shielded. Lateral tracing using the pebble layer or zone in direct contact with the residual material should, however, give a more direct indication of mineralisation than the A_1 horizon.

Using the goethite pellets, it is possible to distinguish between the Makhutso and Vlaklaagte granites whilst the highly mineralised zones are also better defined. The poorly mineralised zones are not detected, which can be ascribed to Cu values which do not differ from the relatively high background values. The goethite pellets therefore outline the extremes very well. Mechanical movement of the goethite pellets could cause false anomalies. The remarkably accurate patterns, however, indicate that the pellets have not moved too far.

The C horizon defines the mineralised zones more accurately than any of the other zones, especially when corrected for Fe and is recommended for both lateral and positional tracing of an ore body. Lateral enrichment causing false anomalies remains a problem. Apart from the fact that Fe-corrected values give more definite anomalies, both Fe and Cu can be enriched over mineralised zones and care should be taken when Cu is corrected for Fe. The lower part of the C horizon is recommended because relicts of the mottled and pallid zones are still expected in the upper parts of the C horizon on the lower and footslopes.

The use of SiO_2/Al_2O_3, Al_2O_3/Fe_2O_3 and SiO_2/Fe_2O_3 ratios in conjunction with the mineralogical and geochemical parameters demand a separate investigation and are thus not considered.

8.3 MOLYBDENUM

Residual soil: C horizon (silt-clay fraction)
Two populations were distinguished (Fig. 8-8a) with:

- Population B representing unmineralised zones.
- Population A representing the Mo mineralised zones.

Pebble layer: (silt-clay fraction)
Two populations were distinguished (Fig. 8-8b) with:

- Population B representing the unmineralised zones.
- Population A representing the Mo mineralised zones.

Goethite pellets (original values).
Five populations were distinguished (Fig. 8-8c) with:

- Populations D and E representing the unmineralised zones.
- Populations B and C indicating zones laterally enriched.
- Population A indicating the mineralised zones.

Transported soil: A_1 horizon (silt-clay fraction).
Two populations were identified (Fig. 8-8d) with:

- Population B representing the unmineralised zones.
- Population A representing the mineralised zones (anomalies 1 and 2).

8.3.1 Discussion

In the A_1 horizon some displaced anomalies are encountered,

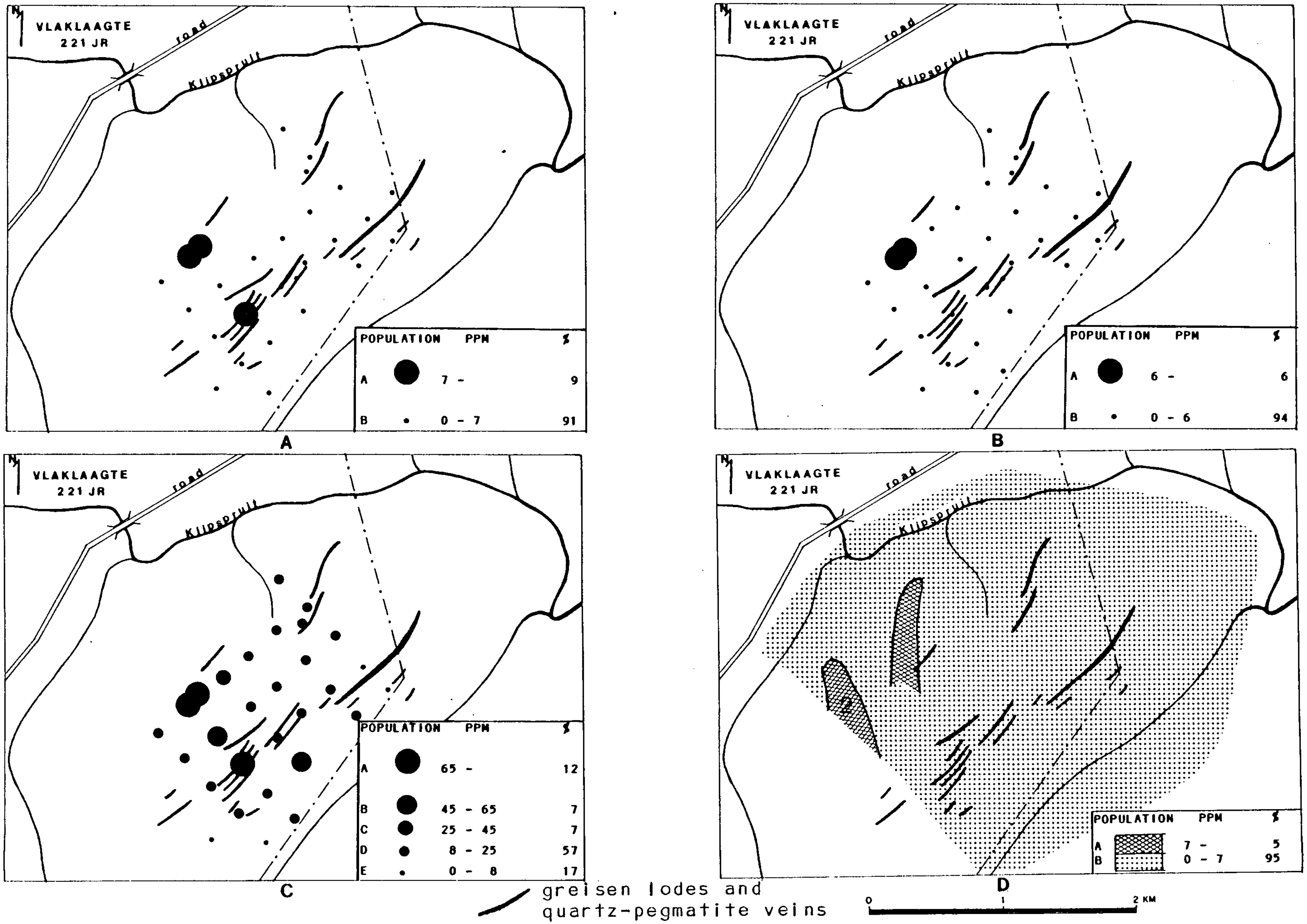


Figure 8-8: Geochemical maps showing the Mo distribution in A) the C horizon (silt-clay fraction), B) the pebble layer (silt-clay fraction), C) the pebble layer (goethite pellets) and D) the A_1 horizon (silt-clay fraction).

indicating zones of mineralisation, some of which are unable to be localised due to shielding by the transported soils (profile 9). Anomaly 2 (Fig. 8-8d) is interpreted as a trace from a source higher up on the slopes. The fact that Cu, Mo and Sn show the same anomaly, suggests that the source should be from the late aplitic to early greisen stage.

The pebble layer and specifically the goethite pellets in it prove to be a most sensitive lateral tracing medium. Mineralisation at profile 9 was not detected, using the silt-clay fraction in the pebble layer and therefore is ascribed to shielding by the residual soils. Goethite pellets are 50 times enriched in Mo relative to the silt-clay fraction in the anomalous areas which makes them more sensitive than the silt-clay fraction in the C horizon.

The C horizon is the most reliable sampling medium to locate the mineralised zones. Using a combination of the lower part of the C horizon and goethite pellets from the lower part of the pebble layer one should be able to detect and localise a Mo-deposit on the upper slopes and ridge. On the middle slope and foot slope care should be taken that the pebble layer is in direct contact with the residual soils. If not the lower part of the C horizon is the only reliable medium.

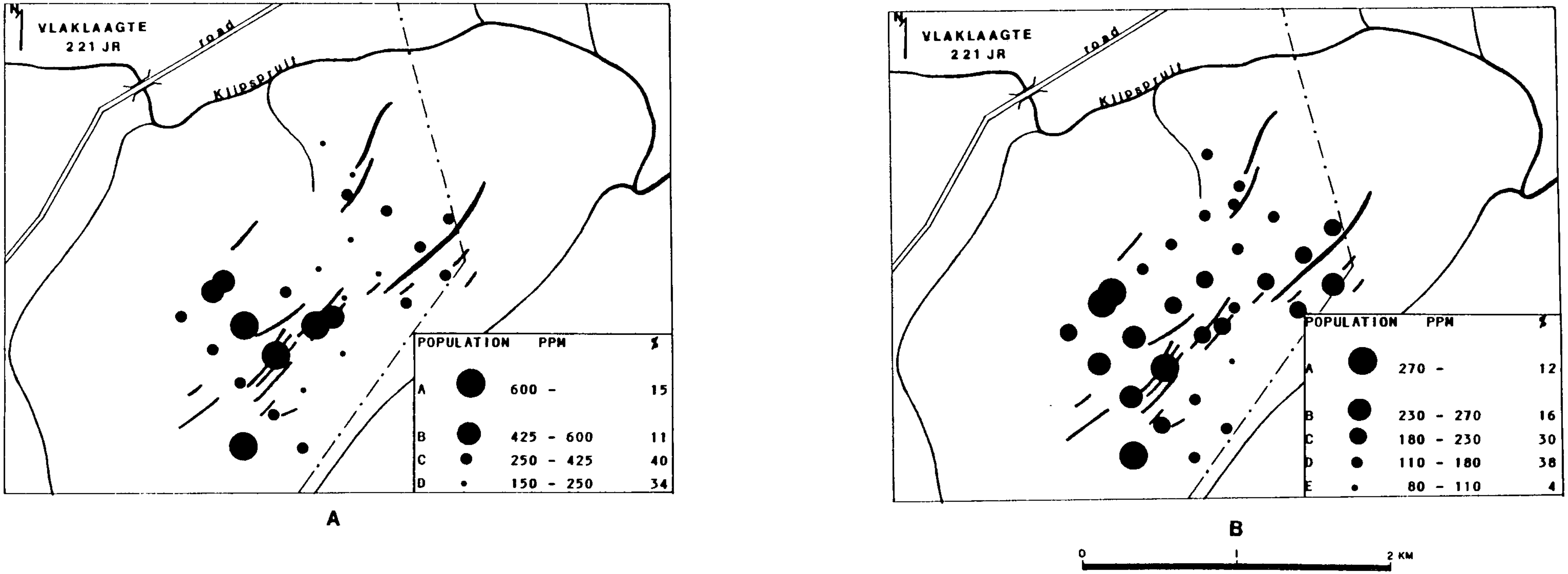
8.4 RUBIDIUM

Residual soil: C horizon (silt-clay fraction).
Four populations were observed (Fig 8-9a) with:

- Populations C and D representing the background.
- Populations A and B indicating metasomatic and differentiated zones.

Pebble layer: (silt-clay fraction).
Five populations were identified (Fig. 8-9b) with:

- Populations D and E representing the background.
- Population C restricted to areas of weak leaching and to the greisenised zone on the contact between the Makhutso and Vlaklaagte granite.
- Population B restricted to slightly enriched zones.
- Population A mainly restricted to the aplitic zones.



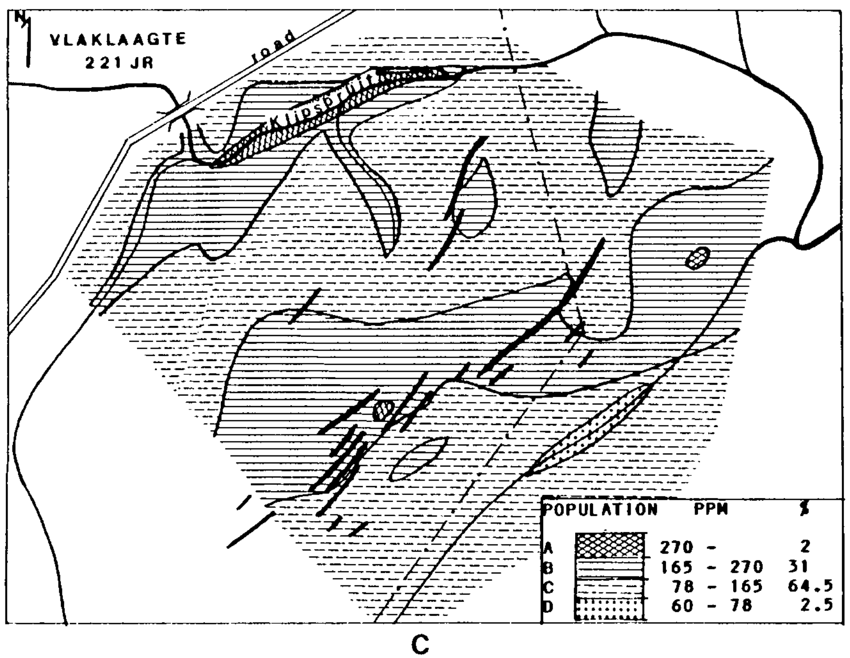


Figure 8-9:
Geochemical maps showing the Rb distribution in A) the C horizon (silt-clay fraction), B) the pebble layer (silt-clay fraction) and C) the A_1 horizon (silt-clay fraction).

Transported soil: A_1 horizon (silt-clay fraction).
Four populations were identified (Fig. 8-9c) with:

- Population D restricted to the sandy valley floor.
- Population C representing the background.
- Population B representing haloes on the hill crest around mineralised zones close to the surface as well as the claye stream bed.
- Population A restricted to the greisen zones and the claye stream bed.

8.4.1 Discussion

The mobility of Rb causes it to be a difficult element to be used as a pathfinder. Distribution of Rb in the transported soils is a function of topography and the associated chemical weathering conditions. Rubidium is intensively leached on the slopes compared to the ridge where leaching is less intensive and where the mineralised zones are still reflected. Rubidium removed from the ridge and slopes, is precipitated in the valleys where clay minerals occur.

Distribution patterns in the pebble layer are due to mechanical transportation. Known anomalous zones observed in the C horizon (profiles 15 and 32), were not observed. The topographical control on the distribution of Rb is also evident from higher values in the region of outcrops with primary feldspar still present and in low energy areas on terraces where Rb is redeposited in clay minerals. Population B (Fig. 8-9b) represents such a terrace.

The A_1 horizon and the pebble layer seems to be unreliable because anomalous zones could be a result of weathering conditions and topography. The C horizon is a relatively reliable sampling medium for lateral tracing, but weathering could cause problems. In less weathered and lower energy zones, Rb will cause false anomalies. The low energy zones cause reprecipitation and the enrichment of Rb. When used, however, the less affected lower part of the C horizon is the most reliable.

8.5 STRONTIUM

Residual soil: C horizon (silt-clay fraction).

Four populations were distinguished (Fig. 8-10a) with:

- Populations C and D indicating the region of greisenised and leached zones.
- Populations A and B indicating rocks with high background values or zones unevenly leached.

Pebble layer: (silt-clay fraction).

Four populations were distinguished (Fig. 8-10b) with:

- Population D indicating some greisenised zones.
- Population C indicating greisenised and leached zones.
- Populations A and B indicating profiles close to outcrops and profiles where deposition of Sr took place.

Transported soil: A_1 horizon (silt-clay fraction).

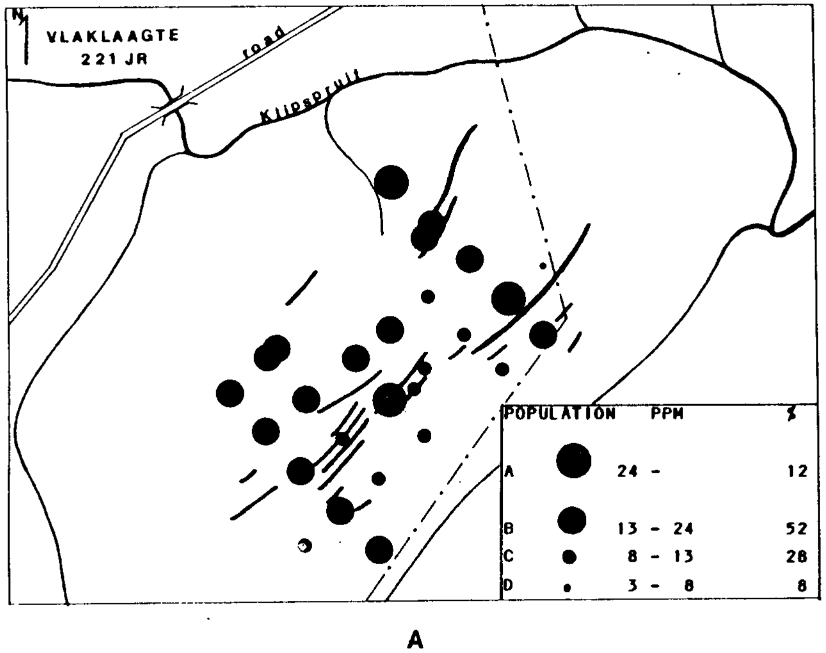
Four populations were identified (Fig. 8-10c) with:

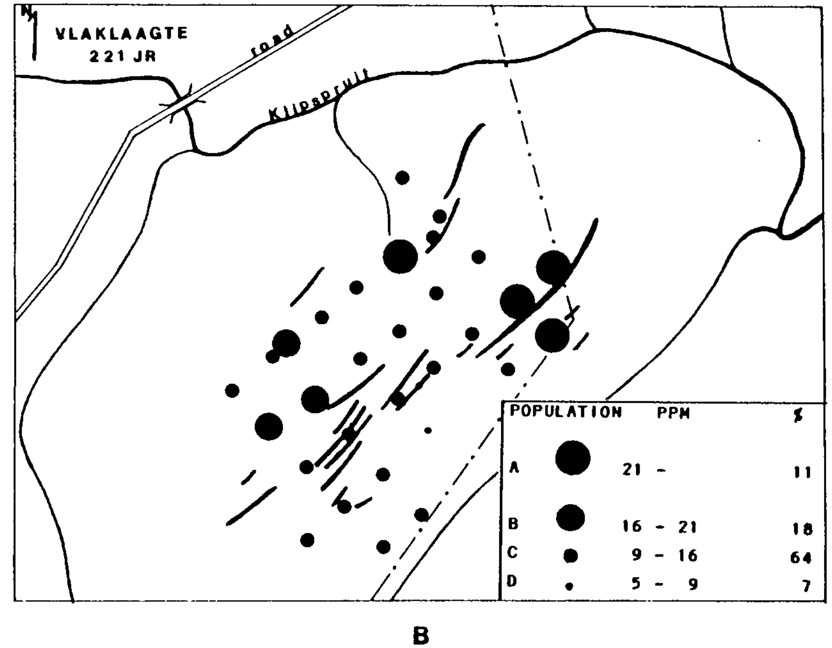
- Population D reflecting the sandy valley floor and the greisenised zone on the contact between the Makhutso and Vlaklaagte granite.
- Population C forming the background population.
- Populations A and B restricted to the valley floor in the west and the terraces where redeposition took place.

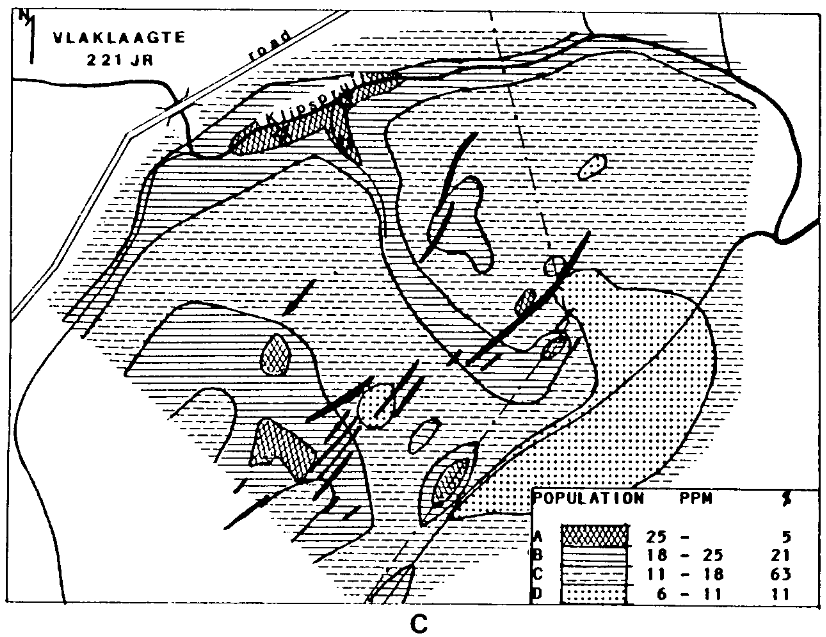
8.5.1 Discussion.

Sr is more mobile than Rb and strongly controlled by topographical and weathering conditions. Except for some indication of highly differentiated zones near the contact of the Makhutso and Vlaklaagte granite, no other highly differentiated zone could be identified using any sampling medium.

Redistribution of Sr has a homogenising effect, with the C horizon the least affected. Enrichment of Rb and Sr in the western valley floor near a spring, indicates that the watertable is close to the surface. The enrichment is thus the result of groundwater transporting the mobile elements to places where they are precipitated by evaporation.







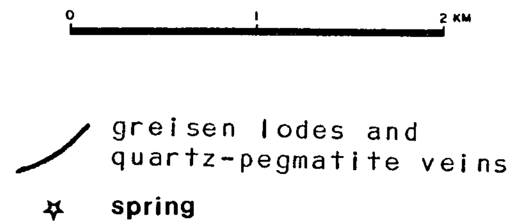


Figure 8-10:
Geochemical maps showing the Sr distribution in A) the C horizon (silt-clay fraction), B) the pebble layer (silt-clay fraction) and C) the A_1 horizon (silt-clay fraction).

8.6 Rb/Sr RATIO

Rb increases with increasing differentiation and Sr decreases, thus the Rb/Sr ratio should indicate mineralised zones.

Residual soil: C horizon (silt-clay fraction).
Five populations were distinguished (Fig. 8-11a) with:

- Populations D and E indicating background values.
- Population C restricted to slightly mineralised and laterally enriched zones.
- Populations A and B representing greisenised, aplitic and sulphide rich zones as well as profiles laterally enriched and weakly weathered.

Pebble layer: (silt-clay fraction).
Four populations were distinguished (Fig. 8-11b) with:

- Populations C and D representing the background.
- Populations A and B representing laterally enriched zones as well as profiles enriched **"in situ"**.

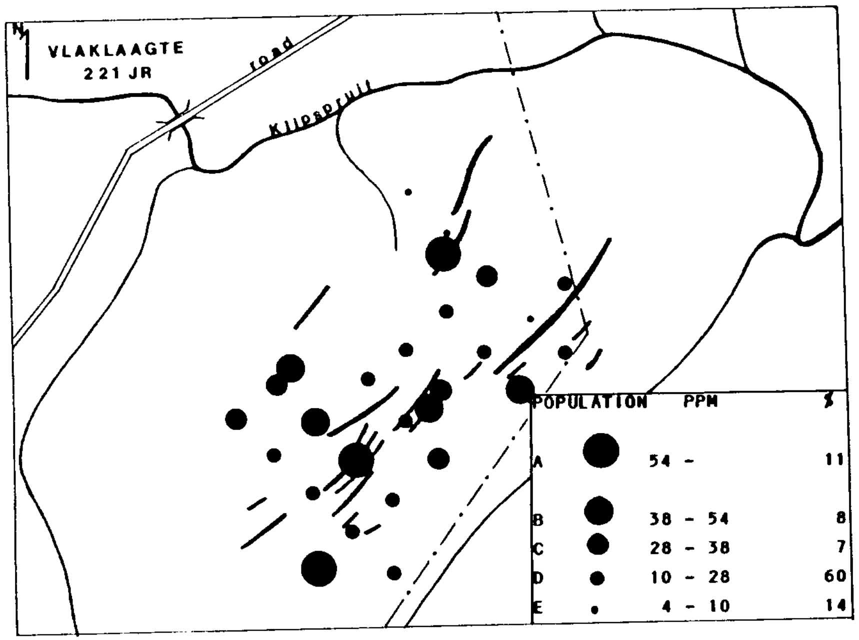
Transported soil: A_1 horizon (silt-clay fraction).
Three populations were distinguished (Fig. 8-11c) with:

- Population C restricted to the lower slopes and in some cases the valley floor.
- Population B restricted to the claye valley floor and also the middle and upper slopes.
- Population A defining the mineralised zones and outcrops of granite.

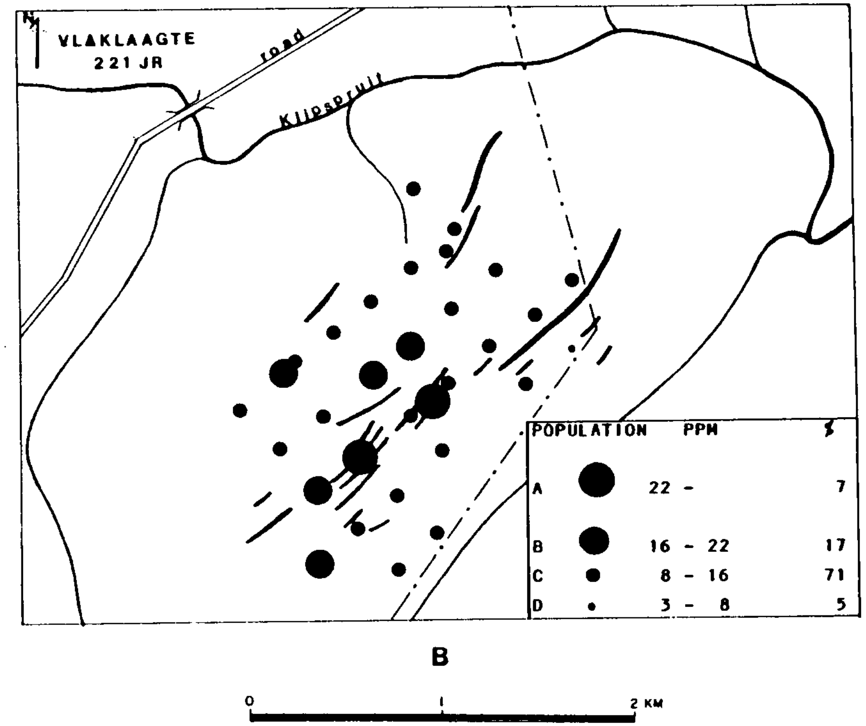
8.6.1 Discussion

The Rb/Sr ratios are not recommended for exploration if either the A_1 horizon or the pebble layer are used. Distribution patterns in these zones are due to the topography. Mineralised zones can be identified on the ridge with just as many false anomalies.

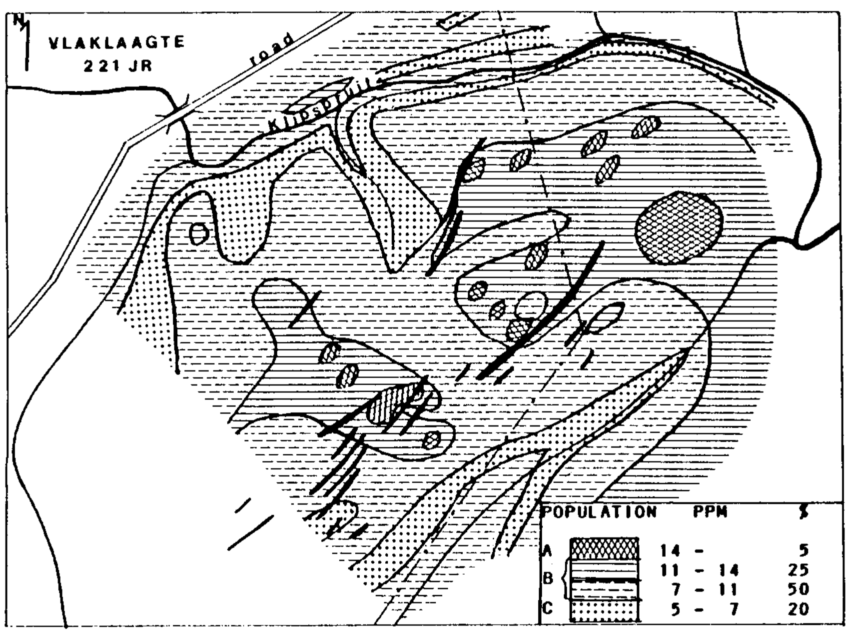
Population C (Fig. 8-11c) in the A_1 horizon is the result of claye soils in the west, with Sr enriched relative to Rb and is also the result of sandy soils in the east with both



A



B



C

Figure 8-11:
Geochemical maps showing the variation in the Rb/Sr ratio in A) the C horizon (silt-clay fraction), B) the pebble layer (silt-clay fraction) and C) the A_1 horizon (silt-clay fraction).

elements intensively leached. In population B (Fig. 8-11c) both Rb and Sr are enriched in the valley floor whilst depleted on the middle and upper slopes. The false anomalies in population A (Fig. 8-11c) due to outcrops, are also misleading. It is thus clear that opposite conditions can result in the same population. This causes confusion and should be avoided.

The C horizon is more succesfull, providing that similar weathering conditions exist throughout. Slight differences in weathering cause abnormalities (profiles 15 and 16). Low ratios at profiles 15 and 16 are unexpected but may be due to a weaker degree of weathering which resulted in higher Sr values. High leaching conditions are expected to have leached both Rb and Sr strongly. The lower part of the C horizon is therefore recommended.

8.7 Rb/Ba RATIO

Ba is less mobile but behaves similar to Sr in the primary environment, thus the Rb/Ba ratio could also be used as an indication of mineralised zones.

Residual soil: C horizon (silt-clay fraction).
Four populations were distinguished (Fig. 8-12) with:

- Populations C and D indicating the background.
- Populations A and B indicating the mineralised zones and laterally disturbed zones.

All the profiles related to mineralisation proved to be positive except profile 16 in which no anomaly was detected. The Rb/Ba ratio gives a better indication of mineralised zones than the Rb/Sr ratio and is therefore recommended in such cases. The less affected lower part of the C horizon would yield the best results.

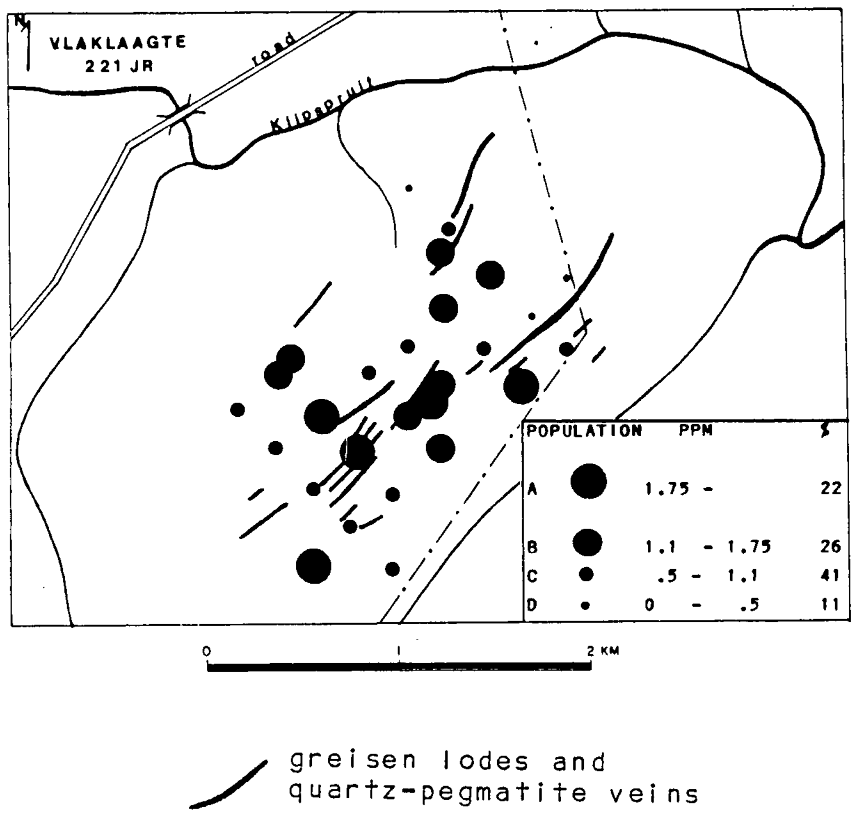


Figure 8-12: Geochemical map showing the variation in the Rb/Ba ratio in the C horizon in the silt-clay fraction.

8.8 GENERAL DISCUSSION

The elements studied in this section can be subdivided into three general groups:

- Mobile chalcophile and siderophile elements (Cu and Mo).
- Mobile lithophile elements (Rb, Sr and Ba).
- Element hosted in resistant minerals (Sn in cassiterite).

Elements of the first group are trapped by iron oxides and never move far from the sources except when mechanical movement is severe. These elements are reasonably reliable lateral indicators for mineralised zones, especially when a combination of the lower part of the lower pebble layer (especially goethite pellets) and the lower part of the C horizon is used.

False anomalies due to iron enrichment occur, especially in the case of Cu, but corrections for the Fe_2O_3 sorptive capacity can rectify this. When both the iron and these elements are enriched above mineralised zones, anomalous sorptive capacities may exist and caution should then be exercised.

Mobile lithophile elements, easily leached and reprecipitated with clay minerals, result in topography dependant anomalies. False anomalies resulting from the topographical control can be very misleading. For these latter elements the lower part of the C horizon is more reliable and ratios appear to be better indicators. Differences in weathering in this zone is a major obstacle.

Elements hosted in resistant minerals yield distribution patterns which are mechanically controlled. In transported soils secondary distribution patterns develop which can be used in regional exploration programmes.

A combination of the Sn concentration and the grain-size distribution of cassiterite in the lower part of the lower pebble layer as well as the concentration ratio between the pebble layer and residual soil can be used for the lateral tracing of possible sources of tin. When the pebble layer is not in direct contact with the residual material the lower part of the zone in contact with the latter should be used instead.

The lower part of the C horizon can only be used to determine the exact position of the ore body.

9 CONCLUSIONS AND RECOMMENDATIONS.

Copper, Sn and Mo give the best indication of mineralised zones, depending on the depositional conditions. The Rb/Sr and Rb/Ba ratios also help to outline highly differentiated zones.

The interference of different climatic conditions and variations in topography on the natural soil forming processes over a long period are the major factors to be considered when soil is used for mineral exploration. The mineralogical association of elements and their mobility also play a major role but are controlled by the first two factors.

As a result the lateral and vertical distribution of elements are dependant on:

- The palaeo- and present climatic conditions.
- The topography (palaeo- and present).
- The primary minerals with which the elements are associated and the weatherability of the minerals.
- The predominant end minerals in the soils and their elemental association.
- The mobility of the elements under different Eh-pH conditions.

The palaeo- and present climatic conditions caused at least three periods of soil formation in the area. A palaeo-layer of transported soils, marked by grading, remained below the pebble layer and represents the oldest period of soil formation in the area. Evidence of the high energy palaeo-conditions that followed is still present in the soil profiles in the form of:

- A pebble layer.
- A reducing mottled and pallid zone (expected to be the palaeo-C horizon which developed during water saturation by vertical and lateral moving groundwater on the contact between the consolidated and unconsolidated zone).
- A distinct palaeo-lateritic $B_2(R)$ horizon below the pebble layer.

Presently the soil formation is marked by lower energy conditions. Evidence of this in the soil profiles are:

- A characteristic transported soil cover overlying the residual soils (even on the upper slopes) with the pebble layer the marker between the two.
- Grading of material from the coarse pebble layer upwards into finer material, indicating reducing energy conditions.
- A B_2(T) horizon in the transported soils which is less lateritic, indicating that the present movement of groundwater is mainly downwards with minor fluctuations in the watertable.

The influence of palaeo- and present climatic conditions is therefore evidently a critical factor, resulting in superimposed profiles. Several periods of stripping and deposition are expected throughout the Bushveld Complex, as the pebble layer(s) is universally present.

The topography on the upper slopes has not changed much from the time of palaeo- soil formation and the present stage. At the lower slopes, however, the transported soils thicken considerably causing a decline in the slopes. The lower slopes thus cause problems in separating the transported soils from the residual soils and therefore even more than one pebble layer can be present as witnessed in some profiles in other parts of the Bushveld Complex. A mature stage of erosion is therefore reached in the area where deposition rather than erosion is dominant in the valleys and on the lower slopes. This is also the case in other felsic parts of the Bushveld Complex where similar conditions prevail. In some areas, however, erosion is still dominant (eg. the Zaaiplaats area) and better results are expected, due to a less dominant cover of transported soils. The pebble layer is, however, still present, especially at the lower slopes. The topography is thus one of the major factors to be considered during exploration.

The primary mineral(s) in which the elements occur, control the leachability of the elements. Depending on the climatic conditions, some minerals are more weathering resistant (eg. quartz, cassiterite, zircon, ilmenite, magnetite etc.) than others (eg. feldspars, micas etc.). Elements predominantly associated with the resistant group of minerals (Si, P, V, Zr and Sn in this study) are therefore not leached and mainly mechanically distributed in the soils (both lateral and vertical). The grain-size of the resistate also influences their mechanical distribution.

Those elements which are predominantly associated with the non-resistant group of minerals (eg. Al, Mg, Ca, Na, K, Co, Ni, Cu, Zn, Rb, Sr, Mo and Ba and also Pb to some extent) are easily leached and mainly chemically distributed.

The problem arises when an element occurs in both resistant and non-resistant minerals (eg. Ti,(V), Mn, Y, Nb, (Sn), Th and U). Depending on the mineral in which it is captured, both mechanical and chemical distribution may be of importance and therefore most confusing distribution patterns may result.

It is thus clear that knowledge of the host mineral phase for each element is a prerequisite for understanding its distribution in soils. Quartz and clay minerals are the predominant end minerals in the secondary environment and therefore together with iron, control the distribution of all the elements. The relative enrichments and depletions of quartz, clay and Fe_2O_3 in the soil profiles are a function of eluviation and illuviation. Quartz is always enriched with eluviation relative to clay, while the inverse applies to illuviation.

An increase in quartz thus dilutes all other elements in the eluvial zones with the exception perhaps of elements captured in other resistates. The elements are thus inversely enriched in the illuvial zones where clay accumulates with the redox potential determining the preference of chalcophile, siderophile or lithophile elements for the zone.

Size fractions in which the quartz, other resistates, clay and Fe-oxides occur, are also a deciding factor when the fraction to be used for a specific element is selected.

The use of SiO_2/Al_2O_3, Al_2O_3/Fe_2O_3 and SiO_2/Fe_2O_3 ratios in conjuction with the mineralogical and chemical parameters, is imperative and requires further investigation.

The mobility of the elements plays a major role in their distribution. Some elements are more mobile than others, for example Sr is more than Ba and Ba more mobile than Rb. The ratios can also easily be distorted as in the case of the Rb/Sr ratio which is only due to varying weathering conditions depending on the topography.

Movement of the following elements (P, V, Mn, Co, Ni, Cu, Zn, Sn, Pb, Mo and U) is controlled by Fe_2O_3 and are strongly sorbed in oxidised zones (the B horizon and goethite pellets in the pebble layer) when leached upon weathering. Their distribution is therefore dominantly controlled by the distribution of Fe_2O_3 as is seen from the behaviour of Cu and Mo. They do not move as far as the majority of lithophile elements during chemical distribution, because iron which is always present, acts as a trap. A combination of the lower part of the C horizon (silt-clay) and goethite pellets in the lower part of the lower pebble layer proved to be a reliable sampling medium for tracing and locating sources, using the former elements (if not hosted in resistates). Corrections for the Fe_2O_3 sorptive capacity rectifies the false anomalies which resulted.

The lithophile elements (Ti, Mg, Ca, Na, Y, Nb, Rb, Sr, Ba and Th) are very mobile due to the fact that apart from clay minerals, nothing else acts as a trap for these elements. Their major precipitation took place as a result of oversaturation in groundwater (eg. spring area) and adsorption onto clay minerals (eg. spring areas and terraces). For these elements the lower part of the C horizon (silt-clay) is the most reliable sampling medium but when hosted in resistates, results may be confusing.

The elements hosted in resistates yield distribution patterns related to mechanical processes. For resistates enriched in the silt-clay fraction (P, Zr and V), a combination of the lower part of the C horizon and the lower part of the lower pebble layer yields reasonable results. In the case of Sn, however, where grain-size is dependant on the source, a combination of

a) the grain-size population pattern of cassiterite in the lower part of the lower pebble layer, b) the Sn-ratio between the lower part of the lower pebble layer and the residual soils (bulk sample) and c) its concentration in the lower part of the C horizon (sand plus silt-clay) enables the tracing and locating of sources.

When all these factors are taken into consideration, more representative anomalies are obtained on the upper slopes and hill crest where a relatively thin transported soil cover is present. This is especially true when residual soils are sampled. On the middle and lower slopes where a thick transported soil cover is present it was impossible to come to any valid conclusions, because anomalies could have been shielded.

The residual soil is the only soil reflecting the true geochemical character of the area. However, mobile elements leached from the transported soils above may also cause false anomalies in the soils below, especially at the lower slopes.

It is evident from this investigation that the sampling of the B_2 horizon can be disastrous, because transported and residual soils interfere with each other over a broad area. The only horizon which is always present, definitely representing the latest period of soil formation, and of residual origin is the lower part of the C horizon, which is therefore recommended for locating the ore. On the middle and foot slopes, relicts of the mottled and pallid zones are still expected in the upper parts of the C horizon. These zones represent heterogenous material and consequently cause unreliable results, especially for leachable elements. The lower pebble layer and in particular the lower part, being the zone in contact with the residual soils, proved to be a sensitive sampling medium using pathfinders which are mechanically or chemically distributed. It is of the utmost importance only to use the pebble layer if it is in direct contact with the residual soils, if not the zone in direct contact should be used instead. Care should be exercised in areas where two or more zones representing different periods of soil formation and possibly different sources interfere with one another (eg. a palaeo- and younger pebble layer). Horizons formed during separate periods of soil formation should therefore be treated as individual zones.

The distribution patterns become broader, less defined and less reliable in the order residual soils, colluvium and alluvium.

The following sequence of operations are therefore recommended in the search for tin deposits using Sn, Cu and Mo:

Determine the nature of the overburden.

The nature of the overburden is a critical sampling parameter. As a result it is first necessary to map the approximate boundaries of the different types of overburden in the area (i.e. residual, colluvium and alluvium).

Determine the developing stage of the soil profile.

The stage of development of the soil profile should be the next parameter to be investigated and is in most cases necessary for lateral mapping of the soils.

First, the master horizons have to be distinguished together with the zones of eluviation and illuviation. Then the transported and residual soils should be identified together with all the palaeo-markers caused by palaeo-climatic conditions.

The latter is very important because the distribution of elements will not be the same in different stages of soil formation, depending on both the palaeo-climatic conditions and the topography as already pointed out.

Determine the recommended horizon to be sampled.

The distribution of the elements in the soil profiles are most important in soil sampling.

If the soils in the area are not in a mature stage of developement any soil horizon will probably give reasonable results, except along the lower slopes where alluvium is expected. In such a case the zones of illuviation will be the most sensitive for Cu and Mo and the zones of eluviation the most enriched in Sn (providing that cassiterite is the dominant Sn bearing mineral). Otherwise Sn would also be more sensitive to the Fe-oxide rich zones as a result of its siderophile tendency.

As soon as the soils reach a mature stage of development as in the case studied, the zone to sample becomes critical and the most representative zone should be selected. The lower part of the C horizon and the lower part of the lower pebble layer are recommended for the lateral tracing and the positional determination of the sources for Cu and Mo. The lower part of the pebble layer or horizon in direct contact with the residual material should be used for the lateral tracing of Sn sources (providing that it is predominantly associated with cassiterite) whereafter the lower part of the C horizon should be used for the positional determination of the source. A combination of these horizons present an excellent exploration medium.

The lower part of the C horizon is therefore generally recommended for all three elements, especially if confusion about the nature of the soils exists.

Determine the soil fraction to be sampled.
The most sensitive soil fraction has to be selected to ensure optimum results in the selected zones.

Due to the variation in the grain size of cassiterite, the sand plus silt-clay fraction is recommended (representing all sorts of mineralized zones) in the C horizon. In the pebble layer the grain-size populations of cassiterite and the ratio of Sn concentrations between the lower pebble layer and residual soils (bulk sample) should alow lateral tracing of the source.

For both Cu and Mo the silt-clay fraction is recommended in the C horizon but in the pebble layer goethite pellets are recommended.

Determine the sampling pattern.
From this study it is evident that the traverse lines should be laid out at right angles to the ore structure if the strike direction is known, as in the case studied (Fig. 2-1). The general strike direction of quartz veins would in most cases also give an indication of the general strike direction of mineralized

zones. There is a possibility that the Sn and Mo anomalies could have been missed if the original traverse lines B, C, D, E and F were laid out parallel to the strike direction of the mineralised zones. If the strike direction is unknown a grid with equal intervals is recommended. The grid layouts proposed by Rose **et al.**, (1979) and Levinson (1980) are recommended as a basis to work from.

The modus operandi should therefore be as follows:

1. First the lithogeochemical Rb/Sr and Rb/Ba ratios should be used on a broad scale (see Walraven, in prep.) to select the correct structural setting of the Bushveld granite. Then alluvium (stream sediments) should be used to locate an area in which a source is shielded (covered). By following the trace of the element upstream it should be possible to locate the point (cut-off point) where the mineralisation is crossed or where the material is supplied by colluvium and/or groundwater from the sides (banks).

2. When this point is reached soil samples from the banks of the stream should be used to locate the side from which the enriched material is supplied.

3. The A horizon can be used directly (if it bears the enriched material) to follow the trace upslope, till another cut-off point is reached, indicating the possible position of the source (which in some cases may well be the case). In most cases, however, lower zones will have to be used to determine the exact position of the source and also the number of other possible mineralised zones normally shielded from exposure by the transported soil cover. The chance is very good that a few mineralised zones occur together and only transported soils would not reveal them all.

4. In order to determine the exact position of all possible mineralised zones in the area the recommended sequence of operations should be followed. However, if time is limited the parameters determined in this study are recommended.

The importance of a preliminary investigation is proved very clearly and should not be ignored. All parameters set out in this study are expected to be fairly consistant for the Bushveld granites, but should rather be confirmed before a large scale programme is commenced, because one abnormality may cause poor results.

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11. REFERENCES

ABBEY, S., 1967. Analysis of rocks and minerals by atomic absorption spectrometry. Geol. Surv. Pap. Can., 67-37, 1-35.

ABBEY, S., 1983. Studies in "standard samples" of silicate rocks and minerals 1969-1982. Geol. Surv. Pap. Can., 83-15, 113 p.

BATES, T.F., 1952. Interrelationships of structure and genesis in the kaolinite group: Problems in Clay and Laterite Genesis. Am. Inst. Min. Met., New York, 144-153.

BAYLISS, P., 1972. An interpretation of the deeply weathered profile. Clay Minerals, 9, 438-440.

BOYLE, R.W. and DASS, A.S., 1967. Geochemical prospecting - use of the A horizon in soil surveys. Econ. Geol., 62, 274-276.

BRIDGES, E.M., 1970. World soils. Cambridge University Press, 89 p.

BRINK, A.B.A. and WILLIAMS, A.A.B., 1977. The description and interpretation of the soil profile for Engineering purposes: Proceedings Seventh National Congress of the Soil Science Society of Southern Africa, Pretoria, 13-23.

CROCKER, I.T. and CALLAGHAN, C.C., 1979. Tin resources of South Africa: Classification and inventory: Bull. Geol. Surv. S. Afr., 66, 27p.

DE BRUIYN, H. and RHODES, R.C., 1975. A new variety of Bushveld Granite in the Dennilton area, Transvaal. Trans. geol. Soc. S. Afr., 78, 89-95.

DE LAPPARENT, J., 1909. Etude comparative de quelques porphyroides francaises. In: MILLOT, G., 1970. Geology of clays: Springer - Verlag, New York, 429p.

EDGE, R.A., 1979. Determination of fluoride in geological materials using a fluoride ion-selective electrode. Geol. Surv. S. Afr., laboratory method (unpubl.), 5p.

EL BOUSEILY, A.M. and EL SOKKARY, A.A., 1975. The relation between Rb, Ba and Sr in Granitic rocks. Chem. Geol., 16, 207-219.

FAIRBRIDGE, R.W., 1968. The encyclopedia of Geomorphology. Encyclopedia of Earth Sciences Series, Volume III. Reinhold Book Corporation, New York, 1295 p.

FRICK, C. and KENT, L.E., 1984. Drift pumice in the Indian and South Atlantic oceans. Trans. geol. Soc. S. Afr., 87, 19-33.

GEE, R.D and GROVES, D.I., 1971. Structural features and mode of emplacement of part of the Blue Tier Batholith in North -east Tasmania. J. Geol. Soc. Austr., 18, 41-57.

GEOLOGICAL SURVEY OF SOUTH AFRICA., 1981. Mineral Map of the Republics of South Africa, Transkei, Bobhuthatswana, Venda and Ciskei and the Kingdoms of Lesotho and Swaziland: Pub. Geol. Surv. S. Afr.

GOLDSCHMIDT, V.M., 1954. Geochemistry. Claredon Press, Oxford, 730 p.

GORDON, M, TRACEY, J.I. and ELLIS, M.W., 1958. Geology of the Arkansas bauxite region. U.S. Geol. Surv. Prof. Paper, 299 p.

GROVES, D.I., 1972. The geochemical evolution of tin bearing granites in the Blue Tier Batholith, Tasmania. Econ. Geol., 67, 445-457.

GROVES, R.W, STEVENSON, B.G, STEVENSON, E.A. and TAYLOR, R.G., 1972. Geochemical and geobotanical studies in the Emuford district of the Herberton Tinfield, North Queensland. Trans. Inst. Min. Met., Section B (Aplied Earth Science), 80, 127-137.

HARMSE, H.J. VON M., 1974. Verwering en eksperimentele verwering. Unpubl. Prof. Paper, P.U. for C.H.E., Potchefstroom. 190 p.

HOSKING, K.F.G., 1971. Problems associated with the application of geochemical methods of exploration, Cornwall. In: BOYLE, R.W.,(Editor), 1971. Geochemical Exploration. Can. Inst. Min. Met., Spec. V. II, 176-189.

JAMES, C.H., 1957. Geochemical dispersion patterns related to arsenical and antimonial Gold Deposits in Southern Rhodesia (unpublished).Imperial College of Science and Technology, 237 p.

JEFFERY, P.G., 1975. Chemical Methods of Rock Analysis. (2 nd. ed.), Pergamon Press, Oxford, 536 p.

JUTA AND CO.,Ltd., 1983. New Visual Atlas for Southern Africa. Juta and Co., Ltd., Cape Town, 65 p.

LEVINSON, A.A., 1980. Introduction to Exploration Geochemistry. (2 nd. ed.), Applied Publishing Ltd., Calgary, 924p.

LOUGHNAN, F.C., 1969. Chemical Weathering of the Silicate Minerals. Elsevier Publishing Company, Inc., New York, 154 p.

MACVICAR, C.N, DE VILLIERS, J.M, LOXTON, R.F, VERSTER, E, LAMBRECHTS, J.J.N, MERRYWEATHER, F.R, LE ROUX, J, VAN ROOYEN, T.H. AND HARMSE, H.J. VON M., 1977. Soil classification. A binomial system for South Africa. Bull. Dep. Agric. Tech. Serv. No. 390, 150 p.

MARLOW, A.G., 1976. The geology of the Bushveld Complex on the Sekhukhune Plateau, Eastern Transvaal. Unpubl. M.Sc. thesis, Univ. Pretoria, 105 p.

MASON, B., 1966. Principles of Geochemistry. (3 rd. ed.), Wiley and Sons, Inc., 329 p.

MAZZUCCHELLI, R.H. and JAMES, C.H., 1966. Arsenic as a guide to gold mineralization in laterite covered areas of Western Australia. Trans. IMMA(Sect. B. Appl. Earth. Sci.), 75, 286-294.

MERENSKY, H., 1908. The rocks belonging to the area of the Bushveld granite in which tin may be expected with a description of the deposits actually found. Trans. geol. Soc. S. Afr., 11, 25-42.

MILLOT, G., 1970. Geology of clays. Springer - Verlag, New York, 429 p.

OMER-COOPER, W.B.R, HEWITT, W.V. and VAN WEES, H., 1974. Exploration for cassiterite - magnetite - sulphide veins on Belitung, Indonesia. In: TAYLOR, R.G., 1979. Geology of tin deposits. Elsevier Scientific Publishing Company, Amsterdam, 543 p.

OWENS, J.W; GLADNEY, E.S. and KNAB, D., 1982. Determination of boron in geological materials by inductively - coupled plasma emission spectrometry. Analytica. Chimica. Acta., 135, 169-172.

PARK, C.F.(Jr.) and MACDIARMID, R.A., 1975. Ore deposits. (3 rd. ed.), Freeman and Company, San Francisco, 529 p.

PELTIER, L., 1950. The geographic cycle in periglacial regions as it is related to climatic geomorphology. Ann. Assoc. Amer. Geog., 40, 214-236.

RANKAMA, K. and SAHAMA, TH.G., 1950. Geochemistry. The University of Chicago Press, Chicago, 912 p.

ROSE, A.W; HAWKES. H.E. AND WEBB, J.S., 1979. Geochemistry in mineral exploration (2 nd.ed.). Academic Press, London, 657 p.

SAND, L.B., 1956. On the genesis of residual kaolins. Am. Min., 41, 28-40.

SCHCHERBA, G.N., 1970a. Greisens (Part 1). Internat. Geology, 12(2), 114-150.

---------- 1970b. Greisens (Part 2). Internat. Geology, 12(3), 239-255.

SHERMAN, G.D. and KANEHIRO, Y., 1954. Origin and developement of ferruginous concretions in the Hawaiian latosols. Soil Science, 77, 1-8.

SIMONSON, R.W., 1957. What soils are. In: HAWKES, H.E. and WEBB, J.S., 1962. Geochemistry in mineral exploration. Harper & Row, Publishers, New York, 415 p.

SINCLAIR, A.J., 1974. Selection of threshold values in geochemical data using probability graphs. J. Geochem. Explor., 3, 129-149.

STEELE, T.W, WILSON, A, GOUDVIS, R, ELLIS, P.J and RADFORD, A.J., 1978. Analysis of the NIMROCK reference samples for minor and trace elements. National Institute for Metallurgy, Johannesburg, Report No. 1945, 222 p.

STEPHEN, I., 1952. A study of rock weathering with reference to the soils of Malvern Hills. Clay Min. Bull. 5, 203-208.

STEYN, J.G.D., 1962. The mineralogy of the more important tin-bearing pipes on Stavoren. Mem. geol. Surv. S. Afr., 51, 103 p.

TAYLOR, R.G., 1979. Geology of tin deposits. Elsevier Scientific Publishing Company, Amsterdam, 543 p.

THORNTON, C.P. and TUTTLE, O.F., 1960. Chemistry of igneous rocks. I: Differentiation index. Am. J. Sci., 258, 664-684.

VERMAAK, J.J., 1984. Aspects of the Secondary Dispersion of Ore - Related Elements in Calcrete - Environments. Unpubl. M.Sc. thesis, Univ. of the Orange Free State, Bloemfontein, 137 p.

WALKER, G.F., 1949. Decomposition of biotite in the soil. Min. Mag. 28, 693-708.

WALRAVEN, F., in prep. Study of the fractionation of Rb, Sr and Ba in tin-bearing and non-tin-bearing granites in the Bushveld Complex, South Africa.

WEDEPOHL, K.H., 1978. Handbook of Geochemistry. Vol. II/1-II/5, Springer - Verlag, Berlin.

WESSELS, J.T., 1940. Field sheet of the area 2528B. Geol. Surv. S. Afr., (unpubl.).

APPENDIX A: DESCRIPTION, MINERALOGY AND GEOCHEMISTRY OF 32 SOIL PROFILES.

(B_2(R) = B_2 HORIZON IN RESIDUAL SOIL)
(B_2(T) = B_2 HORIZON IN TRANSPORTED SOIL)

LEGEND

H.M. - HEAVY MINERALS
CAS - CASSITERITE
GH - GOETHITE
HEM - HEMATITE
ILM - ILMENITE
LIM - LIMONITE
MAG - MAGNETITE
ZR - ZIRCON

(Fe = TOTAL Fe AS Fe_2O_3)

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
						GEOCHEMICAL DATA (PPM)																				
A_1	0.2	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		157	1617	20	230	16086	<5	<5	16	10	161	10	55	356	14	<5	110	23	<5	36	17	<5
				>2	18.9	109	1072	32	163	36368	8	<5	28	<5	474	11	57	183	18	<5	95	26	11	71	21	<5
				.425-2	47.5	130	1437	15	200	13988	7	<5	6	<5	88	10	46	336	10	<5	83	<5	<5	47	15	<5
				.180-.425	21.9	183	1677	17	230	12519	<5	<5	8	<5	100	10	51	370	13	<5	114	18	<5	42	15	<5
				.075-.180	7.4	283	2276	8	253	15596	<5	<5	12	8	103	12	68	557	14	<5	150	15	<5	34	19	<5
				<.075	4.3	353	3893	33	416	24478	12	6	14	<5	152	20	137	1239	21	<5	258	<5	<5	58	37	14
A_2(E)	0.3	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		182	1720	30	130	26186	11	<5	14	7	170	7	54	360	16	<5	113	17	<5	26	15	<5
				>2	10.2	231	1131	85	178	33142	9	<5	25	9	271	7	26	121	19	<5	79	23	<5	78	21	<5
				.425-2	47.6	135	1572	14	142	12243	<5	<5	7	<5	152	<5	36	183	11	<5	90	10	<5	43	8	<5
				.180-.425	27.2	162	1931	16	117	17248	7	7	8	10	173	7	49	271	15	<5	112	9	<5	36	13	<5
				.075-.180	8.5	221	3324	23	143	22132	12	8	16	14	225	9	106	806	23	<5	175	15	<5	53	27	<5
				<.075	6.5	269	4123	41	198	33156	16	14	41	35	296	16	125	925	27	<5	219	17	<5	57	41	12
P	0.4	ZONE MARKED BY QUARTZ PEBBLES, ROCK DEBRIS AND IRON OXIDES.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES; GOETHITE PELLETS; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND CAS, BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM, CAS AND ZR.	TOTAL		122	1377	17	178	20982	<5	<5	19	<5	255	9	57	283	14	<5	105	70	<5	38	20	<5
				>2	41.5	87	898	19	253	30669	<5	<5	24	<5	418	12	57	168	12	<5	89	97	14	57	24	<5
				.425-2	35.9	165	1678	15	148	16086	<5	<5	15	<5	162	7	50	291	12	<5	86	48	<5	31	13	<5
				.180-.425	14.4	209	2036	23	200	22240	<5	<5	21	13	147	10	59	375	15	<5	120	50	<5	41	20	<5
				.075-.180	4.0	226	2515	20	186	21681	8	<5	21	<5	188	10	77	553	15	<5	150	43	<5	41	19	<5
				<.075	4.2	288	3594	41	267	34970	19	16	37	22	306	16	133	966	21	<5	200	31	<5	60	38	12
B_2(R)	1.0	RED SOFT PLINTIC B HORIZON WHICH STILL PRESERVES THE GRANITIC STRUCTURE. (ZONE OF ILLUVIATION WITH MOTTLED STRUCTURES).	QUARTZ (ANGULAR AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; ENRICHED IN KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, CAS, LIM AND ZR.	TOTAL		170	2668	48	565	42663	16	12	44	36	258	10	76	408	21	<5	190	63	<5	112	31	8
				>2	33.7	135	2216	46	893	37068	10	<5	27	13	328	8	64	316	14	<5	283	51	<5	168	24	<5
				.425-2	36.3	170	2575	50	550	36368	12	10	28	20	230	9	75	421	16	<5	192	33	<5	130	27	<5
				.180-.425	15.2	205	3414	55	454	43362	27	13	37	21	249	9	92	525	20	<5	206	26	<5	97	34	<5
				.075-.180	7.5	226	3534	56	364	44761	19	33	43	32	233	10	96	595	19	<5	184	43	<5	89	34	7
				<.075	7.3	205	3833	52	394	48258	31	21	64	35	288	10	109	654	26	<5	194	54	<5	88	42	8
B_3	1.2	WHITISH-GREY HORIZON CONTAINING MUCH CLAY MINERALS. THE GRANITIC STRUCTURE IS STILL PRESERVED.	QUARTZ (ANGULAR AND SUBANGULAR); ALTERED FELDSPAR AND BIOTITE; WHITE CONCRETIONS OF MAINLY KAOLINITE. H.M. - MAG, ILM, LIM, GH, HEM CAS, AND ZR.	TOTAL		90	2300	39	510	33150	16	11	24	35	325	10	70	362	24	<5	191	52	<5	101	31	9
				>2	31.2	103	1910	48	493	51420	12	15	30	38	424	9	63	273	26	<5	178	43	<5	85	30	7
				.425-2	38.3	92	2212	26	375	29656	8	7	21	32	315	6	58	321	21	<5	165	26	<6	51	21	<5
				.180-.425	15.7	151	2931	34	333	23525	7	12	27	47	276	9	73	454	20	<5	168	21	<5	63	26	<5
				.075-.180	8.0	213	4114	48	356	30111	16	17	39	51	293	10	106	762	24	<5	235	36	<5	72	35	7
				<.075	6.8	219	4362	65	440	42725	21	34	54	74	366	14	115	783	32	<5	262	43	<5	85	49	10
C	1.7	BROWN WEATHERED BEDROCK. (UNCONSOLIDATED).	QUARTZ; KAOLINISED, ILLITISED AND HEMATITISED FELDSPARS; CHLORITISED AND HEMATITISED BIOTITE. H.M.- HEM, MAG, CAS, ILM AND ZR.	TOTAL		35	1510	11	361	31200	8	12	12	28	430	11	69	267	31	<5	185	43	<5	75	35	7
				>2	40.1	32	1420	7	341	30526	8	6	6	17	621	9	65	238	26	<5	172	31	<5	92	28	<5
				.425-2	42.2	41	1380	7	285	27892	<5	<5	<5	18	536	8	61	237	24	<5	155	19	<5	61	26	<5
				.180-.425	8.5	36	1210	8	336	40288	16	21	10	22	652	10	71	283	32	<5	201	17	<5	85	37	<5
				.075-.180	4.4	52	1731	10	395	54241	20	22	19	36	764	12	102	461	40	<5	253	24	<5	73	61	9
				<.075	4.8	53	1785	8	361	58921	21	20	36	40	753	12	95	389	45	<5	283	32	<5	72	69	11
R	1.7	WEATHERED VLAKLAAGTE GRANITE.	QUARTZ; SERICITISED AND KAOLINISED POTASH FELDSPAR AND PLAGIOCLASE; THE BIOTITE IS CHLORITISED. H.M. - MAG, CAS, ILM, HEM AND ZR.			44	1371	10	208	22589	<5	<5	25	13	735	12	60	224	21	<5	205	26	<5	84	24	<5

Description, mineralogy and trace element geochemistry of weathering profile 1 on red-grey Vlaklaagte granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
						GEOCHEMICAL DATA (PPM)																				
A_1	0.2	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		104	1737	17	62	4895	<5	<5	<5	<5	73	8	33	355	11	<5	89	13	<5	11	5	<5
				>2	3.4	96	1976	29	74	9791	<5	<5	<5	<5	83	10	43	443	13	<5	105	7	<5	29	11	<5
				.425-2	55.8	87	1317	15	25	3636	<5	<5	<5	<5	51	5	20	212	8	<5	60	<5	<5	16	<5	<5
				.180-.425	25.7	117	2036	21	81	7973	<5	<5	<5	<5	100	9	36	349	11	<5	127	7	<5	25	6	<5
				.075-.180	9.7	153	2527	15	89	6294	<5	<5	<5	<5	90	10	54	567	16	<5	127	23	<5	20	11	<5
				<.075	5.4	231	4193	22	178	10491	<5	<5	<5	<5	116	18	105	1207	23	<5	181	<5	<5	26	25	8
A_2(E)	0.35	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		104	2216	34	34	15386	<5	<5	<5	<5	100	10	52	450	19	<5	110	<5	<5	27	27	15
				>2	6.0	130	2336	29	29	14407	<5	<5	10	12	91	10	39	399	12	<5	96	<5	<5	32	10	<5
				.425-2	65.5	87	1916	23	14	11889	<5	<5	<5	<5	78	8	30	310	10	<5	72	<5	<5	28	6	<5
				.180-.425	18.0	130	2995	23	35	16086	<5	12	9	7	120	12	45	422	15	<5	146	11	<5	27	15	<5
				.075-.180	5.7	139	3474	20	61	14689	<5	17	10	9	114	14	61	646	19	<5	145	17	<5	26	24	8
				<.075	4.8	144	4252	35	70	18883	8	5	9	9	139	16	95	1028	23	<5	167	<5	<5	29	27	18
A_3	0.45	BROWN WEAKLY STRUCTURED SOILS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; MINOR IRON OXIDES; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		78	2276	23	8	11190	5	<5	7	<5	94	10	41	399	15	<5	107	7	<5	26	14	5
				>2	2.5	65	1725	60	7	18883	<5	<5	<5	<5	79	11	38	343	13	<5	153	<5	<5	32	17	9
				.425-2	58.6	82	1856	23	7	8392	<5	<5	<5	<5	73	7	27	262	9	<5	83	<5	<5	27	6	<5
				.180-.425	26.0	130	3354	27	15	15386	<5	<5	9	<5	128	10	49	475	15	<5	158	7	<5	19	13	<5
				.075-.180	7.5	153	3773	30	49	17485	<5	<5	7	<5	126	12	66	702	18	<5	171	<5	<5	30	19	<5
				<.075	5.4	174	4911	33	63	21681	13	14	19	7	149	15	95	1000	27	<5	195	19	<5	25	29	8
B_1	0.55	REDDISH - BROWN WEAKLY STRUCTURED SOILS.	QUARTZ (ROUNDED AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		88	2371	26	10	13120	<5	7	7	7	95	10	42	385	14	<5	106	8	<5	25	14	6
				>2	3.0	74	1824	61	9	20526	<5	<5	<5	<5	82	10	40	320	13	<5	149	<5	<5	29	16	7
				.425-2	57.2	93	1932	25	9	10256	<5	<5	<5	<5	72	7	29	225	8	<5	85	7	<5	29	7	<5
				.180-.425	27.4	141	3421	29	17	17482	<5	13	11	<5	134	11	50	467	14	<5	155	8	<5	21	14	<5
				.075-.180	7.7	162	3823	31	51	19252	6	23	10	8	131	12	67	692	17	<5	169	9	<5	32	20	<5
				<.075	4.7	183	5052	34	67	23252	14	20	21	13	156	14	97	983	25	<5	189	20	<5	27	29	10
B_2(T)	0.6	REDDISH APEDAL B HORIZON. (ZONE OF ILLUVIATION)	QUARTZ (ROUNDED AND SUBANGULAR); NO FELDSPAR AND BIOTITE; KAOLINITE AND OTHER MIXED LAYERED CLAY MINERALS. H.M. - MAG, ILM, LIM, GH, HEM AND ZR.	TOTAL		109	2455	29	15	15806	<5	<5	6	6	96	9	43	397	13	<5	104	<5	<5	24	12	<5
				>2	3.7	126	1497	188	12	70639	20	14	24	<5	56	5	27	249	11	<5	36	<5	<5	21	9	7
				.425-2	54.2	83	1617	23	19	11889	<5	<5	<5	<5	66	6	24	225	9	<5	65	12	<5	24	<5	<5
				.180-.425	27.1	165	3713	43	53	22380	<5	29	14	15	142	14	58	512	18	<5	178	7	<5	33	22	7
				.075-.180	9.1	200	4612	39	70	26577	8	27	19	17	148	15	79	776	24	<5	195	14	<5	25	30	10
				<.075	5.9	196	4971	43	104	29374	14	29	22	20	162	16	96	902	25	<5	199	<5	<5	31	31	8
P	1.1	HORIZON MARKED BY ROUNDED QUARTZ PEBBLES AND GOETHITE PELLETS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES AND GRAINS STAINED WITH IRON OXIDES; GOETHITE PELLETS; MINOR CLAY MINERALS; NO FELDSPAR AND BIOTITE. H.M. - GH, HEM, MAG, ILM AND ZR.	TOTAL		122	2575	87	8	40565	11	7	18	<5	90	10	45	418	15	<5	111	<5	<5	24	18	7
				>2	40.3	10	1138	164	12	97216	58	34	51	<5	49	<5	30	301	12	<5	<5	<5	<5	<5	12	14
				.425-2	31.5	104	1976	30	14	16086	<5	<5	6	<5	67	7	28	265	11	<5	75	11	<5	22	8	<5
				.180-.425	17.7	161	3833	41	47	21681	<5	<5	<5	<5	134	11	62	534	15	<5	195	<5	<5	40	20	<5
				.075-.180	6.2	187	4672	41	41	26577	10	14	19	5	135	13	80	785	23	<5	186	8	<5	25	28	9
				<.075	4.3	192	5031	53	67	3357	18	27	25	10	143	14	96	964	25	<5	214	<5	<5	30	31	9
C	1.3	BROWN HORIZON OF HIGHLY WEATHERED BEDROCK. (UNCONSOLIDATED).	MAINLY QUARTZ; ALTERED FELDSPAR AND BIOTITE; H.M - MAG, ILM, HEM AND ZR.	TOTAL		206	3001	26	232	38255	13	10	71	21	225	22	75	389	24	<5	251	19	<5	63	29	6
				>2	32.5	358	2621	65	411	60824	25	15	149	14	199	18	63	334	19	<5	183	7	<5	97	27	8
				.425-2	36.9	209	2631	17	212	32526	10	7	72	15	252	23	69	292	22	<5	302	23	<5	59	28	<5
				.180-.425	16.3	191	3245	12	198	31252	9	<5	65	13	273	23	70	326	23	<5	333	25	<5	55	28	<5
				.075-.180	8.6	223	4152	25	256	41262	15	17	82	32	249	24	101	552	31	<5	279	39	<5	54	41	9
				<.075	5.7	221	4183	41	309	45212	26	20	99	25	222	18	115	676	33	<5	243	12	<5	79	47	14

Description, mineralogy and trace element geochemistry of weathering profile 2 possibly on Vlaklaagte granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	GEOCHEMICAL DATA (PPM)																				
						P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
A_1	0.3	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		154	1783	14	115	11523	<5	<5	12	<5	98	13	42	313	13	<5	127	18	<5	40	10	<5
				>2	4.8	152	2156	23	126	16082	<5	<5	19	<5	109	12	65	482	14	<5	139	<5	<5	59	19	<5
				.425-2	61.1	139	1737	13	108	14407	<5	<5	12	<5	85	10	43	317	10	<5	85	<5	<5	57	7	<5
				.180-.425	24.4	157	1880	13	119	11819	<5	<5	12	<5	101	11	45	322	12	<5	131	21	<5	40	10	<5
				.075-.180	6.5	187	2276	18	148	17485	<5	<5	17	<5	111	15	74	600	16	<5	140	15	<5	49	16	<5
				<.075	3.2	283	4252	39	312	26577	20	<5	44	8	167	24	150	1254	28	<5	257	<5	<5	60	31	12
A_2(E)	0.5	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		183	2695	34	88	28675	11	<5	54	8	135	10	62	405	14	<5	125	<5	<5	47	14	<5
				>2	12.6	196	2875	46	126	34900	11	8	47	14	136	10	62	414	13	<5	135	<5	<5	62	17	<5
				.425-2	40.8	148	2096	24	58	21681	<5	<5	36	<5	99	6	43	294	10	<5	87	<5	<5	42	6	<5
				.180-.425	27.5	205	2815	37	111	31473	10	6	45	12	149	12	65	409	13	<5	130	<5	<5	52	16	<5
				.075-.180	11.2	226	3594	46	111	38467	24	13	72	14	181	13	102	742	19	<5	159	<5	<5	59	26	<5
				<.075	7.9	248	4133	69	163	51056	32	38	92	35	226	15	116	730	24	<5	182	<5	<5	62	34	8
A_3	0.7	BROWN WEAKLY STRUCTURED SOILS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; MINOR IRON OXIDES; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		196	2755	41	141	31473	13	8	49	16	135	13	73	483	17	<5	119	<5	<5	55	21	7
				>2	10.3	178	2635	38	89	27976	13	<5	44	<5	123	8	68	458	14	<5	117	<5	<5	59	18	<5
				.425-2	38.1	144	1677	23	72	19583	<5	<5	25	<5	87	9	43	261	8	<5	57	<5	<5	57	7	<5
				.180-.425	27.2	209	3174	41	89	32172	15	<5	60	10	154	11	74	453	15	<5	137	<5	<5	62	19	<5
				.075-.180	13.2	248	3893	53	141	41264	22	22	64	21	179	15	111	800	22	<5	160	<5	<5	65	30	9
				<.075	11.2	253	4193	70	148	47559	35	27	95	24	208	14	122	789	22	<5	174	<5	<5	64	33	7
B_1	0.9	REDDISH - BROWN WEAKLY STRUCTURED SOILS.	QUARTZ (ROUNDED AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		194	2757	43	138	30284	12	7	45	14	130	11	69	471	15	<5	120	<5	<5	54	19	<5
				>2	11.4	183	2677	37	99	28120	11	<5	41	<5	124	9	69	447	14	<5	119	<5	<5	53	18	<5
				.425-2	37.0	152	1882	26	89	19998	6	<5	24	7	98	8	52	282	9	<5	68	<5	<5	51	9	<5
				.180-.425	26.2	201	3272	39	97	33242	13	11	56	11	157	12	77	473	17	<5	141	<5	<5	57	20	7
				.075-.180	14.2	251	3882	56	145	42611	19	13	59	24	183	14	114	812	24	<5	166	<5	<5	59	33	7
				<.075	11.2	257	4212	69	162	49152	32	29	99	29	215	17	127	805	26	<5	173	<5	<5	58	36	10
B_2(T)	1.3	REDDISH APEDAL B HORIZON. (ZONE OF ILLUVIATION)	QUARTZ (ROUNDED AND SUBANGULAR); NO FELDSPAR AND BIOTITE; KAOLINITE AND OTHER MIXED LAYERED CLAY MINERALS. H.M. - MAG, ILM, LIM, GH, HEM AND ZR.	TOTAL		187	2695	42	109	31374	10	<5	40	<5	121	10	65	444	11	<5	123	<5	<5	54	16	<5
				>2	19.2	196	2911	50	141	35669	10	<5	46	9	112	9	57	405	13	<5	105	<5	<5	66	17	<5
				.425-2	38.8	146	2078	23	44	18883	<5	<5	32	<5	86	7	41	284	9	<5	73	<5	<5	51	7	<5
				.180-.425	24.4	231	3833	44	119	39166	20	15	70	27	166	13	83	543	22	<5	147	<5	<5	47	28	<5
				.075-.180	11.1	240	4013	58	148	41964	24	17	66	9	184	13	113	829	20	<5	166	<5	<5	64	30	6
				<.075	6.5	266	4552	61	171	50356	31	35	107	33	222	15	125	820	28	<5	173	<5	<5	49	39	9
P	1.6	HORIZON MARKED BY ROUNDED QUARTZ PEBBLES AND GOETHITE PELLETS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES AND GRAINS STAINED WITH IRON OXIDES; GOETHITE PELLETS; MINOR CLAY MINERALS; NO FELDSPAR AND BIOTITE. H.M. - GH, HEM, MAG, ILM AND ZR.	TOTAL		183	2156	174	163	99998	34	29	98	<5	93	10	58	371	15	<5	45	<5	<5	46	25	17
				>2	69.3	135	1725	211	171	99898	54	28	102	<5	69	7	45	294	11	<5	<5	<5	<5	55	24	21
				.425-2	13.8	196	3174	70	186	53154	19	16	61	26	138	12	73	431	17	<5	136	16	<5	60	24	7
				.180-.425	10.8	218	3594	56	156	44761	23	11	69	8	167	12	93	591	20	<5	161	<5	<5	58	28	<5
				.075-.180	2.9	235	3773	62	178	47559	21	21	71	22	178	14	109	725	22	<5	160	<5	<5	60	31	7
				<.075	3.2	214	3773	70	183	50356	32	18	94	18	187	15	114	700	22	<5	172	<5	<5	66	32	7
C	1.7	BROWN HORIZON OF HIGHLY WEATHERED BEDROCK. (UNCONSOLIDATED).	MAINLY QUARTZ; ALTERED FELDSPAR AND BIOTITE; H.M - MAG, ILM, HEM AND ZR.	TOTAL		208	3010	25	245	37152	14	11	69	19	305	23	91	432	24	<5	305	10	<5	54	31	6
				>2	19.3	371	2621	59	448	79232	25	16	148	13	277	16	74	365	22	<5	235	<5	<5	89	29	10
				.425-2	58.4	219	2734	17	231	32156	10	6	65	13	365	23	79	321	22	<5	362	11	<5	65	27	<5
				.180-.425	12.8	204	3212	11	211	30542	11	7	63	11	382	24	81	354	23	<5	382	21	<5	59	29	<5
				.075-.180	4.4	239	4156	25	251	41121	17	17	81	29	363	24	117	619	29	<5	331	22	<5	57	39	9
				<.075	5.1	222	4215	37	305	46194	29	19	99	24	311	18	131	721	31	<5	298	9	<5	73	45	9

Description, mineralogy and trace element geochemistry of weathering profile 3 on Vlaklaagte granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
						GEOCHEMICAL DATA (PPM)																				
A_1	0.15	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		122	1677	9	104	11540	<5	9	17	7	114	14	56	390	14	<5	151	52	<5	39	13	<5
				>2	3.6	144	1976	10	89	13148	<5	<5	18	<5	117	13	64	452	17	<5	166	75	<5	39	16	<5
				.425-2	40.2	104	1317	7	74	9791	<5	8	10	<5	86	9	41	287	13	<5	87	63	<5	33	11	<5
				.180-.425	38.5	130	1797	<5	81	9092	<5	<5	16	<5	121	12	45	300	15	<5	171	81	<5	34	14	<5
				.075-.180	12.3	187	2635	12	148	14687	<5	<5	19	<5	156	20	93	703	20	<5	431	77	<5	46	23	7
				<.075	5.4	309	4193	28	312	27276	11	12	38	21	201	28	179	1378	30	<5	320	81	<5	52	43	18
A_2(E	0.3	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		130	2036	11	52	13988	<5	<5	26	<5	125	11	68	374	16	<5	163	83	<5	45	12	<5
				>2	5.5	117	1797	17	81	19513	<5	64	26	11	118	12	58	390	16	<5	131	75	<5	43	19	<5
				.425-2	38.8	240	4612	34	171	32172	19	13	63	16	230	19	167	1229	30	<5	297	48	<5	48	42	13
				.180-.425	38.8	109	1557	10	41	13288	<5	20	17	6	131	12	51	308	14	<5	148	55	<5	38	17	<5
				.075-.180	10.5	205	2995	13	96	23779	<5	37	40	17	184	17	90	594	22	<5	237	59	<5	43	23	7
				<.075	6.4	74	1299	13	44	10491	<5	<5	17	<5	97	11	43	283	12	<5	116	30	<5	42	15	6
A_3	0.45	BROWN WEAKLY STRUCTURED SOILS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; MINOR IRON OXIDES; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		135	2036	20	89	21681	<5	89	38	17	144	12	63	427	16	<5	148	38	<5	46	18	<5
				>2	10.6	148	2276	17	70	20982	6	<5	36	6	134	8	58	388	15	<5	135	48	<5	39	14	<5
				.425-2	45.9	139	1856	20	58	18184	<5	9	28	15	116	9	48	316	14	<5	109	87	<5	45	13	<5
				.180-.425	29.6	152	2396	11	55	1883	<5	<5	41	9	152	10	56	367	15	<5	162	58	<5	45	15	<5
				.075-.180	8.3	209	3354	23	133	29374	9	33	57	15	196	15	102	747	20	<5	243	34	<5	47	28	6
				<.075	5.6	240	4372	42	133	41264	28	36	99	37	247	16	136	966	27	<5	256	36	<5	54	39	9
B_1	0.6	REDDISH - BROWN WEAKLY STRUCTURED SOILS.	QUARTZ (ROUNDED AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		183	2815	29	81	29374	14	75	67	23	167	10	71	439	17	<5	182	145	<5	44	22	<5
				>2	10.3	200	2695	33	96	33291	10	6	53	25	154	9	62	397	15	<5	139	37	<5	42	20	<5
				.425-2	46.9	152	2156	18	54	20970	7	<5	44	11	126	6	48	321	12	<5	117	24	<5	37	12	<5
				.180-.425	26.8	213	2995	27	104	33571	12	<5	62	33	177	11	68	395	16	<5	173	34	<5	47	22	<5
				.075-.180	8.8	261	3773	41	133	41964	20	24	76	38	217	15	111	717	23	<5	230	28	<5	53	35	9
				<.075	7.2	248	4073	54	163	50356	33	56	99	53	259	16	126	811	28	<5	247	59	<5	57	44	10
B_2(T	0.9	REDDISH APEDAL B HORIZON. (ZONE OF ILLUVIATION)	QUARTZ (ROUNDED AND SUBANGULAR); NO FELDSPAR AND BIOTITE; KAOLINITE AND OTHER MIXED LAYERED CLAY MINERALS. H.M. - MAG, ILM, LIM, GH, HEM AND ZR.	TOTAL		240	3174	25	119	34970	14	32	67	34	174	12	80	486	18	<5	197	34	<5	45	24	<5
				>2	12.9	209	2991	31	111	33571	14	<5	58	16	153	8	72	467	16	<5	167	26	<5	52	21	<5
				.425-2	38.4	166	2036	16	66	22380	<5	<5	35	17	112	7	49	291	12	<5	97	38	<5	37	13	<5
				.180-.425	26.3	226	3054	23	89	30074	10	<5	62	20	172	10	72	424	18	<5	185	40	<5	44	20	<5
				.075-.180	12.7	218	3594	30	126	38467	24	62	86	30	220	13	103	701	22	<5	236	51	<5	48	32	<5
				<.075	9.5	257	4312	46	141	47559	33	28	114	45	244	13	129	805	27	<5	227	38	<5	53	41	8
P	1.6	HORIZON MARKED BY ROUNDED QUARTZ PEBBLES AND GOETHITE PELLETS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES AND GRAINS STAINED WITH IRON OXIDES; GOETHITE PELLETS; MINOR CLAY MINERALS; NO FELDSPAR AND BIOTITE. H.M. - GH, HEM, MAG, ILM AND ZR,	TOTAL		248	3114	64	148	60148	25	12	82	22	171	10	87	508	19	<5	201	46	<5	48	30	7
				>2	50.7	218	1497	154	126	98475	27	18	70	8	62	5	45	239	11	<5	<5	35	<5	39	22	16
				.425-2	23.7	196	2977	34	141	37767	15	<5	62	17	166	9	77	418	18	<5	325	78	<5	53	24	<5
				.180-.425	13.2	240	3653	38	163	42663	16	18	79	43	223	13	99	523	24	<5	211	63	<5	55	34	<5
				.075-.180	6.8	248	3833	37	178	44761	21	48	88	159	230	15	131	741	27	<5	227	68	<5	63	39	8
				<.075	5.6	253	4193	54	223	51056	28	31	94	46	250	15	163	868	25	<5	242	35	<5	76	47	11
C	2.1	BROWN HORIZON OF HIGHLY WEATHERED BEDROCK. (UNCONSOLIDATED).	MAINLY QUARTZ; ALTERED FELDSPAR AND BIOTITE; H.M - MAG, ILM, HEM AND ZR.	TOTAL		187	3174	35	163	41961	17	11	72	35	206	13	94	530	23	<5	229	19	<5	47	31	6
				>2	24.9	192	2935	78	141	60847	22	8	74	20	170	8	83	448	19	<5	149	13	<5	62	26	6
				.425-2	39.5	170	2875	21	133	30074	9	<5	59	32	191	11	82	449	21	<5	178	23	<5	47	26	<5
				.180-.425	17.9	209	3534	31	186	37068	11	11	75	24	242	15	100	514	22	<5	252	17	<5	67	33	<5
				.075-.180	10.8	200	3893	27	163	38467	23	10	97	37	240	14	123	735	28	<5	261	37	<5	58	37	<5
				<.075	6.9	205	4552	39	215	45461	30	30	112	43	275	15	158	969	33	<5	259	29	<5	68	50	12

Description, mineralogy and trace element geochemistry of weathering profile 4 on Vlaklaagte granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
A_1	0.3	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		113	1377	15	96	14687	<5	<5	16	7	136	18	50	328	15	<5	174	44	<5	48	12	<5
				>2	1.8	NO SAMPLE																				
				.425-2	30.9	130	1317	11	89	11889	<5	<5	11	<5	101	13	37	249	12	<5	124	62	<5	51	10	<5
				.180-.425	53.3	139	1557	8	59	8392	<5	<5	11	<5	139	16	39	256	13	<5	208	53	<5	48	10	<5
				.075-.180	9.6	261	2455	9	119	16086	<5	<5	17	<5	227	27	69	542	22	<5	310	55	<5	60	21	7
				<.075	4.4	318	4193	16	223	23080	14	<5	40	<5	220	30	155	1247	30	<5	343	40	<5	69	39	13
A_2(E)	0.5	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		152	2336	11	24	20282	10	<5	44	10	164	14	52	352	18	<5	178	45	<5	43	14	<5
				>2	2.4	NO SAMPLE																				
				.425-2	44.8	152	2396	10	20	18883	9	<5	40	7	140	11	47	310	16	<5	176	55	<5	46	14	<5
				.180-.425	41.4	170	2396	13	52	21891	<5	<5	38	15	166	15	48	293	16	<5	212	85	<5	54	14	<5
				.075-.180	6.6	205	3713	21	74	33571	18	7	70	19	242	20	98	686	26	<5	273	52	<5	64	31	<5
				<.075	4.8	235	4193	53	148	46859	24	29	86	41	259	21	126	870	31	<5	256	31	<5	69	44	12
A_3	0.7	BROWN WEAKLY STRUCTURED SOILS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; MINOR IRON OXIDES; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		174	2455	29	71	29374	16	8	53	24	184	15	68	404	19	<5	172	40	<5	48	20	<5
				>2	2.9	139	2276	37	119	29374	17	<5	62	16	161	12	74	401	18	<5	186	56	<5	104	22	<5
				.425-2	39.0	178	2318	24	58	26577	10	<5	45	20	152	13	55	311	17	<5	172	54	<5	57	18	<5
				.180-.425	42.4	192	2755	26	37	27976	15	<5	66	19	197	15	61	353	20	<5	211	70	<5	59	20	<5
				.075-.180	10.1	244	3833	49	111	47559	27	29	92	46	257	18	107	630	27	<5	223	36	<5	68	37	8
				<.075	5.6	235	4013	49	117	51056	38	31	120	45	256	15	116	689	28	<5	214	19	<5	65	42	8
B_1	0.9	REDDISH - BROWN WEAKLY STRUCTURED SOILS.	QUARTZ (ROUNDED AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		205	3174	29	81	32871	12	<5	65	19	188	15	75	439	19	<5	200	20	<5	57	22	<5
				>2	5.5	170	2575	46	171	36368	15	9	50	20	162	13	77	462	19	<5	174	37	<5	80	27	7
				.425-2	34.4	174	2575	19	89	25877	<5	<5	41	10	146	11	58	331	17	<5	183	54	<5	53	17	<5
				.180-.425	39.2	218	3054	35	74	32871	11	6	52	22	202	17	74	386	19	<5	226	28	<5	71	23	<5
				.075-.180	13.2	231	4013	44	104	44761	29	21	94	30	246	17	115	709	28	<5	227	29	<5	74	37	8
				<.075	7.9	244	4133	58	163	52455	30	35	124	45	251	17	129	757	29	<5	233	11	<5	78	44	10
B_2(T)	1.5	REDDISH APEDAL B HORIZON. (ZONE OF ILLUVIATION)	QUARTZ (ROUNDED AND SUBANGULAR); NO FELDSPAR AND BIOTITE; KAOLINITE AND OTHER MIXED LAYERED CLAY MINERALS. H.M. - MAG, ILM, LIM, GH, HEM AND ZR.	TOTAL		192	2995	33	133	35669	11	7	54	19	192	16	78	460	20	<5	203	22	<5	62	26	<5
				>2	9.4	196	3294	42	171	39865	17	<5	68	13	181	13	78	444	22	<5	223	50	<5	69	27	6
				.425-2	37.4	185	2594	20	93	26242	<5	<5	41	16	145	12	56	324	16	<5	170	46	<5	64	18	<5
				.180-.425	34.3	206	3513	16	89	33761	14	<5	68	14	212	20	78	414	21	<5	247	37	<5	78	23	10
				.075-.180	13.1	226	4013	46	156	45461	20	24	98	34	252	20	121	728	28	<5	247	17	<5	78	40	10
				<.075	5.8	218	449	42	133	47559	35	23	132	33	247	17	138	851	32	<5	235	22	<5	71	46	10
P	2.0	HORIZON MARKED BY ROUNDED QUARTZ PEBBLES AND GOETHITE PELLETS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES AND GRAINS STAINED WITH IRON OXIDES; GOETHITE PELLETS; MINOR CLAY MINERALS; NO FELDSPAR AND BIOTITE. H.M. - GH, HEM, MAG, ILM AND ZR.	TOTAL		200	2276	94	476	79591	27	11	100	14	129	10	63	328	18	<5	155	20	<5	104	26	13
				>2	52.5	253	2695	128	744	89523	23	28	80	16	118	15	56	291	20	<5	293	<5	<5	125	42	30
				.425-2	19.8	170	3234	42	312	47559	22	6	88	19	179	13	78	385	21	<5	215	25	<5	91	28	6
				.180-.425	16.6	196	3534	33	156	41264	15	12	77	28	243	19	88	444	25	<5	258	37	<5	72	33	6
				.075-.180	9.8	205	4133	37	148	44761	25	14	105	28	259	18	119	689	30	<5	250	26	<5	71	41	8
				<.075	1.3	209	4133	57	208	52455	28	31	103	40	256	18	144	837	33	<5	219	25	<5	81	50	12
C	2.3	BROWN HORIZON OF HIGHLY WEATHERED BEDROCK. (UNCONSOLIDATED).	MAINLY QUARTZ; ALTERED FELDSPAR AND BIOTITE; H.M - MAG, ILM, HEM AND ZR.	TOTAL		165	2995	46	193	45461	19	9	72	20	222	17	90	475	24	<5	232	27	<5	68	30	7
				>2	24.5	170	2995	64	245	60847	22	7	84	9	185	14	84	419	21	<5	210	15	<5	78	30	11
				.425-2	29.9	157	2995	26	148	35669	10	5	70	24	216	18	82	405	22	<5	249	35	<5	87	29	6
				.180-.425	26.6	161	3534	21	126	35669	15	<5	87	17	268	21	88	442	24	<5	288	36	<5	68	30	<5
				.075-.180	12.3	183	4133	30	171	44062	21	19	92	33	281	21	127	719	32	<5	293	38	<5	75	43	9
				<.075	6.7	170	4492	47	193	49657	36	23	123	31	278	18	154	858	35	<5	247	16	<5	75	51	12

Description, mineralogy and trace element geochemistry of weathering profile 5 on Vlaklaagte granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
						GEOCHEMICAL DATA (PPM)																				
A_1	0.15	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		178	1677	16	163	15386	<5	<5	42	12	116	12	45	296	14	<5	124	68	<5	17	10	<5
				>2	6.3	235	2396	17	171	22380	9	10	60	8	135	13	57	386	18	<5	167	77	<5	31	16	<5
				.425-2	49.3	235	2036	<5	163	16086	<5	<5	40	10	118	12	39	246	14	<5	158	62	<5	33	8	<5
				.180-.425	35.1	183	1916	7	163	14687	<5	<5	37	<5	104	11	40	277	12	<5	137	43	<5	37	8	<5
				.075-.180	5.8	253	2396	17	208	19583	6	8	54	16	191	20	87	533	20	<5	241	73	<5	26	20	<5
				<.075	3.5	427	4552	24	320	31473	22	45	98	23	211	23	124	963	28	<5	301	32	<5	36	33	10
A_2(E)	0.25	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		130	1797	13	111	13988	<5	<5	44	<5	119	10	46	316	15	<5	124	90	<5	20	10	<5
				>2	3.2	205	2216	50	245	42663	27	37	96	23	134	13	63	409	18	<5	165	56	<5	42	19	8
				.425-2	38.4	144	1737	9	104	11889	<5	<5	42	<5	90	9	37	234	14	<5	114	91	<5	30	9	<5
				.180-.425	47.8	187	1916	11	141	18883	<5	20	45	9	123	12	41	271	12	<5	140	27	<5	34	9	<5
				.075-.180	7.1	226	2935	16	163	22380	<5	15	67	10	183	16	87	600	21	<5	237	62	<5	30	21	<5
				<.075	3.5	296	4492	32	223	37068	18	44	94	28	216	19	122	919	29	<5	252	21	<5	31	37	10
A_3	0.35	BROWN WEAKLY STRUCTURED SOILS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; MINOR IRON OXIDES; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		152	2096	12	126	18883	<5	11	54	15	129	11	50	318	16	<5	129	94	<5	13	12	<5
				>2	2.9	174	2390	43	122	35669	16	11	94	9	137	11	73	402	17	<5	148	53	<5	30	18	<5
				.425-2	40.3	130	1677	9	111	16086	<5	9	46	12	98	9	38	257	14	<5	108	179	<5	31	18	<5
				.180-.425	45.6	178	2336	17	111	18184	<5	<5	55	<5	133	10	45	295	14	<5	174	62	<5	18	9	<5
				.075-.180	6.9	261	3534	32	186	32871	8	16	87	27	204	17	86	573	23	<5	235	53	<5	27	26	6
				<.075	4.3	253	4432	44	193	39865	27	27	123	26	216	16	109	820	27	<5	238	14	<5	35	34	8
B_1	0.45	REDDISH - BROWN WEAKLY STRUCTURED SOILS.	QUARTZ (ROUNDED AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		181	2211	15	131	20111	7	10	59	8	121	11	55	322	16	<5	151	88	<5	24	16	<5
				>2	3.3	201	2491	30	127	37543	15	10	97	9	131	10	73	409	16	<5	153	55	<5	28	22	<5
				.425-2	39.9	147	1781	11	117	19233	6	9	51	11	92	9	41	261	14	<5	112	90	<5	31	12	<5
				.180-.425	44.9	192	2431	19	118	21121	<5	7	62	6	129	11	47	295	15	<5	175	57	<5	20	11	<5
				.075-.180	7.6	283	2689	25	192	34621	10	28	93	29	199	15	91	601	23	<5	253	45	<5	27	27	7
				<.075	4.3	294	2543	46	197	41343	27	29	131	31	209	17	111	781	28	<5	234	23	<5	34	35	7
B_2(T)	0.5	REDDISH APEDAL B HORIZON. (ZONE OF ILLUVIATION)	QUARTZ (ROUNDED AND SUBANGULAR); NO FELDSPAR AND BIOTITE; KAOLINITE AND OTHER MIXED LAYERED CLAY MINERALS. H.M. - MAG, ILM, LIM, GH, HEM AND ZR.	TOTAL		205	2695	22	141	25178	9	9	66	6	147	11	61	399	15	<5	184	36	<5	40	18	<5
				>2	5.6	261	2935	35	223	43362	11	15	106	20	152	13	68	444	19	<5	190	77	<5	30	23	8
				.425-2	36.3	183	2276	10	111	19583	<5	17	63	7	101	7	40	265	14	<5	138	38	<5	27	9	<5
				.180-.425	42.3	240	2815	21	141	28675	9	<5	75	22	155	12	58	349	18	<5	190	62	<5	27	15	<5
				.075-.180	9.3	253	4013	34	186	38467	21	28	111	21	211	15	92	665	24	<5	251	22	<5	36	29	6
				<.075	6.5	279	4672	46	200	47559	26	36	130	43	218	16	107	758	30	<5	228	29	<5	31	38	9
P	0.6	HORIZON MARKED BY ROUNDED QUARTZ PEBBLES AND GOETHITE PELLETS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES AND GRAINS STAINED WITH IRON OXIDES; GOETHITE PELLETS; MINOR CLAY MINERALS; NO FELDSPAR AND BIOTITE. H.M. - GH, HEM, MAG, ILM AND ZR.	TOTAL		231	2036	33	409	97916	33	47	119	27	103	7	46	352	18	<5	71	25	<5	29	29	17
				>2	37.1	50	664	65	394	73185	87	70	210	30	68	<5	39	305	18	18	<5	<5	<5	69	36	27
				.425-2	40.3	274	2515	50	372	46160	7	7	80	19	115	9	47	316	17	<5	189	92	<5	46	18	<5
				.180-.425	13.5	213	3174	20	163	28675	11	51	84	14	162	11	55	395	18	<5	217	50	<5	30	15	<5
				.075-.180	5.2	274	3953	26	186	37668	13	23	94	29	210	17	77	591	24	<5	239	37	<5	28	26	<5
				<.075	3.9	283	4732	38	215	43362	27	58	120	23	210	15	106	885	28	<5	256	16	<5	34	34	7
C+B_2	0.7	BROWN HORIZON OF HIGHLY WEATHERED BEDROCK. (UNCONSOLIDATED).	MAINLY QUARTZ; ALTERED FELDSPAR AND BIOTITE; H.M - MAG, ILM, HEM AND ZR.	TOTAL		305	3120	25	151	35126	12	36	72	14	423	18	88	435	27	<5	445	19	<5	120	41	18
				>2	21.3	442	2681	61	321	70213	24	41	149	8	354	14	73	366	21	<5	331	<5	<5	190	31	25
				.425-2	57.7	307	2734	17	178	31240	9	15	66	9	432	21	76	314	25	<5	489	14	<5	131	34	16
				.180-.425	10.5	286	3282	11	153	29621	9	10	63	7	428	21	74	351	24	<5	513	15	<5	111	33	<5
				.075-.180	5.4	313	4132	25	182	41256	14	7	79	26	424	22	113	618	34	<5	455	29	<5	109	47	20
				<.075	5.1	321	4216	36	201	45389	27	29	89	19	402	18	127	713	34	<5	413	7	<5	148	53	29
R R1		SLIGHTLY WEATHERED GREY VLAKLAAGTE GRANITE WITH ALTERATION ZONES.	DISCUSSED IN TEXT.			288	1916	7	55	20842	6	22	39	<5	630	50	83	295	23	<5	778	18	<5	82	33	17
R2						196	1617	<5	46	13148	<5	<5	12	<5	575	68	89	273	20	<5	651	16	<5	60	29	16
R3	0.7					240	1617	<5	59	18184	<5	17	<5	<5	571	94	109	259	21	<5	607	14	<5	46	32	16
R4						240	1679	<5	119	14687	<5	7	<5	10	434	96	151	258	20	<5	549	10	<5	26	25	14

Description, mineralogy and trace element geochemistry of weathering profile 6 on grey Vlaklaagte granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
						GEOCHEMICAL DATA (PPM)																				
A_1	0.1	DARK BROWN, ORGANIC	ALMOST ONLY ROUNDED AND SUBANGULAR	TOTAL		91	1485	6	113	1119	<5	<5	8	<5	44	5	25	251	10	<5	34	24	<5	18	<5	<5
		RICH, ORTHIC A	QUARTZ GRAINS (SLIGHTLY STAINED WITH	>2	2.7					NO		SAMPLE														
		HORIZON WITH WEAKLY	IRON OXIDES); NO FELDSPAR AND BIOTITE;	.425-2	27.6	81	970	12	87	2670	<5	<5	9	<5	27	<5	11	115	8	<5	7	44	<5	10	<5	<5
		STRUCTURED SOILS.	MINOR KAOLINITE AND OTHER CLAY	.180-.425	44.4	117	1701	<5	102	887	<5	<5	14	<5	48-	5	23	209	11	<5	35	56	<5	18	<5	<5
			MINERALS. H.M- GH, HEM, MAG, ILM,	.075-.180	16.8	188	2648	<5	192	4456	<5	<5	17	7	74	9	56	537	17	<5	90	68	<5	19	11	<5
			LIM AND ZR.	<.075	8.5	245	3977	<5	309	6614	<5	<5	17	8	94	16	93	1023	24	<5	150	35	<5	32	21	8
A_2(E)	0.25	LIGHT COLOURED, LOOSE	ALMOST ONLY ROUNDED AND SUBANGULAR	TOTAL		87	1690	<5	115	4318	<5	<5	20	10	51	5	30	276	12	<5	34	63	<5	16	<5	<5
		STRUCTURED, HORIZON OF	QUARTZ GRAINS; NO FELDSPAR AND	>2	2.6	98	2212	11	158	8345	<5	<5	17	7	75	8	41	358	14	<5	76	61	<5	44	8	<5
		MAXIMUM ELUVIATION.	BIOTITE; TRACES OF KAOLINITE AND	.425-2	48.5	97	1438	5	89	964	<5	<5	6	<5	38	<5	19	182	8	<5	23	69	<5	21	<5	<5
			OTHER CLAY MINERALS. H.M.- GH, MAG,	.180-.425	36.4	131	2220	<5	134	5066	<5	<5	13	<5	55	5	25	239	10	<5	58	34	<5	29	<5	<5
			ILM, LIM AND ZR.	.075-.180	7.7	127	2529	<5	159	2047	<5	<5	15	<5	69	6	56	530	15	<5	81	67	<5	23	8	<5
				<.075	4.8	157	4263	<5	212	3823	6	<5	22	<5	100	13	94	1026	24	<5	136	53	<5	26	22	6
A_3	0.35	BROWN WEAKLY	MAINLY ROUNDED AND SUBANGULAR QUARTZ	TOTAL		80	2237	5	77	2992	<5	<5	19	10	69	5	36	321	13	<5	53	79	<5	17	6	<5
		STRUCTURED	PEBBLES; MINOR IRON OXIDES; MINOR	>2	2.9	71	2348	19	113	7123	5	<5	21	<5	82	7	44	398	15	<5	77	50	<5	27	8	<5
		SOILS.	KAOLINITE, ILLITE AND OTHER MIXED	.425-2	31.9	95	2020	<5	116	6274	<5	<5	13	<5	53	5	25	222	10	<5	38	33	<5	31	<5	<5
			LAYERED CLAYS; NO FELDSPAR AND	.180-.425	52.1	117	2870	<5	80	2853	<5	<5	26	7	81	6	40	330	15	<5	82	82	<5	19	5	<5
			BIOTITE. H.M.- GH, HEM, MAG, ILM,	.075-.180	7.9	140	3702	<5	138	6984	<5	<5	30	17	106	10	66	572	19	<5	117	51	<5	33	13	<5
			LIM AND ZR.	<.075	5.0	147	4813	<5	171	8341	10	<5	40	25	139	15	95	901	27	<5	145	52	<5	34	25	5
B_1	0.5	REDDISH - BROWN	QUARTZ (ROUNDED AND SUBANGULAR)	TOTAL		110	2451	7	98	8431	<5	<5	26	16	79	6	43	333	14	<5	61	74	<5	23	8	<5
		WEAKLY STRUCTURED	STAINED WITH IRON OXIDES; NO FRESH	>2	3.5	154	2962	21	119	16542	<5	<5	36	14	81	6	38	362	14	<5	84	25	<5	36	8	<5
		SOILS.	FELDSPAR OR BIOTITE;	.425-2	36.1	98	2131	<5	76	21561	<5	<5	19	6	59	<5	29	227	11	<5	53	44	<5	24	<5	<5
			KAOLINITE, ILLITE AND OTHER CLAY	.180-.425	49.2	134	3456	<5	89	14361	<5	<5	36	21	98	6	46	354	14	<5	98	57	<5	31	11	<5
			MINERALS; IRON OXIDES. H.M.- HEM,	.075-.180	6.1	161	4289	<5	119	9531	10	<5	43	18	132	9	76	590	18	<5	139	40	<5	31	19	<5
			GH, MAG, ILM, LIM AND ZR.	<.075	5.1	154	5131	<5	141	10341	11	<5	61	27	162	11	86	634	27	<5	148	51	<5	32	25	<5
B_2(T)	0.9	REDDISH APEDAL B	QUARTZ (ROUNDED AND SUBANGULAR);	TOTAL		128	2844	10	109	10207	8	<5	36	22	91	6	47	341	15	<5	68	72	<5	31	9	<5
		HORIZON. THE	NO FELDSPAR AND BIOTITE;	>2	7.8	173	3179	31	134	27946	6	<5	42	16	91	5	44	327	14	<5	92	23	<5	47	9	<5
		SOILS ARE	KAOLINITE AND OTHER MIXED LAYERED	.425-2	39.7	109	2328	<5	85	5305	<5	<5	19	<5	63	<5	30	225	10	<5	57	42	<5	29	<5	<5
		SANDY.	CLAY MINERALS. H.M. - MAG, ILM, LIM,	.180-.425	39.7	156	3790	<5	109	10331	10	<5	43	27	111	7	53	372	18	<5	108	54	<5	36	12	<5
		(ZONE OF	GH, HEM AND ZR.	.075-.180	7.6	171	4697	<5	131	10501	14	<5	52	22	141	9	80	623	22	<5	152	40	<5	37	20	<5
		ILLUVIATION)		<.075	5.2	168	5416	<5	132	12024	19	10	71	38	170	11	92	690	27	<5	162	46	<5	38	28	<5
P	1.5	HORIZON MARKED BY	MAINLY ROUNDED AND SUBANGULAR	TOTAL		112	2999	80	82	37133	12	<5	59	<5	76	6	50	417	17	<5	83	43	<5	16	12	<5
		ROUNDED QUARTZ	QUARTZ PEBBLES AND GRAINS STAINED	>2	45.9	4	1066	172	669	90922	61	27	141	<5	56	<5	33	266	13	<5	<5	<5	<5	22	16	24
		PEBBLES AND	WITH IRON OXIDES; GOETHITE PELLETS;	.425-2	30.5	96	2442	47	93	27489	<5	<5	43	8	59	5	32	237	13	<5	43	36	<5	22	5	<5
		GOETHITE PELLETS.	MINOR CLAY MINERALS; NO FELDSPAR	.180-.425	12.8	109	3589	19	97	20094	5	<5	41	<5	86	6	46	362	16	<5	102	44	<5	29	8	<5
		(YELLOW ZONE)	AND BIOTITE. H.M. - GH, HEM,	.075-.180	5.9	125	4531	18	125	24674	9	<5	51	7	108	9	76	658	23	<5	132	48	<5	30	18	<5
			MAG, ILM AND ZR,	<.075	4.9	134	5080	45	161	36812	12	8	64	20	127	13	92	826	28	<5	151	41	<5	34	28	9

Description, mineralogy and trace element geochemistry of weathering profile 7 on grey Vlaklaagte granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m)	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm)	WEIGHT %	GEOCHEMICAL DATA (PPM) P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
A_1	0.2	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON (THE SOILS ARE WEAKLY STRUCTURED).	ALMOST ONLY QUARTZ (ROUNDED AND SUBANGULAR GRAINS); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND MIXED LAYERED CLAYS. H.M.-GH, HEM, MAG, ILM AND ZR.	TOTAL		130	1729	20	143	17377	<5	<5	28	6	89	11	56	425	16	<5	55	74	<5	43	20	7
				>2	6.5	162	1744	42	113	29855	12	<5	53	<5	72	6	48	344	14	<5	72	58	<5	43	14	<5
				.425-2	45.9	139	1628	11	125	13005	<5	<5	23	<5	71	8	40	282	13	<5	56	42	<5	40	12	<5
				.180-.425	35.0	234	2705	7	185	16795	6	<5	38	<5	96	7	53	419	15	<5	97	60	<5	40	13	<5
				.075-.180	6.9	298	3416	14	230	22265	13	<5	41	11	118	12	93	780	24	<5	126	72	<5	37	31	8
				<.075	5.7	293	4229	22	269	24650	16	<5	61	12	141	15	116	1025	27	<5	174	43	<5	50	38	9
A_2(E)	0.35	LIGHT COLOURED HORIZON OF MAXIMUM ELUVIATION (THE SOILS HAVE A LOOSE STRUCTURE).	MAINLY QUARTZ (ROUNDED AND SUBANGULAR GRAINS): NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND MIXED LAYERED CLAYS. H.M.- GH, HEM, MAG, ILM AND ZR.	TOTAL		123	1938	15	150	12517	<5	<5	22	<5	84	8	54	432	15	<5	87	66	<5	34	17	<5
				>2	3.5	132	1839	34	185	22825	10	<5	40	9	88	9	73	441	18	<5	88	74	<5	54	24	7
				.425-2	41.1	99	1378	7	88	7779	<5	<5	14	<5	59	6	32	228	11	<5	40	46	<5	39	8	<5
				.180-.425	39.0	179	2511	16	189	16891	<5	<5	32	8	94	8	50	387	16	<5	94	86	<5	59	16	<5
				.075-.180	10.1	191	3169	9	190	16339	8	<5	35	<5	107	9	79	701	21	<5	130	61	<5	33	26	<5
				<.075	5.3	196	3995	32	326	25702	12	10	47	11	148	16	126	1117	29	<5	164	26	<5	63	43	13
A_3	0.5	BROWN WEAKLY STRUCTURED SOILS.	MAINLY QUARTZ (ROUNDED AND SUBANGULAR); NO FELDSPAR OR BIOTITE; MINOR KAOLINITE AND MIXED CLAYS; MINOR IRON OXIDES. H.M.-GH, HEM, MAG, ILM AND ZR.	TOTAL		113	1943	19	118	17405	<5	<5	26	<5	92	9	52	418	14	<5	69	35	<5	43	17	<5
				>2	7.1	164	2659	18	110	19312	7	<5	42	<5	95	7	49	429	17	<5	103	55	<5	37	17	<5
				.425-2	37.2	172	2579	6	116	18303	<5	<5	35	8	85	8	52	441	16	<5	80	97	<5	33	15	<5
				.180-.425	38.4	133	1950	14	81	14788	<5	<5	27	<5	94	7	45	346	12	<5	69	52	<5	48	14	<5
				.075-.180	10.7	204	3332	12	146	23465	12	<5	51	14	123	10	89	768	25	<5	119	80	<5	34	31	6
				<.075	6.6	239	4871	41	240	34795	26	14	88	17	185	15	118	1019	32	<5	207	30	<5	51	46	12
B_1	1.0	REDDISH-BROWN WEAKLY STRUCTURED SOILS.	MAINLY QUARTZ (SUBANGULAR TO ROUNDED AND IRON STAINED); NO FELDSPAR OR BIOTITE; KAOLINITE AND MIXED CLAY MINERALS; IRON OXIDES. H.M.-HEM, GH, MAG, ILM AND ZR.	TOTAL		188	2764	25	92	24835	9	<5	58	8	112	7	64	490	17	<5	101	41	<5	34	22	<5
				>2	8.8	201	3094	26	119	31661	7	<5	58	14	113	8	60	453	17	<5	96	49	<5	53	23	<5
				.425-2	39.5	153	2112	16	46	17880	<5	<5	44	<5	74	5	33	227	11	<5	59	26	<5	29	7	<5
				.180-.425	30.5	213	2793	22	98	27801	7	<5	56	15	110	7	52	365	16	<5	85	70	<5	44	18	<5
				.075-.180	12.8	241	3798	25	110	30665	15	6	66	9	137	9	94	784	22	<5	127	24	<5	39	31	6
				<.075	8.4	275	4599	52	156	45302	26	29	98	36	190	13	106	830	30	<5	156	22	<5	50	45	11
B_2(T)	1.6	RED APEDAL B HORIZON OF MAXIMUM CLAY AND IRON ACCUMULATION. (THE SOILS ARE WEAKLY STRUCTURED).	MAINLY IRON STAINED ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR OR BIOTITE; KAOLINITE AND OTHER MIXED CLAY MINERALS; IRON OXIDES. H.M.-HEM, GH, MAG, ILM AND ZR.	TOTAL		176	2063	30	98	27143	11	<5	59	16	111	8	70	503	20	<5	83	54	<5	38	27	<5
				>2	16.3	191	2863	27	86	27953	12	<5	67	8	100	6	59	449	19	<5	80	51	<5	42	19	<5
				.425-2	36.0	167	2122	19	95	21726	<5	<5	42	10	79	6	44	281	13	<5	66	45	<5	47	13	<5
				.180-.425	24.7	205	3398	16	95	27768	11	<5	71	10	121	6	68	463	20	<5	105	87	<5	37	23	<5
				.075-.180	11.8	246	4272	35	140	36311	16	18	79	24	150	10	109	846	29	<5	134	71	<5	39	41	9
				<.075	11.2	245	4862	50	163	44010	30	21	106	22	185	11	112	845	29	<5	169	6	<5	54	45	8
P	1.8	YELLOW ZONE MARKED BY QUARTZ PEBBLES AND IRON OXIDES.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES AND GRAINS STAINED WITH YELLOW IRON OXIDES; GOETHITE PELLETS; YELLOWISH CLAY MINERALS; NO FELDSPAR AND BIOTITE. H.M.-GH, HEM, MAG, ILM AND ZR.	TOTAL		152	2827	77	99	46796	16	<5	68	<5	106	7	66	479	17	<5	90	24	<5	40	26	7
				>2	50.8	118	941	117	61	57819	14	<5	58	<5	36	6	26	153	9	<5	5	44	<5	54	14	12
				.425-2	23.7	118	2351	37	122	29090	9	<5	53	<5	93	5	52	350	13	<5	66	5	<5	72	17	<5
				.180-.425	11.4	168	3413	40	135	36724	10	<5	63	13	133	9	75	494	19	<5	107	34	<5	59	27	<5
				.075-.180	5.8	178	4186	44	142	38329	18	8	81	9	147	10	101	775	24	<5	143	17	<5	55	36	7
				<.075	8.3	193	4853	51	163	46395	22	22	93	25	174	12	117	912	33	<5	154	46	<5	51	44	10
C	2.1	BROWN ZONE OF WEATHERED BEDROCK (GRANITIC STRUCTURE STILL PRESERVED).	QUARTZ; THE PLAGIOCLASE AND POTASH FELDSPAR ALMOST COMPLETELY ILLITISED, HEMATITISED AND KAOLINISED; BIOTITE (CHLORITISED AND HEMATITISED). H.M.-HEM, MAG, ILM, GH AND ZR.	TOTAL		132	2931	47	135	35439	8	<5	51	<5	120	9	74	549	16	<5	84	5	<5	47	26	6
				>2	27.3	103	1941	82	60	44499	9	<5	53	<5	64	5	41	292	9	<5	32	5	<5	58	14	<5
				.425-2	46.2	118	2700	42	121	34928	6	<5	52	8	88	6	52	350	14	<5	71	5	<5	48	17	<5
				.180-.425	11.9	143	3922	42	123	40796	14	<5	82	8	124	7	75	484	19	<5	108	17	<5	54	25	<5
				.075-.180	7.4	157	3968	56	154	40675	13	9	64	11	135	10	98	765	22	<5	125	5	<5	57	35	8
				<.075	7.2	161	4893	61	191	47600	27	15	90	7	168	12	121	984	30	<5	167	10	<5	59	45	12

Description, mineralogy and trace element geochemistry of weathering profile 8 possibly on the grey Vlaklaagte granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m)	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm)	WEIGHT %	GEOCHEMICAL DATA (PPM)																				
						P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
A_1	0.15	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON (WEAKLY STRUCTURED SOILS).	ALMOST ONLY QUARTZ (ROUNDED AND SUBANGULAR GRAINS); NO FELDSPAR AND BIOTITE, MINOR KAOLINITE AND MIXED CLAYS. H.M.-GH, LIM, MAG, ILM, ZR.	TOTAL		94	1395	13	137	10560	<5	<5	10	14	121	12	63	407	17	<5	59	148	10	52	21	9
				>2	3.8	109	1317	27	163	33362	20	6	12	8	231	9	67	329	25	<5	92	41	9	75	27	8
				.425-.2	44.1	122	1257	<5	111	11190	<5	<5	<5	9	100	8	43	259	12	<5	40	74	<5	44	12	<5
				.180-.425	37.4	109	1437	8	119	9092	<5	<5	7	6	114	8	58	344	16	<5	65	157	<5	45	14	<5
				.075-.180	8.8	152	1856	13	163	13988	7	<5	7	13	129	11	90	639	20	<5	68	158	<5	48	22	7
				<.075	5.9	279	3653	17	297	18883	11	7	14	12	201	20	143	1149	28	<5	130	81	<5	79	41	15
A_2(E)	0.3	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION. PIECES OF FINE-GRAINED GRANITE ARE RECOGNISED.	MAINLY QUARTZ (ROUNDED AND SUBANGULAR GRAINS); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND MIXED CLAYS. H.M.-GH, LIM, MAG, ILM, ZR.	TOTAL		135	1467	24	43	19373	11	<5	34	7	129	5	62	400	19	<5	63	146	<5	39	15	<5
				>2	4.6	189	898	79	89	30110	10	<5	46	9	227	6	34	165	22	<5	25	395	<5	90	22	8
				.425-2	42.2	87	1257	8	89	9791	<5	<5	14	<5	108	<5	44	222	14	<5	40	73	<5	55	8	<5
				.180-425	44.1	117	1677	9	29	14687	6	<5	19	14	133	7	56	306	17	<5	63	117	<5	46	14	<5
				.075-.180	5.6	174	3054	16	59	19583	11	<5	37	15	183	9	112	961	27	<5	123	163	<5	62	28	<5
				<.075	3.2	218	3893	32	111	30773	15	14	59	38	252	15	133	1061	32	<5	145	131	<5	67	42	11
P	0.4	ZONE MARKED BY QUARTZ PEBBLES ROCK DEBRIS AND IRON OXIDES.	MAINLY ANGULAR AND SUBANGULAR QUARTZ PEBBLES: KAOLINITE AND MIXED CLAY MINERALS; NO FELDSPAR OR BIOTIE; IRON OXIDES. H.M.-GH, LIM, HEM, MAG, ILM, CAS, ZR.	TOTAL		152	1737	42	167	36298	12	18	35	28	215	13	91	344	23	18	95	1200	9	116	36	15
				>2	61.2	170	820	58	133	44062	13	<5	31	<5	212	6	66	126	15	12	58	990	<5	111	26	8
				.425-2	21.4	139	1641	21	126	26227	10	<5	24	24	200	7	60	246	19	<5	77	650	<5	70	23	<5
				.180-.425	7.6	157	2276	27	119	28675	14	<5	32	25	230	8	79	423	21	<5	120	700	<5	67	27	<5
				.075-.180	5.2	212	3114	39	171	35669	20	21	35	40	265	13	120	899	28	<5	141	710	<5	82	43	14
				<.075	4.6	231	3653	61	186	42663	32	27	49	42	320	13	124	758	29	<5	151	610	<5	100	49	13
B_2(R)	0.6	RED SOFT PLINTIC B HORIZON WHICH STILL PRESERVES THE GRANITIC STRUCTURE. (MAXIMUM CLAY AND IRON ACCUMULATION).	QUARTZ STAINED WITH IRON OXIDES (HEMATITE AND GOETHITE). NO FRESH FELDSPARS; KAOLINITE, SERICITE AND OTHER MIXED CLAY MINERALS. H.M.-HEM, GH, LIM, ILM, MAG, CAS, ZR.	TOTAL		200	1600	36	340	37837	23	12	36	20	300	12	74	320	25	12	120	980	10	120	36	10
				>2	31.3	220	1230	41	339	57254	20	17	42	22	370	9	61	220	26	16	110	1210	<5	103	35	8
				.425-2	34.5	199	1560	19	245	36251	16	6	32	17	291	<5	57	270	22	6	101	1450	<5	76	25	<5
				.180-.425	18.3	299	2023	25	210	31216	14	11	38	33	267	9	76	410	23	7	103	1170	<5	86	28	<5
				.075-.180	8.6	360	3150	40	230	36572	22	19	57	37	280	9	111	710	26	7	150	1030	<5	92	40	7
				<.075	7.3	382	3362	56	270	48256	26	41	68	62	320	12	122	780	33	8	160	990	<5	124	57	14
B_3	1.0	HORIZON CONTAINING REDDISH UNCONSOLIDATED WEATHERED BEDROCK WITH WHITE CONCRETIONS OF CLAY MINERALS. (MOTTLING).	QUARTZ: ALMOST NO FELDSPAR: WHITE CONCRETIONS OF KAOLINITE AND MIXED CLAYS; QUARTZ STAINED WITH HEMATITE AND GOETHITE. H.M.-HEM, MAG, ILM, GH, LIM, CAS, ZR.	TOTAL		104	1431	28	297	39865	23	11	25	19	375	10	71	273	26	7	120	910	<5	107	34	9
				>2	34.7	113	1060	39	290	59449	19	16	32	23	464	9	63	172	28	13	115	1100	<5	93	34	7
				.425-2	36.3	104	1365	17	186	37347	15	<5	23	18	363	7	60	225	23	<5	105	1342	<5	55	24	<5
				.180-.425	14.2	165	2096	23	141	31473	13	12	28	32	301	10	75	355	22	<5	107	1150	<5	66	27	<5
				.075-.180	7.3	222	3234	37	163	38467	23	17	42	35	330	11	109	662	26	<5	159	1030	<5	78	37	8
				<.075	7.5	231	3474	54	230	50356	28	35	59	59	406	14	120	698	34	8	161	980	<5	119	53	12
C	1.4	RED UNCONSOLIDATED WEATHERED BEDROCK. GRANITIC STRUCTURE STILL PRESERVED.	QUARTZ: THE PLAGIOCLASE AND POTASH FELDSPAR ALMOST COMPLETELY SERICITISED, HEMATITISED AND KAOLINISED; BIOTITE (CHLORITISED AND HEMATITISED). H.M.-HEM, MAG, ILM, GH, LIM, CAS, ZR.	TOTAL		48	868	7	260	28813	12	11	13	28	574	10	71	185	32	18	114	900	15	78	37	<5
				>2	40.1	43	838	<5	238	28816	12	6	25	16	547	9	67	158	28	21	120	910	<5	96	30	<5
				.425-2	42.2	52	826	6	186	15179	6	<5	25	18	450	9	63	149	26	9	108	950	<5	63	28	<5
				.180-.425	7.5	48	763	8	238	28188	23	22	21	23	575	10	72	192	34	16	143	905	<5	84	40	<5
				.075-.180	4.4	65	1257	10	290	32596	27	23	22	37	683	13	104	360	44	25	165	850	8	76	66	11
				<.075	5.8	61	1281	8	267	37142	39	41	39	41	679	11	97	392	49	33	168	814	9	92	71	9
R	1.4	SLIGHTLY WEATHERED RED VLAKLAAGTE GRANITE.	QUARTZ: SERICITISED AND HEMATITISED POTASH FELDSPAR: KAOLINISED AND HEMATITISED PLAGIOCLASE; BIOTITE (CHLORITISED AND HEMATITISED). H.M.-HEM, MAG, ILM, CAS, ZR.			24	555	<5	180	26437	6	6	37	13	740	11	68	148	24	16	168	890	<5	100	29	6

Description, mineralogy and trace element geochemistry of weathering profile 9 on the red Vlaklaagte granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
						GEOCHEMICAL DATA (PPM)																				
A_1	0.1	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, CAS, LIM AND ZR.	TOTAL		119	1458	<5	159	9029	<5	<5	12	<5	173	11	67	348	19	<5	120	79	<5	42	23	<5
				>2	6.1	140	1431	25	172	21219	<5	<5	19	<5	146	9	58	312	18	<5	102	48	<5	59	21	<5
				.425-2	39.8	104	1179	11	136	6610	<5	<5	14	<5	167	11	53	261	19	<5	98	82	<5	46	20	6
				.180-.425	37.7	150	1652	<5	145	8313	<5	<5	17	<5	178	10	54	264	20	<5	136	90	<5	45	18	<5
				.075-.180	10.5	173	2288	<5	192	11407	<5	<5	16	<5	200	15	114	673	30	<5	168	99	<5	48	38	10
				<.075	5.9	258	3858	11	309	15729	10	9	24	<5	243	23	192	1217	40	<5	251	60	<5	65	63	19
A_2(E	0.2	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, CAS, LIM AND ZR.	TOTAL		107	1245	8	132	12313	<5	<5	16	9	173	12	68	350	18	<5	121	81	<5	39	21	<5
				>2	5.8	63	476	9	128	15212	<5	<5	18	<5	101	7	43	156	12	<5	89	62	<5	58	22	<5
				.425-2	41.5	101	1032	<5	118	9056	<5	<5	12	<5	118	8	49	218	16	<5	121	82	<5	43	19	<5
				.180-.425	43.5	196	2096	<5	157	18321	<5	<5	18	11	192	13	57	493	26	<5	134	101	<5	46	18	<5
				.075-.180	5.3	201	2432	8	173	20526	<5	<5	21	12	201	14	121	702	30	<5	158	99	<5	46	40	11
				<.075	3.9	283	3876	16	232	23213	14	10	28	16	232	18	193	1131	38	<5	232	70	<5	63	65	21
P	0.35	ZONE MARKED BY QUARTZ PEBBLES, ROCK DEBRIS AND IRON OXIDES.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES; GOETHITE PELLETS; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, CAS, LIM AND ZR.	TOTAL		129	1389	19	145	22996	<5	<5	26	7	182	12	67	316	21	<5	112	99	<5	39	27	9
				>2	32.3	153	769	76	159	61134	6	<5	51	<5	59	5	17	112	11	12	16	71	<5	45	13	12
				.425-2	30.0	101	1180	6	132	10581	<5	<5	19	7	189	11	55	237	19	<5	102	127	<5	44	22	<5
				.180-.425	27.8	145	1767	6	143	13645	<5	<5	27	10	199	11	67	303	22	<5	135	129	<5	45	23	<5
				.075-.180	6.2	159	2244	11	165	16995	6	<5	31	11	220	16	121	672	33	<5	156	149	<5	46	46	14
				<.075	3.8	212	3207	19	238	22758	8	31	46	18	257	19	168	1004	39	<5	227	104	<5	55	61	17
B_2(R	1.4	RED SOFT PLINTIC B HORIZON WHICH STILL PRESERVES THE GRANITIC STRUCTURE. (ZONE OF ILLUVIATION).	QUARTZ (ANGULAR AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; ENRICHED IN KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		105	1356	9	134	21811	<5	<5	56	9	484	17	92	214	37	<5	246	19	<5	55	56	6
				>2	14.1	87	996	13	110	22101	<5	<5	38	<5	414	14	65	149	23	<5	226	22	<5	59	35	<5
				.425-2	59.4	99	1224	<5	101	15399	<5	<5	46	6	472	16	65	151	29	<5	237	23	<5	59	37	<5
				.180-.425	13.2	125	2142	12	154	33955	13	13	97	26	589	16	128	280	59	<5	284	25	<5	67	80	9
				.075-.180	6.8	145	2334	27	192	42334	31	28	122	38	510	13	183	431	69	<5	255	23	<5	72	111	15
				<.075	6.5	164	2358	26	198	43761	39	28	126	39	470	13	195	451	67	<5	230	16	<5	69	115	18
B_3	1.7	WHITISH-GREY HORIZON CONTAINING MUCH CLAY MINERALS. THE GRANITIC STRUCTURE IS STILL PRESERVED.	QUARTZ (ANGULAR AND SUBANGULAR); ALTERED FELDSPAR AND BIOTITE; WHITE CONCRETIONS OF MAINLY KAOLINITE. H.M. - MAG, ILM, LIM, GH, HEM AND ZR.	TOTAL		78	1099	<5	90	12470	<5	<5	38	6	539	19	101	199	36	<5	269	18	<5	53	56	5
				>2	11.1	65	477	<5	106	7573	<5	<5	12	<5	403	16	49	102	12	<5	194	10	<5	53	23	<5
				.425-2	62.2	62	635	<5	106	9497	<5	<5	19	<5	521	19	59	113	19	<5	254	11	<5	60	32	<5
				.180-.425	14.4	130	2137	<5	159	31445	<5	13	76	35	666	21	166	275	64	<5	350	21	<5	77	96	9
				.075-.180	5.5	148	2821	13	197	39865	19	28	98	47	591	19	315	634	101	<5	320	21	<5	87	172	24
				<.075	6.8	131	2386	13	194	37494	30	31	96	48	517	19	326	608	91	<5	251	14	<5	79	159	28
C	1.8	BROWN WEATHERED BEDROCK. (UNCONSOLIDATED).	QUARTZ; KAOLINISED, ILLITISED AND HEMATITISED FELDSPARS; CHLORITISED AND HEMATITISED BIOTITE. H.M.- HEM, MAG, ILM AND ZR.	TOTAL		82	601	<5	111	9356	<5	<5	43	15	823	21	123	153	35	<5	301	16	<5	67	76	<5
				>2	13.2	85	383	<5	121	828	<5	<5	16	9	631	17	70	82	18	<5	224	11	<5	65	43	<5
				.425-2	59.1	103	521	<5	123	9156	<5	<5	24	7	801	19	79	91	24	<5	283	10	<5	73	54	<5
				.180-.425	14.4	107	2021	<5	179	28215	<5	17	89	49	983	23	183	231	78	<5	383	23	<5	85	131	<5
				.075-.180	7.8	126	2731	10	201	33525	21	31	109	63	954	21	335	459	121	<5	356	19	<5	98	224	26
				<.075	5.5	128	2156	11	234	35621	33	34	106	75	898	21	354	432	113	<5	284	17	<5	83	196	31

Description, mineralogy and trace element geochemistry of weathering profile 10 on grey Vlaklaagte granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
						GEOCHEMICAL DATA (PPM)																				
A_1	0.2	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		113	1377	11	44	10421	<5	<5	12	<5	136	11	39	268	13	<5	140	34	<5	18	<5	<5
				>2	3.6	139	1737	28	223	27976	20	<5	24	16	151	16	61	345	16	<5	296	26	19	38	15	<5
				.425-2	32.5	117	1317	9	25	7273	<5	<5	10	<5	106	8	33	230	12	<5	117	69	<5	25	<5	<5
				.180-.425	54.1	117	1377	9	18	6504	<5	<5	10	<5	139	12	32	219	12	<5	180	53	<5	22	<5	<5
				.075-.180	6.1	270	2575	<5	81	13288	<5	<5	24	<5	242	23	67	484	20	<5	300	48	<5	33	17	<5
				<.075	4.0	309	3833	14	200	19583	11	<5	36	<5	231	25	112	910	27	<5	342	39	<5	34	26	<5
A_2(E)	0.3	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		96	1377	16	29	10980	<5	<5	13	<5	148	13	42	274	15	<5	149	60	<5	26	11	<5
				>2	4.6	130	1856	22	59	19583	7	<5	22	<5	164	13	56	345	16	<5	192	61	<5	35	12	<5
				.425-2	42.5	130	1677	12	37	13008	<5	<5	14	<5	136	10	39	251	13	<5	140	27	<5	27	8	<5
				.180-.425	44.7	113	1377	14	19	10491	<5	<5	10	<5	150	13	34	225	13	<5	191	53	<5	25	7	<5
				.075-.180	5.0	130	2036	18	46	15386	<5	<5	17	<5	229	20	65	435	17	<5	290	55	<5	37	15	<5
				<.075	3.2	218	3893	19	111	27276	11	<5	43	16	254	20	110	844	27	<5	263	31	<5	36	29	6
A_3	0.4	BROWN WEAKLY STRUCTURED SOILS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; MINOR IRON OXIDES; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		152	2336	26	49	19723	13	<5	44	7	200	10	59	358	17	<5	185	24	<5	33	16	<5
				>2	3.6	174	2036	40	81	36368	18	<5	59	<5	175	10	102	335	17	<5	164	39	<5	38	20	<5
				.425-2	44.8	139	1677	16	18	13288	<5	<5	24	<5	136	10	39	259	14	<5	138	70	<5	24	9	<5
				.180-.425	41.6	126	1916	11	16	14687	<5	<5	30	<5	174	11	43	273	14	<5	185	37	<5	28	9	<5
				.075-.180	4.4	196	3354	17	53	29374	12	<5	59	13	266	16	79	522	24	<5	245	47	<5	32	24	<5
				<.075	5.6	209	4133	32	104	39865	27	16	86	27	293	15	103	727	29	<5	250	26	<5	43	32	<5
B_1	0.6	REDDISH - BROWN WEAKLY STRUCTURED SOILS.	QUARTZ (ROUNDED AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		113	1737	22	51	22101	9	<5	27	10	173	12	49	303	16	<5	146	42	<5	22	12	<5
				>2	4.6	174	2455	40	81	38467	14	<5	50	14	194	10	63	375	18	<5	162	24	<5	37	20	<5
				.425-2	35.5	144	1916	20	52	21669	8	<5	32	22	156	9	46	258	15	<5	122	57	<5	29	15	<5
				.180-.425	42.9	183	2396	22	71	27276	12	<5	42	17	208	12	54	305	17	<5	203	36	<5	37	16	<5
				.075-.180	9.5	226	3773	39	119	41964	20	21	67	29	290	16	99	614	27	<5	253	28	<5	37	34	<5
				<.075	7.5	218	4133	46	126	45752	27	31	85	40	309	15	107	625	30	<5	224	22	<5	50	41	<5
B_2(T)	1.0	REDDISH APEDAL B HORIZON. (ZONE OF ILLUVIATION)	QUARTZ (ROUNDED AND SUBANGULAR); NO FELDSPAR AND BIOTITE; KAOLINITE AND OTHER MIXED LAYERED CLAY MINERALS. H.M. - MAG, ILM, LIM, GH, HEM AND ZR.	TOTAL		152	2695	22	62	27486	15	<5	54	17	210	10	70	408	20	<5	184	35	<5	35	20	<5
				>2	8.6	196	2875	51	74	43362	19	<5	76	10	198	11	66	396	20	<5	182	16	<5	35	22	<5
				.425-2	32.1	139	2096	13	37	20282	9	<5	32	<5	152	7	47	277	15	<5	139	41	<5	34	13	<5
				.180-.425	35.5	192	3354	17	59	31473	9	<5	58	13	222	13	59	317	20	<5	210	30	<5	34	19	<5
				.075-.180	11.7	218	4133	32	111	41964	25	15	82	23	295	15	103	638	29	<5	243	24	<5	44	35	<5
				<.075	12.1	213	4372	46	133	46859	30	21	89	26	303	14	111	678	31	<5	249	10	<5	54	40	<5
P	1.2	HORIZON MARKED BY ROUNDED QUARTZ PEBBLES AND GOETHITE PELLETS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES AND GRAINS STAINED WITH IRON OXIDES; GOETHITE PELLETS; MINOR CLAY MINERALS; NO FELDSPAR AND BIOTITE. H.M. - GH, HEM, MAG, CAS, ILM AND ZR.	TOTAL		257	2575	66	253	80431	22	13	108	14	194	10	72	388	21	23	159	68	<5	61	25	8
				>2	59.3	115	1198	74	460	90922	50	30	220	22	84	<5	48	274	16	62	145	45	<5	107	26	26
				.425-2	15.5	218	2875	63	327	64344	20	14	100	16	215	11	78	377	21	21	196	39	<5	90	28	9
				.180-.425	12.9	174	2935	33	148	40565	17	10	67	18	265	15	77	389	23	9	237	35	<5	55	27	75
				.075-.180	5.2	205	3953	49	193	51056	18	22	84	26	312	17	101	557	29	11	266	18	<5	66	38	6
				<.075	7.1	205	4193	55	238	56301	27	29	92	25	309	16	120	698	32	14	250	13	<5	69	43	10
C	1.5	BROWN HORIZON OF HIGHLY WEATHERED BEDROCK. (UNCONSOLIDATED).	MAINLY QUARTZ; ALTERED FELDSPAR AND BIOTITE; H.M - MAG, ILM, HEM AND ZR.	TOTAL		205	1995	27	238	27066	13	10	74	22	377	21	80	416	25	7	366	20	<5	69	33	6
				>2	21.3	262	1575	66	431	64126	26	14	152	17	318	16	67	354	21	36	270	<5	<5	90	28	14
				.425-2	57.5	209	1695	18	223	23182	9	<5	69	14	404	24	70	307	24	6	400	25	<5	70	29	<5
				.180-.425	11.7	196	2174	11	200	32172	9	<5	67	12	437	23	70	347	24	<5	430	25	<5	64	29	<5
				.075-.180	4.1	222	3073	27	245	42621	10	18	87	31	417	23	107	603	33	12	362	45	<5	64	43	9
				<.075	5.4	218	3193	39	297	45163	28	19	105	23	477	19	120	709	32	7	326	6	<5	82	48	9
R	1.5	SLIGHTLY WEATHERED GREY VLAKLAAGTE GRANITE.	QUARTZ; SLIGHTLY SERITISISED POTASH FELDSPAR; SERITISISED AND KAOLINISED PLAGIOCLASE; BIOTITE CHLORITISED. H.M - MAG, ILM, HEM AND ZR.			180	1677	10	111	18184	<5	<5	40	10	536	66	70	255	20	20	519	9	<5	45	25	14

Description, mineralogy and trace element geochemistry of weathering profile 11 on grey Vlaklaagte granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
						GEOCHEMICAL DATA (PPM)																				
A_1	0.2	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, CAS, LIM AND ZR.	TOTAL		104	1482	9	89	11179	<5	<5	<5	<5	180	16	45	317	13	8	194	120	<5	30	15	<5
				>2	4.6	134	1422	40	145	40005	14	<5	32	<5	203	18	44	275	14	28	174	27	<5	47	19	8
				.425-2	36.2	110	1295	<5	40	8672	<5	<5	<5	<5	164	13	35	250	12	<5	154	94	<5	41	10	<5
				.180-.425	47.9	112	1421	<5	42	8822	<5	<5	<5	<5	177	15	38	264	11	<5	180	63	<5	49	10	<5
				.075-.180	7.5	169	2505	12	108	15103	<5	<5	10	<5	247	22	82	613	23	<5	292	68	<5	45	26	<5
				<.075	3.8	204	3900	15	247	21915	10	<5	16	<5	252	27	136	1123	28	<5	333	49	<5	51	36	12
A_2(E)	0.3	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		92	1560	18	61	18797	<5	<5	9	<5	196	16	50	331	14	16	188	20	<5	32	18	<5
				>2	5.8	186	1846	87	154	58383	13	8	56	7	169	13	49	295	16	35	169	7	<5	42	23	9
				.425-2	42.5	120	1564	10	49	14424	<5	<5	9	<5	183	14	42	273	15	10	177	29	<5	36	15	<5
				.180-.425	42.5	109	1516	8	19	13401	<5	13	8	<5	196	15	44	283	13	<5	152	22	<5	40	15	<5
				.075-.180	5.1	164	2503	15	72	19940	<5	<5	16	10	250	21	79	571	22	11	249	27	<5	38	28	6
				<.075	4.1	190	3381	26	130	26447	13	13	19	11	265	22	120	936	25	6	290	<5	<5	51	37	12
P	0.4	ZONE MARKED BY QUARTZ PEBBLES, ROCK DEBRIS AND IRON OXIDES.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES; GOETHITE PELLETS; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		155	1541	59	42	47086	17	<5	54	<5	141	10	52	257	13	30	118	14	<5	26	16	<5
				>2	46.9	222	1184	124	184	94391	44	21	133	35	81	<5	27	181	13	90	<5	<5	<5	66	19	17
				.425-2	18.6	109	1522	11	48	16890	<5	<5	6	<5	182	12	41	258	11	7	173	<5	<5	42	13	<5
				.180-.425	25.6	118	1816	11	25	15330	<5	<5	10	<5	203	13	45	277	14	9	203	31	<5	39	13	<5
				.075-.180	5.5	176	3138	18	86	27329	10	<5	27	6	275	18	89	626	23	15	273	27	<5	39	29	<5
				<.075	3.4	211	3940	39	147	39575	22	15	40	12	293	19	133	972	27	17	282	<5	<5	60	42	12
B_2(R)	0.7	RED SOFT PLINTIC B HORIZON WHICH STILL PRESERVES THE GRANITIC STRUCTURE. (ZONE OF ILLUVIATION).	QUARTZ (ANGULAR AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; ENRICHED IN KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		224	2431	33	131	43821	34	20	49	29	351	13	76	431	24	112	301	18	<5	54	41	11
				>2	33.1	187	2412	36	130	52731	37	21	51	27	391	12	71	421	23	161	314	<5	<5	64	41	11
				.425-2	41.3	301	2215	23	115	40214	23	11	39	26	341	10	69	321	22	145	276	25	<5	59	32	9
				.180-.425	14.8	201	2536	27	119	43621	31	18	44	26	391	13	74	351	22	134	321	25	<5	54	35	<5
				.075-.180	5.8	256	2631	46	133	53861	33	32	65	32	471	15	89	414	23	162	341	20	<5	61	46	9
				<.075	5.0	244	2810	45	101	50210	45	35	78	33	454	16	93	371	24	169	382	<5	<5	71	49	12
B_3 + C	0.9	WHITISH-GREY HORIZON CONTAINING MUCH CLAY MINERALS. THE GRANITIC STRUCTURE IS STILL PRESERVED.	QUARTZ (ANGULAR AND SUBANGULAR); ALTERED FELDSPAR AND BIOTITE; GREYISH MATRIX OF PREDOMINANTLY KAOLINITE. H.M. - MAG, ILM, LIM, GH AND ZR.	TOTAL		183	2276	31	126	41964	27	21	40	33	395	15	87	356	24	123	324	18	<5	47	40	11
				>2	31.3	166	2249	34	121	48727	32	21	40	31	431	14	89	325	25	153	344	<5	<5	57	45	15
				.425-2	43.1	277	2111	22	104	38123	19	9	31	30	363	13	77	283	23	136	295	31	<5	51	34	10
				.180-.425	13.8	181	2376	26	110	41635	27	17	37	30	433	16	86	342	21	123	351	26	<5	49	39	8
				.075-.180	6.8	233	2457	43	123	50852	29	31	57	36	521	18	103	444	26	146	384	20	<5	54	47	11
				<.075	5.0	220	2632	42	94	49361	39	36	66	37	511	17	110	497	25	153	412	<5	<5	60	51	12
R	1.8	SLIGHTLY WEATHERED BEDROCK.	QUARTZ; KAOLINISED, SERICITISED AND HEMATITISED FELDSPARS; CHLORITISED AND HEMATITISED BIOTITE. H.M.- HEM, MAG AND ZR.			196	1677	7	111	25178	<5	<5	14	11	570	42	136	258	23	222	627	12	<5	40	35	6

Description, mineralogy and trace element geochemistry of weathering profile 12 on aplitic Vlaklaagte granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	GEOCHEMICAL DATA (PPM)																				
						P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
A_1	0.2	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M.- MAG, ILM AND ZR.	TOTAL		100	1297	27	115	7636	<5	<5	8	<5	64	12	33	306	11	<5	99	104	<5	19	9	<5
				>2	2.6	NOT ENOUGH SAMPLE																				
				.425-2	34.2	75	692	18	72	3880	<5	<5	<5	<5	29	6	11	105	7	<5	48	152	<5	18	<5	<5
				.180-.425	40.5	93	1194	28	59	3267	<5	<5	7	<5	68	10	21	196	11	<5	111	135	<5	17	<5	<5
				.075-.180	14.9	177	2277	29	174	9773	<5	<5	6	<5	111	19	71	704	16	<5	188	88	<5	36	17	7
				<.075	7.8	188	3964	18	237	8585	6	<5	10	<5	121	29	115	1249	25	<5	336	69	<5	24	28	13
A_2(E)	0.3	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION. THE SOIL IS SANDY.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- MAG, ILM AND ZR.	TOTAL		36	1330	32	106	7365	<5	<5	<5	<5	61	12	37	371	10	<5	94	74	7	27	11	6
				>2	2.6	37	349	40	87	11799	<5	<5	10	<5	20	7	10	96	7	<5	17	<5	<5	28	<5	<5
				.425-2	39.7	32	507	20	42	592	<5	<5	<5	<5	23	4	8	90	6	<5	26	103	<5	15	<5	<5
				.180-.425	39.7	64	1628	27	79	4512	<5	<5	<5	<5	67	9	27	257	10	<5	103	112	<5	15	<5	<5
				.075-.180	12.7	73	2470	31	119	3999	<5	<5	<5	<5	104	15	76	770	17	<5	180	117	<5	25	14	7
				<.075	5.3	81	3659	15	167	5598	<5	<5	<5	<5	117	24	111	1211	24	<5	228	46	<5	25	26	14
SANDY LAYER	0.5	A LAYER OF ALMOST PURE SAND.	MAINLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; MINOR IRON OXIDES; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- MAG, ILM AND ZR.	TOTAL		47	1447	23	97	5895	<5	<5	<5	<5	57	11	34	333	11	<5	79	78	<5	23	7	<5
				>2	3.1	36	353	40	61	8895	<5	<5	<5	<5	21	8	11	97	7	<5	30	<5	<5	33	6	6
				.425-2	35.4	33	437	21	60	3055	<5	<5	<5	<5	21	5	8	79	6	<5	14	113	<5	15	<5	<5
				.180-.425	37.8	44	1509	24	57	1596	<5	<5	<5	<5	62	8	24	217	9	<5	85	129	<5	21	<5	<5
				.075-.180	12.9	65	2793	22	129	5139	<5	<5	<5	<5	105	16	78	766	19	<5	183	95	<5	32	16	8
				<.075	10.8	62	4091	14	167	2420	<5	<5	<5	>5	114	23	113	1251	25	<5	242	41	<5	33	23	12
CLAY BAND	0.6	A BLACK CONSOLIDATED, ORGANIC RICH, CLAY BAND.	ALMOST ONLY CLAY MINERALS (MAINLY KAOLINITE); FINE QUARTZ GRAINS ARE ALSO PRESENT. H.M.- MAG, ILM AND ZR.			54	2560	19	51	8576	<5	<5	21	<5	123	13	43	348	15	<5	183	110	<5	19	9	<5

Description, mineralogy and trace element geochemistry of weathering profile 13. The nature of the underlying rocks is unknown.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
A_1	0.15	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		155	1474	20	187	15781	<5	<5	34	6	102	12	56	343	14	<5	108	267	<5	39	16	<5
				>2	3.8	159	1668	24	191	17042	<5	<5	41	<5	106	12	58	382	13	<5	129	174	<5	61	16	<5
				.425-2	49.8	169	1310	12	143	13200	<5	<5	26	<5	79	8	35	226	11	<5	74	227	<5	41	9	<5
				.180-.425	33.9	203	1786	17	175	13862	<5	<5	35	<5	114	10	47	284	11	<5	128	211	<5	49	10	<5
				.075-.180	8.3	328	2802	24	327	26500	<5	11	59	14	138	17	89	643	20	<5	175	244	<5	44	26	9
				<.075	4.2	399	4503	37	513	32258	19	13	89	14	177	23	146	1166	29	<5	275	88	<5	63	40	14
A_2(E)	0.3	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		152	1677	16	134	14312	<5	<5	40	<5	101	9	52	328	12	<5	101	138	<5	37	11	<5
				>2	3.2	185	2082	27	140	22618	<5	<5	55	14	123	12	64	404	16	<5	101	95	<5	51	21	8
				.425-2	55.2	151	1585	10	86	11977	<5	<5	37	<5	83	6	38	242	11	<5	87	104	<5	41	7	<5
				.180-.425	36.0	168	1894	17	138	17526	<5	<5	44	10	121	11	54	314	12	<5	117	107	<5	50	14	<5
				.075-.180	1.3	263	3137	20	156	25477	<5	<5	77	8	142	11	90	644	19	<5	166	149	<5	49	21	<5
				<.075	4.3	308	4333	49	257	39009	19	23	106	28	192	17	142	1060	29	<5	227	76	<5	56	42	13
A_3	0.5	BROWN WEAKLY STRUCTURED SOILS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; MINOR IRON OXIDES; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		179	2095	31	91	23411	6	<5	63	18	125	11	65	393	17	<5	106	245	<5	38	20	6
				>2	9.3	190	2528	30	89	24412	6	<5	76	9	131	9	65	415	15	<5	143	110	<5	62	20	<5
				.425-2	41.5	172	1895	15	91	19665	<5	<5	49	11	97	7	41	256	12	<5	89	168	<5	48	11	<5
				.180-.425	34.4	229	2763	24	116	26319	<5	<5	81	12	139	8	65	359	14	<5	154	239	<5	50	13	<5
				.075-.180	9.2	269	3633	46	169	38674	14	19	101	31	174	13	98	705	23	<5	169	293	<5	59	31	8
				<.075	5.6	274	4440	59	168	46139	31	23	154	33	216	14	118	836	29	<5	203	92	<5	65	40	9
B_1	0.7	REDDISH - BROWN WEAKLY STRUCTURED SOILS.	QUARTZ (ROUNDED AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		200	2381	34	98	25311	8	7	77	18	131	10	71	401	16	<5	110	150	<5	42	20	6
				>2	7.0	201	2723	34	93	28465	6	<5	83	11	137	9	67	399	17	<5	138	99	<5	63	21	<5
				.425-2	47.1	189	1985	25	94	21521	<5	<5	57	13	104	6	45	266	12	<5	83	85	<5	47	13	<5
				.180-.425	33.4	235	2865	27	121	27512	<5	<5	91	15	145	8	69	371	15	<5	146	161	<5	53	13	<5
				.075-.180	7.4	271	3821	51	176	41212	15	25	113	34	181	11	101	698	22	<5	151	172	<5	62	33	9
				<.075	5.1	276	4421	63	177	49621	31	31	165	37	222	12	119	801	29	<5	198	77	<5	61	42	10
B_2(T)	1.1	REDDISH APEDAL B HORIZON. (ZONE OF ILLUVIATION)	QUARTZ (ROUNDED AND SUBANGULAR); NO FELDSPAR AND BIOTITE; KAOLINITE AND OTHER MIXED LAYERED CLAY MINERALS. H.M. - MAG, ILM, LIM, GH, HEM AND ZR.	TOTAL		223	2955	37	103	33475	10	9	106	19	142	8	71	416	17	<5	125	68	<5	46	21	<5
				>2	11.8	265	2696	48	154	41808	9	23	105	31	128	9	65	360	18	<5	124	81	<5	61	24	6
				.425-2	42.2	168	2063	26	68	23691	7	<5	74	8	105	5	46	266	11	<5	89	63	<5	51	11	<5
				.180-.425	29.2	249	3250	41	118	39979	13	15	106	30	168	10	82	426	20	<5	137	108	<5	57	27	5
				.075-.180	10.9	272	3965	60	140	48637	28	25	158	35	200	10	107	689	24	<5	166	51	<5	65	35	7
				<.075	5.9	277	4264	71	173	56273	31	47	169	59	228	12	113	673	30	<5	171	56	<5	56	46	11
P	1.5	HORIZON MARKED BY ROUNDED QUARTZ PEBBLES AND GOET-HITE PELLETS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES AND GRAINS STAINED WITH IRON OXIDES; GOETHITE PELLETS; MINOR CLAY MINERALS; NO FELDSPAR AND BIOTITE. H.M. - GH, HEM, MAG, CAS, ILM AND ZR.	TOTAL		296	4550	70	183	55217	29	36	166	23	217	13	120	791	33	<5	156	105	<5	55	46	11
				>2	81.2	43	1257	145	99	102811	60	34	349	<5	57	5	53	302	15	<5	<5	13	<5	79	35	38
				.425-2	8.7	236	2155	44	120	36622	7	8	95	23	102	8	52	303	15	<5	82	197	<5	48	19	<5
				.180-.425	3.3	289	3253	49	148	40863	22	21	131	25	172	11	95	526	23	<5	175	190	<5	61	31	<5
				.075-.180	3.9	289	4149	63	180	50725	20	29	143	41	193	12	108	720	29	<5	159	100	<5	59	40	10
				<.075	2.9	294	2254	133	130	76950	23	13	170	<5	87	7	58	336	13	<5	71	12	<5	65	12	18
C	2.5	BROWN HORIZON OF HIGHLY WEATHERED BEDROCK. (UNCONSOLIDATED).	MAINLY QUARTZ; ALTERED FELDSPAR AND BIOTITE; H.M - MAG, ILM, HEM AND ZR.	TOTAL		109	1386	25	79	18243	7	10	79	15	189	7	59	273	11	<5	157	104	<5	19	19	<5
				>2	61.3	89	1134	11	45	13897	<5	<5	69	<5	81	<5	32	167	10	<5	75	94	<5	29	13	<5
				.425-2	15.4	153	2064	14	78	22438	9	<5	82	15	109	5	53	301	13	<5	87	121	<5	37	21	<5
				.180-.425	7.8	201	2951	29	117	35210	15	7	95	29	157	7	87	501	18	<5	146	176	<5	34	33	<5
				.075-.180	9.8	224	2621	36	121	40121	21	10	122	24	171	9	109	619	19	<5	189	123	<5	39	38	6
				<.075	5.7	229	3151	45	162	45212	35	19	144	32	215	10	115	821	19	<5	183	76	<5	43	47	7

Description, mineralogy and trace element geochemistry of weathering profile 14 on altered Makhutso Granite -very close to the contact with the Vlaklaagte granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	GEOCHEMICAL DATA (PPM)																				
						P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
A_1	0.3	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, HEM, MAG, ILM, CAS, LIM AND ZR.	TOTAL		113	1377	13	58	11889	<5	<5	36	8	99	11	62	370	15	<5	80	272	<5	32	16	<5
				>2	2.3	99	1257	39	63	21681	10	9	44	<5	109	22	60	368	19	12	121	109	21	66	38	32
				.425-2	46.2	135	1377	13	55	10491	<5	<5	33	6	87	10	54	297	13	<5	69	155	<5	43	12	<5
				.180-.425	37.8	148	1497	9	45	9092	<5	<5	40	<5	102	9	56	317	12	<5	100	228	<5	38	11	<5
				.075-.180	9.7	200	2156	16	89	15385	<5	<5	43	9	120	14	103	696	18	<5	135	193	<5	48	22	7
				<.075	4.0	305	3893	22	178	23080	14	6	97	16	162	20	157	1316	29	<5	214	148	<5	53	38	16
A_2(E	0.5	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, CAS, LIM AND ZR.	TOTAL		126	1856	19	37	15806	6	<5	69	7	115	9	69	414	16	<5	96	210	<5	33	16	<5
				>2	4.5	122	1497	20	42	17904	<5	<5	56	12	96	10	55	346	14	<5	70	159	<5	45	17	6
				.425-2	38.0	130	1617	13	28	12589	<5	<5	56	<5	94	6	47	306	12	<5	70	135	<5	37	11	<5
				.180-.425	42.2	170	1976	18	68	20282	<5	8	69	17	128	11	64	363	16	<5	112	195	<5	51	18	<5
				.075-.180	8.4	226	3054	25	81	26577	11	15	107	17	154	13	106	777	22	<5	152	150	<5	51	29	9
				<.075	6.9	279	4432	45	156	43362	21	34	152	45	218	18	146	1047	33	<5	192	95	<5	59	48	18
A_3	0.6	BROWN WEAKLY STRUCTURED SOILS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; MINOR IRON OXIDES; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, CAS, LIM AND ZR.	TOTAL		165	2036	22	70	21681	9	7	74	20	126	11	68	429	18	<5	106	158	<5	43	23	6
				>2	8.5	148	2096	20	42	20282	7	<5	88	14	117	8	61	405	17	<5	95	112	<5	45	16	<5
				.425-2	43.5	148	1797	16	62	19583	<5	16	65	16	106	9	52	321	14	<5	86	118	<5	48	16	<5
				.180-.425	27.2	192	2336	18	54	22380	8	<5	96	16	135	9	65	397	16	<5	128	151	<5	49	19	<5
				.075-.180	13.5	235	3294	37	119	35669	15	19	118	35	175	15	110	788	25	<5	150	122	<5	55	36	12
				<.075	7.3	240	4013	51	141	44761	31	32	180	40	222	15	128	914	29	<5	190	57	<5	67	45	15
B_1	0.7	REDDISH - BROWN WEAKLY STRUCTURED SOILS.	QUARTZ (ROUNDED AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, CAS, LIM AND ZR.	TOTAL		169	2140	22	69	22481	8	9	86	20	127	10	70	450	18	<5	114	163	<5	45	23	6
				>2	10.5	170	2176	21	43	21342	6	7	94	17	113	9	65	436	16	<5	97	117	<5	47	18	<5
				.425-2	43.5	170	1830	17	57	19982	<5	20	72	19	111	9	57	357	15	<5	91	123	<5	48	21	<5
				.180-.425	25.2	200	2476	20	56	23456	7	13	105	21	142	8	71	423	13	<5	135	172	<5	53	21	<5
				.075-.180	12.5	250	3391	41	114	36230	17	22	127	41	162	16	121	824	27	<5	156	133	<5	61	40	11
				<.075	8.5	271	4213	54	152	46721	27	36	192	49	231	17	137	923	32	<5	201	98	<5	73	49	14
B_2(T	0.95	REDDISH APEDAL B HORIZON. GRADING OCCUR INTO THE PEBBLE LAYER. (ZONE OF ILLUVIATION)	QUARTZ (ROUNDED AND SUBANGULAR); NO FELDSPAR AND BIOTITE; KAOLINITE AND OTHER MIXED LAYERED CLAY MINERALS. H.M. - MAG, ILM, LIM, GH, CAS, HEM AND ZR.	TOTAL		170	2336	23	68	23989	10	14	104	18	131	9	75	491	18	<5	110	175	<5	49	22	<5
				>2	17.9	205	2336	30	104	28535	6	41	88	23	115	11	65	420	17	<5	99	111	<5	49	23	8
				.425-2	36.9	157	1916	15	48	18184	6	<5	75	9	96	7	50	330	13	<5	90	141	<5	47	13	<5
				.180-.425	25.5	218	2695	25	96	29374	9	24	101	29	151	12	78	461	20	<5	132	204	<5	47	25	6
				.075-.180	10.9	257	3773	32	104	35669	20	18	142	28	174	12	108	824	26	<5	169	128	<5	56	33	8
				<.075	8.8	292	4312	54	156	48258	27	38	165	51	217	15	131	930	31	<5	184	72	<5	71	46	14
P	1.2	HORIZON MARKED BY ROUNDED QUARTZ PEBBLES GOETHITE PELLETS AND ROCK DEBRIS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES AND GRAINS STAINED WITH IRON OXIDES; GOETHITE PELLETS; MINOR CLAY MINERALS; NO FELDSPAR AND BIOTITE. H.M. - GH, HEM, MAG, CAS, ILM AND ZR,	TOTAL		251	2216	78	267	58749	21	17	152	18	110	9	70	436	21	<5	108	1235	<5	84	24	12
				>2	48.9	235	1713	115	186	91219	31	27	256	14	73	5	45	270	14	<5	8	731	<5	68	22	17
				.425-2	26.6	178	2276	29	104	29374	<5	6	92	20	118	9	66	409	16	<5	100	1570	<5	56	19	<5
				.180-.425	13.8	222	3174	32	89	32172	15	15	131	24	163	11	94	572	21	<5	159	1051	<5	59	28	5
				.075-.180	5.9	248	3713	37	126	37767	18	22	120	31	176	14	120	864	27	<5	179	751	<5	61	39	12
				<.075	4.8	270	4492	49	148	47559	35	30	192	40	206	13	131	920	30	<5	185	473	<5	68	43	11
R	1.2	HIGHLY WEATHERED GREISEN.	MAINLY QUARTZ; ALTERED BIOTITE AND MUSCOVITE(MAINLY SERICITE); KAOLINITE; CAS, HEM AND ZR AND MAG.			102	1072	27	119	33571	8	10	91	<5	920	78	78	193	19	<5	796	1219	<5	280	65	<5

Description, mineralogy and trace element geochemistry of weathering profile 15 on greisen.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
						GEOCHEMICAL DATA (PPM)																				
A_1	0.15	DARK BROWN, ORGANIC	ALMOST ONLY ROUNDED AND SUBANGULAR	TOTAL		151	1914	14	70	15307	5	<5	67	<5	132	9	67	381	15	<5	137	149	<5	23	12	<5
		RICH, ORTHIC A	QUARTZ GRAINS (SLIGHTLY STAINED WITH	>2	3.6	188	2400	21	71	23575	8	<5	100	<5	162	9	75	464	17	<5	141	169	<5	47	14	<5
		HORIZON WITH WEAKLY	IRON OXIDES); NO FELDSPAR AND BIOTITE;	.425-2	46.9	154	1746	6	58	13254	<5	<5	57	<5	110	7	47	310	12	<5	116	179	<5	37	7	<5
		STRUCTURED SOILS.	MINOR KAOLINITE AND OTHER CLAY	.180-.425	37.8	194	2319	9	65	16903	<5	<5	76	<5	157	11	59	333	15	<5	178	175	<5	35	10	<5
			MINERALS. H.M- GH, HEM, MAG, ILM,	.075-.180	7.5	210	2733	7	84	19079	7	<5	85	<5	153	12	93	617	20	<5	172	177	<5	29	18	<5
			LIM AND ZR.	<.075	4.2	272	4545	24	161	36243	22	13	165	22	209	17	161	1209	32	<5	226	73	<5	34	41	10
A_2(E)	0.25	LIGHT COLOURED, LOOSE	ALMOST ONLY ROUNDED AND SUBANGULAR	TOTAL		146	1829	17	87	19360	<5	<5	60	<5	135	11	67	380	15	<5	133	230	<5	19	10	<5
		STRUCTURED, HORIZON OF	QUARTZ GRAINS; NO FELDSPAR AND	>2	5.2	175	2161	16	60	20535	7	<5	75	11	139	11	69	419	18	<5	137	166	<5	37	16	<5
		MAXIMUM ELUVIATION.	BIOTITE; TRACES OF KAOLINITE AND	.425-2	42.8	165	1926	7	43	15612	5	<5	62	9	111	8	48	290	14	<5	112	155	<5	34	9	<5
			OTHER CLAY MINERALS. H.M.- GH, MAG,	.180-.425	42.8	191	2344	11	58	19940	<5	<5	74	12	159	12	69	350	16	<5	168	198	<5	37	15	<5
			ILM, LIM AND ZR.	.075-.180	5.9	220	2874	22	87	25028	7	<5	89	16	165	14	106	694	21	<5	183	141	<5	34	24	<5
				<.075	3.3	258	4146	30	166	37227	18	16	138	24	203	17	156	1160	30	<5	212	74	<5	43	34	10
A_3	- 0.4	BROWN WEAKLY	MAINLY ROUNDED AND SUBANGULAR QUARTZ	TOTAL		164	2374	13	31	19865	8	<5	98	7	138	8	54	367	16	<5	142	188	<5	19	12	<5
		STRUCTURED	GRAINS ; MINOR IRON OXIDES; MINOR	>2	4.6	150	2055	22	46	24045	7	<5	97	<5	125	8	62	391	16	<5	120	181	<5	35	13	<5
		SOILS.	KAOLINITE, ILLITE AND OTHER MIXED	.425-2	43.4	143	1906	8	19	14463	<5	<5	69	<5	106	6	45	278	13	<5	106	161	<5	31	6	<5
			LAYERED CLAYS; NO FELDSPAR AND	.180-.425	40.4	175	2421	10	38	20055	6	<5	92	5	164	10	60	359	16	<5	191	165	<5	39	13	<5
			BIOTITE. H.M.- GH, HEM, MAG, ILM,	.075-.180	7.3	213	3372	10	63	27501	12	<5	128	12	171	11	111	752	23	<5	182	132	<5	27	25	<5
			LIM AND ZR.	<.075	4.3	239	4190	35	120	38854	25	14	174	21	208	14	141	1054	29	<5	212	59	<5	34	38	10
B_1	1.0	REDDISH - BROWN	QUARTZ (ROUNDED AND SUBANGULAR)	TOTAL		212	3169	27	95	32343	14	5	127	26	167	10	81	505	21	<5	160	146	<5	29	23	<5
		WEAKLY STRUCTURED	STAINED WITH IRON OXIDES; NO FRESH	>2	9.7	198	2927	23	104	31947	9	<5	109	16	150	9	77	495	18	<5	134	71	<5	48	21	<5
		SOILS.	FELDSPAR OR BIOTITE;	.425-2	39.5	181	2234	15	70	23484	<5	<5	85	13	117	7	57	319	14	<5	104	145	<5	35	13	<5
			KAOLINITE, ILLITE AND OTHER CLAY	.180-.425	31.3	228	3399	22	79	34043	12	7	135	27	189	11	84	490	23	<5	188	137	<5	37	26	<5
			MINERALS; IRON OXIDES. H.M.- HEM,	.075-.180	12.2	249	3931	31	126	40317	19	17	148	28	200	12	120	831	27	<5	191	84	<5	42	33	6
			GH, MAG, ILM, LIM AND ZR.	<.075	7.3	249	4257	50	131	47900	29	28	186	39	221	12	134	886	31	<5	186	55	<5	45	41	9
B_2(T)	1.7	REDDISH APEDAL	QUARTZ (ROUNDED AND SUBANGULAR);	TOTAL		180	2951	16	82	27779	14	<5	134	10	144	7	84	500	19	<5	127	98	<5	25	19	<5
		B HORIZON.	NO FELDSPAR AND BIOTITE;	>2	18.3	169	2328	26	55	30374	7	<5	110	5	93	5	53	324	16	<5	76	47	<5	35	12	<5
		(ZONE OF	KAOLINITE AND OTHER MIXED LAYERED	.425-2	34.5	176	2807	14	66	24116	11	<5	121	9	128	6	61	372	18	<5	122	108	<5	39	13	<5
		ILLUVIATION)	CLAY MINERALS. H.M. - MAG, ILM, LIM,	.180-.425	29.4	217	3845	20	114	36124	20	<5	170	18	198	10	100	590	25	<5	186	141	<5	33	28	<5
			GH, HEM AND ZR.	.075-.180	10.2	220	3982	36	152	40207	22	7	166	12	198	10	112	789	26	<5	181	58	<5	48	30	<5
				<.075	7.6	223	4582	34	165	45395	31	19	218	29	219	11	147	964	33	<5	175	66	<5	43	42	7
P	2.4	HORIZON MARKED BY	MAINLY ROUNDED AND SUBANGULAR	TOTAL		198	2735	38	156	38334	12	<5	123	14	134	8	75	546	19	<5	112	113	<5	34	20	<5
		ROUNDED QUARTZ	QUARTZ PEBBLES AND GRAINS STAINED	>2	41.8	218	1665	77	126	59984	6	<5	112	<5	57	7	38	345	11	<5	47	537	<5	47	11	6
		PEBBLES AND GOET-	WITH IRON OXIDES; GOETHITE PELLETS;	.425-2	28.9	194	2853	22	118	31360	11	<5	119	17	148	9	74	524	20	<5	140	177	<5	47	20	<5
		HITE PELLETS.	MINOR CLAY MINERALS; NO FELDSPAR	.180-.425	13.6	223	2175	31	180	41991	17	12	158	24	212	12	109	692	27	<5	181	105	<5	48	33	<5
		(GRADING OCCUR	AND BIOTITE. H.M. - GH, HEM,	.075-.180	8.8	224	3962	31	196	42036	18	14	157	25	199	12	125	909	28	<5	184	95	<5	51	37	7
		INTO THE B_2 HORIZON)	MAG, CAS, ILM AND ZR,	<.075	6.9	227	4383	49	244	49802	23	26	177	26	226	12	148	1045	31	<5	191	35	<5	62	46	10
C	2.5	BROWN HORIZON	MAINLY QUARTZ;	TOTAL		188	2915	39	143	32143	12	7	98	21	225	19	84	402	24	<5	257	45	<5	63	31	7
		OF HIGHLY	ALTERED FELDSPAR	>2	32.1	210	2671	80	122	49282	7	6	101	13	183	14	63	376	22	<5	231	79	<5	98	26	6
		WEATHERED BEDROCK.	AND BIOTITE; H.M - MAG, ILM,	.425-2	41.3	192	2653	25	101	29260	11	<5	116	15	234	18	69	327	23	<5	331	131	<5	67	26	<5
		(UNCONSOLIDATED).	HEM AND ZR.	.180-.425	14.8	219	3089	34	176	35243	15	8	163	13	256	19	67	367	24	<5	351	101	<5	61	27	<5
				.075-.180	6.8	216	3974	32	196	36921	17	12	159	29	289	21	98	590	31	<5	301	98	<5	62	39	9
				<.075	7.0	221	4083	48	247	41562	21	18	186	25	273	17	101	634	32	<5	298	76	<5	78	45	11

Description, mineralogy and trace element geochemistry of weathering profile 16 on slightly altered Vlaklaagte granite -very close to the contact with the Makhutso Granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
A_1	0.2	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		162	1824	15	65	13107	5	<5	38	<5	70	8	63	361	12	<5	91	74	<5	20	11	<5
				>2	2.6	144	2217	20	70	19603	7	<5	50	<5	81	7	72	452	15	<5	101	73	<5	37	15	<5
				.425-2	45.8	167	1820	8	63	11657	<5	<5	27	<5	66	7	45	325	11	<5	87	78	<5	31	8	<5
				.180-.425	37.9	204	2220	9	69	17538	<5	<5	40	<5	82	10	52	349	14	<5	130	79	<5	31	11	<5
				.075-.180	8.2	230	2621	8	79	19572	6	<5	55	<5	98	10	89	625	18	<5	127	82	<5	27	18	<5
				<.075	5.5	302	4267	21	131	26561	15	6	80	7	140	15	158	1195	28	<5	181	40	<5	32	39	<5
A_2(E)	0.35	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		156	1817	16	81	12237	<5	<5	30	<5	72	9	69	356	14	<5	81	59	<5	17	9	7
				>2	4.8	151	2176	19	70	17512	6	<5	35	7	66	8	71	449	17	<5	94	63	<5	35	17	<5
				.425-2	41.3	171	1917	7	51	10513	<5	<5	30	6	59	7	53	310	13	<5	86	58	<5	30	10	<5
				.180-.425	42.9	195	2243	10	52	15321	<5	<5	40	7	89	11	74	366	15	<5	124	78	<5	33	14	<5
				.075-.180	6.8	205	2816	20	71	17567	<5	<5	59	8	102	12	112	692	20	<5	146	49	<5	30	21	<5
				<.075	4.2	265	4019	27	145	21583	14	8	72	18	151	15	167	1175	30	<5	182	41	<5	37	30	8
A_3	0.5	BROWN WEAKLY STRUCTURED SOILS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ GRAINS ; MINOR IRON OXIDES; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		161	2271	14	46	17215	7	<5	42	<5	76	9	73	336	15	<5	101	76	<5	18	10	<5
				>2	4.4	155	1931	23	45	21316	<5	<5	51	6	69	9	79	362	15	<5	84	69	<5	37	14	<5
				.425-2	42.3	161	1917	8	30	15823	<5	<5	47	5	62	8	62	254	13	<5	75	63	<5	29	7	<5
				.180-.425	39.6	172	2318	9	41	19563	6	<5	48	7	91	12	81	312	15	<5	142	58	<5	31	10	<5
				.075-.180	8.4	210	3267	11	67	26538	9	<5	61	9	107	14	119	702	21	<5	141	62	<5	35	21	<5
				<.075	5.3	239	4096	31	111	35693	21	10	91	20	166	17	171	1076	29	<5	186	39	<5	41	39	9
B_1	0.9	REDDISH - BROWN WEAKLY STRUCTURED SOILS.	QUARTZ (ROUNDED AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		175	2346	24	81	23578	11	<5	61	6	81	8	79	317	20	<5	126	52	<5	21	21	<5
				>2	9.5	161	1917	29	84	21542	7	<5	52	8	76	8	73	313	20	<5	92	45	<5	41	22	<5
				.425-2	40.3	171	2015	11	71	23718	<5	<5	54	7	66	7	54	278	16	<5	74	39	<5	33	14	<5
				.180-.425	30.7	185	2378	14	81	34586	6	<5	62	11	93	10	89	402	21	<5	148	42	<5	34	25	<5
				.075-.180	11.3	205	3156	25	120	38672	14	9	73	17	120	11	119	721	24	<5	156	48	<5	41	32	6
				<.075	8.2	236	4158	32	129	41238	22	19	101	22	170	15	130	956	30	<5	177	34	<5	47	40	7
B_2(T)	1.7	REDDISH APEDAL B HORIZON. GRADING OCCUR INTO THE PEBBLE LAYER. (ZONE OF ILLUVIATION)	QUARTZ (ROUNDED AND SUBANGULAR); NO FELDSPAR AND BIOTITE; KAOLINITE AND OTHER MIXED LAYERED CLAY MINERALS. H.M. - MAG, ILM, LIM, GH, HEM AND ZR.	TOTAL		162	2864	15	74	28345	12	<5	62	7	82	7	78	425	19	<5	131	48	<5	21	20	<5
				>2	17.4	154	2024	24	60	26918	7	<5	78	7	79	7	69	312	18	<5	101	52	<5	39	11	<5
				.425-2	35.5	176	2631	12	63	22454	6	<5	64	6	71	6	49	361	15	<5	94	43	<5	31	14	<5
				.180-.425	30.3	189	3642	15	91	34916	14	6	73	8	99	9	81	567	24	<5	147	51	<5	35	27	<5
				.075-.180	9.6	220	3781	21	130	40443	19	11	91	17	124	11	114	758	25	<5	166	60	<5	41	28	<5
				<.075	7.2	221	4352	35	151	44512	29	21	127	24	181	14	130	898	30	<5	185	40	<5	48	43	6
P	2.4	HORIZON MARKED BY ROUNDED QUARTZ PEBBLES AND GOETHITE PELLETS. GRADING OCCUR INTO THE B_2 HORIZON.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES AND GRAINS STAINED WITH IRON OXIDES; GOETHITE PELLETS; MINOR CLAY MINERALS; NO FELDSPAR AND BIOTITE. H.M. - GH, HEM, MAG, CAS, ILM AND ZR,	TOTAL		198	2642	32	111	36921	11	<5	48	12	74	7	69	466	19	<5	94	53	<5	19	21	7
				>2	39.7	201	2153	47	97	48712	6	<5	51	7	69	6	41	325	12	<5	38	61	<5	34	12	<5
				.425-2	29.9	187	2481	19	110	29583	12	<5	61	6	68	6	61	516	21	<5	98	62	<5	31	16	<5
				.180-.425	14.9	231	3467	25	131	39516	16	7	62	11	89	9	101	691	26	<5	110	53	<5	30	25	<5
				.075-.180	8.5	230	3623	33	186	42931	17	13	79	17	109	10	121	925	29	<5	137	59	<5	36	29	7
				<.075	6.8	225	4152	47	231	48721	24	24	101	18	164	12	141	1010	30	<5	152	43	<5	41	45	11
PAL-COL	2.7	BROWN HORIZON OF WEAKLY STRUCTURED SOILS.	MAINLY QUARTZ (ROUNDED AND SUBANGULAR); NO FELDSPAR OR BIOTITE; KAOLINITE AND MIXED LAYERED CLAY MINERALS; IRON OXIDES. H.M. - MAG, ILM, HEM AND ZR.	TOTAL		163	2361	29	88	36926	11	<5	60	8	72	7	68	338	15	<5	98	31	<5	19	10	<5
				>2	8.6	84	2148	41	79	41517	7	<5	75	7	71	6	38	341	17	<5	94	48	<5	35	15	<5
				.425-2	38.7	172	2219	28	83	28756	13	<5	69	7	69	7	58	267	14	<5	82	41	<5	31	8	<5
				.180-.425	31.2	193	2986	29	109	40196	17	6	75	10	81	8	97	308	16	<5	128	47	<5	34	11	<5
				.075-.180	12.5	207	3148	34	154	44512	19	9	101	15	104	10	114	717	20	<5	131	39	<5	35	22	7
				<.075	9.0	211	3565	42	191	51761	22	22	116	20	157	13	137	1036	28	<5	174	45	<5	36	37	11

Description, mineralogy and trace element geochemistry of weathering profile 17. (Nature of underlying rocks unknown).

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
						GEOCHEMICAL DATA (PPM)																				
A_1	0.1	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, CAS, LIM AND ZR.	TOTAL		101	1213	9	96	10337	<5	<5	5	<5	91	9	53	351	11	<5	55	187	<5	23	19	<5
				>2	27.4	39	442	10	87	7884	<5	<5	<5	<5	107	5	24	140	7	<5	37	98	<5	36	7	<5
				.425-2	44.7	109	1277	7	76	8043	<5	<5	<5	<5	79	6	41	286	9	<5	52	133	<5	32	12	<5
				.180-.425	15.4	130	1432	7	94	9439	<5	<5	6	<5	101	7	62	352	12	<5	72	274	<5	27	20	<5
				.075-.180	7.4	170	1723	9	111	10239	<5	<5	5	<5	103	10	86	622	17	<5	89	264	<5	32	29	<5
				<.075	5.1	247	3638	18	244	18548	11	<5	20	9	152	18	150	1241	26	<5	182	188	<5	35	50	11
A_2(E	0.2	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, CAS, LIM AND ZR.	TOTAL		91	1325	17	57	17845	<5	<5	9	<5	83	9	53	312	12	<5	49	167	<5	24	21	<5
				>2	25.0	183	1502	64	149	56341	<5	<5	44	7	74	6	49	276	13	<5	33	96	<5	34	8	<5
				.425-2	47.1	114	1213	11	46	13252	<5	<5	9	<5	79	7	43	266	12	<5	44	141	<5	28	14	<5
				.180-.425	17.4	102	1205	8	17	12421	<5	<5	9	10	87	8	46	269	10	<5	65	263	<5	31	23	<5
				.075-.180	6.5	156	2246	14	69	18631	<5	<5	15	13	110	11	83	553	18	<5	73	278	<5	30	31	7
				<.075	5.0	187	3021	27	127	25215	11	16	18	16	121	13	127	898	23	<5	178	193	<5	41	51	11
P	0.35	ZONE MARKED BY QUARTZ PEBBLES, ROCK DEBRIS AND IRON OXIDES.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES; GOETHITE PELLETS; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, CAS, LIM AND ZR.	TOTAL		76	954	19	91	16925	<5	<5	9	7	134	7	39	235	10	<5	59	147	<5	21	16	<5
				>2	49.3	63	538	9	48	12790	<5	<5	<5	<5	99	<5	18	108	6	<5	13	65	<5	31	6	<5
				.425-2	31.4	121	1360	11	65	13487	<5	<5	11	10	90	6	41	257	10	<5	56	117	<5	27	13	<5
				.180-.425	12.4	168	1944	17	95	18245	<5	<5	17	11	116	8	57	353	15	<5	96	271	<5	38	22	<5
				.075-.180	4.1	209	2291	31	95	20024	<5	<5	29	23	131	10	87	595	19	<5	109	212	<5	27	31	5
				<.075	2.8	225	3341	40	164	29526	13	34	37	23	178	15	138	1095	24	<5	151	148	<5	44	52	11
B_2(R	0.7	RED SOFT PLINTIC B HORIZON WHICH STILL PRESERVES THE GRANITIC STRUCTURE. (ZONE OF ILLUVIATION).	QUARTZ (ANGULAR AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; ENRICHED IN KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		117	1485	16	81	18506	6	<5	22	8	173	5	61	283	11	<5	60	75	<5	22	21	<5
				>2	46.4	97	1186	11	48	14162	<5	<5	15	<5	88	<5	36	177	9	<5	42	55	<5	30	12	<5
				.425-2	27.6	162	2268	15	81	24720	10	<5	39	17	114	5	62	327	14	<5	77	114	<5	36	23	<5
				.180-.425	12.6	235	3190	32	123	34522	18	8	59	32	162	8	94	499	20	<5	122	150	<5	37	39	<5
				.075-.180	8.4	249	3297	43	142	37208	25	12	55	30	177	9	116	690	21	<5	148	110	<5	46	44	6
				<.075	5.2	231	3634	51	171	44334	37	24	70	39	206	10	124	738	23	<5	145	57	<5	51	52	7
B_3 + C	1.3	WHITISH-GREY HORIZON CONTAINING MUCH CLAY MINERALS. THE GRANITIC STRUCTURE IS STILL PRESERVED.	QUARTZ (ANGULAR AND SUBANGULAR); ALTERED FELDSPAR AND BIOTITE; GREYISH MATRIX OF PREDOMINANTLY KAOLINITE. H.M. - MAG, ILM, LIM, GH AND ZR.	TOTAL		131	1537	15	78	16730	<5	<5	23	17	197	6	56	264	10	<5	65	55	<5	22	21	<5
				>2	57.6	107	1176	12	63	14925	<5	<5	15	11	75	<5	41	197	9	<5	29	23	<5	32	15	<5
				.425-2	25.9	178	2078	19	100	21199	7	<5	32	24	108	6	67	332	15	<5	69	72	<5	30	25	<5
				.180-.425	11.4	251	3183	41	156	31692	20	16	48	35	173	8	109	516	20	<5	126	111	<5	52	43	5
				.075-.180	4.8	282	3470	39	172	34166	22	23	58	42	182	10	133	719	25	<5	142	109	<5	38	52	10
				<.075	5.3	286	3825	55	181	39237	29	32	75	57	211	11	137	698	28	<5	148	47	<5	49	59	10

Description, mineralogy and trace element geochemistry of weathering profile 18 on altered Makhutso Granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	GEOCHEMICAL DATA (PPM) P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
A_1	0.2	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		101	1241	6	47	13518	<5	<5	10	<5	96	6	51	320	13	<5	68	61	<5	30	14	<5
				>2	7.7	132	1569	15	69	12627	<5	<5	25	<5	123	7	66	421	13	<5	89	24	<5	39	15	<5
				.425-2	55.2	109	1112	10	29	7536	<5	<5	19	<5	94	7	44	262	10	<5	61	71	<5	32	11	<5
				.180-.425	26.3	169	1763	13	68	13092	<5	<5	10	<5	137	7	63	351	15	<5	101	69	<5	37	17	<5
				.075-.180	6.2	166	1898	18	94	13189	<5	<5	18	<5	139	8	86	627	17	<5	114	68	<5	38	21	<5
				<.075	4.6	251	3563	32	193	21576	11	7	35	7	176	17	139	1124	20	<5	196	76	<5	51	39	14
A_2(E)	0.35	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		103	1362	17	58	12636	<5	<5	8	<5	109	7	57	324	13	<5	71	58	<5	33	15	<5
				>2	6.8	81	1092	14	31	12218	<5	<5	18	<5	89	8	53	271	10	<5	42	34	<5	36	12	<5
				.425-2	52.2	111	1178	15	49	11536	<5	<5	16	<5	77	6	44	254	10	<5	56	68	<5	29	10	<5
				.180-.425	29.8	151	1783	15	61	14629	<5	<5	8	<5	134	7	61	341	16	<5	82	71	<5	28	19	<5
				.075-.180	7.8	172	2152	22	98	17825	6	<5	15	6	147	9	98	696	21	<5	102	74	<5	36	19	7
				<.075	3.4	246	3765	40	169	27536	14	11	29	9	187	16	139	1076	22	<5	173	75	<5	45	41	13
A_3	0.6	BROWN WEAKLY STRUCTURED SOILS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ GRAINS ; MINOR IRON OXIDES; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		109	1592	16	32	13812	<5	<5	11	<5	123	7	62	356	12	<5	73	54	<5	41	17	<5
				>2	7.8	62	1067	15	21	8492	<5	<5	17	<5	77	7	38	241	9	<5	38	30	<5	31	8	<5
				.425-2	49.8	81	1054	12	19	10143	<5	<5	14	<5	98	7	39	256	8	<5	41	41	<5	29	9	<5
				.180-.425	28.9	148	2175	22	45	18567	6	<5	12	<5	159	8	74	472	17	<5	101	52	<5	35	21	<5
				.075-.180	8.8	192	3051	24	78	24152	10	<5	21	7	177	10	101	658	20	<5	131	42	<5	39	31	7
				<.075	4.7	201	3872	37	111	28658	21	13	37	12	194	17	131	1016	27	<5	164	38	<5	41	41	10
B_1	0.8	REDDISH - BROWN WEAKLY STRUCTURED SOILS.	QUARTZ (ROUNDED AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		111	1423	17	38	13916	<5	<5	15	9	127	7	57	376	12	<5	68	46	<5	43	18	<5
				>2	9.0	67	906	15	25	8562	<5	<5	14	<5	82	<5	37	204	8	<5	24	36	<5	29	8	<5
				.425-2	41.2	89	1052	14	24	9835	<5	<5	13	<5	97	7	38	216	8	<5	43	19	<5	35	9	<5
				.180-.425	29.1	154	2156	19	62	18567	7	<5	26	6	162	7	67	451	17	<5	109	46	<5	35	24	<5
				.075-.180	8.4	201	3066	23	84	26513	13	7	29	9	184	10	94	624	19	<5	142	61	<5	39	35	7
				<.075	7.3	218	3842	39	119	29516	23	14	41	16	201	17	121	871	24	<5	178	64	<5	42	52	11
B_2(T)	1.0	REDDISH APEDAL B HORIZON. (ZONE OF ILLUVIATION)	QUARTZ (ROUNDED AND SUBANGULAR); NO FELDSPAR AND BIOTITE; KAOLINITE AND OTHER MIXED LAYERED CLAY MINERALS. H.M. - MAG, ILM, LIM, GH, HEM AND ZR.	TOTAL		115	1401	15	43	14991	7	<5	19	10	131	7	54	312	12	<5	69	32	<5	45	16	<5
				>2	13.9	69	807	16	26	13512	<5	<5	17	<5	94	7	38	196	9	<5	27	26	<5	31	10	<5
				.425-2	52.3	97	1073	13	31	10567	<5	<5	18	<5	102	8	38	217	9	<5	41	27	<5	37	10	<5
				.180-.425	23.7	182	2318	23	79	23815	9	6	29	16	167	9	78	431	16	<5	107	35	<5	39	27	8
				.075-.180	6.8	225	3056	38	101	32627	16	9	29	12	187	11	87	616	22	<5	143	68	<5	44	37	8
				<.075	3.8	246	3851	45	134	36824	24	18	54	21	214	18	119	801	27	<5	184	51	<5	49	49	14
P	1.4	HORIZON MARKED BY ROUNDED QUARTZ PEBBLES AND GOETHITE PELLETS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES AND GRAINS STAINED WITH IRON OXIDES; GOETHITE PELLETS; MINOR CLAY MINERALS; NO FELDSPAR AND BIOTITE. H.M. - GH, HEM, MAG, ILM AND ZR,	TOTAL		132	1833	19	44	17167	7	<5	16	<5	119	5	61	387	17	<5	71	31	<5	40	19	<5
				>2	51.3	68	806	13	21	9513	<5	<5	14	<5	47	<5	31	151	14	<5	5	24	<5	29	6	<5
				.425-2	24.8	121	1911	21	51	15168	8	<5	16	<5	117	5	66	334	15	<5	68	24	<5	35	19	<5
				.180-.425	10.8	202	3455	30	89	32519	21	9	21	10	172	8	104	601	24	<5	141	37	<5	34	41	6
				.075-.180	7.5	222	3712	35	121	34525	21	13	22	12	172	9	114	721	27	<5	139	43	<5	41	44	8
				<.075	5.6	229	4156	49	146	39685	27	18	29	17	187	11	126	815	29	<5	168	40	<5	46	51	12
C	1.7	BROWN HORIZON OF HIGHLY WEATHERED BEDROCK. (UNCONSOLIDATED).	MAINLY QUARTZ; ALTERED FELDSPAR AND BIOTITE; H.M - MAG, ILM, HEM AND ZR.	TOTAL		139	1921	19	78	22199	8	<5	13	9	142	8	67	402	16	<5	85	20	<5	38	25	5
				>2	48.5	92	1112	19	46	12517	<5	<5	14	<5	84	9	41	217	12	<5	64	11	<5	31	12	<5
				.425-2	28.3	141	1963	24	81	19141	6	<5	16	7	147	8	71	367	15	<5	92	19	<5	32	21	<5
				.180-.425	10.9	192	3584	38	142	35629	20	14	24	17	209	10	115	679	27	<5	156	21	<5	46	44	9
				.075-.180	5.5	209	3751	46	166	36524	21	17	27	26	207	13	121	601	27	<5	180	27	<5	46	49	10
				<.075	6.8	201	4177	52	182	40326	25	24	31	27	227	21	135	856	29	<5	228	27	<5	51	51	11

Description, mineralogy and trace element geochemistry of weathering profile 19 on the grey Makhutso Granite.

APPENDIX A: (CONTINUED).

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba Sn	W	Pb	Th	U
						GEOCHEMICAL DATA (PPM)																			
A_1	0.2	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		132	1358	10	51	13156	<5	<5	21	<5	85	6	54	335	12	<5	71 49	<5	26	13	<5
				>2	6.9	141	1696	13	70	11628	<5	<5	36	<5	97	6	67	436	13	<5	85 31	<5	34	16	<5
				.425-2	47.2	111	1251	9	45	8849	<5	<5	10	<5	82	6	46	283	11	<5	71 66	<5	31	8	<5
				.180-.425	33.3	167	1852	13	69	13176	<5	<5	24	<5	96	7	67	362	14	<5	98 68	<5	35	10	<5
				.075-.180	7.5	169	1963	17	98	13251	<5	<5	41	<5	112	9	89	643	18	<5	116 72	<5	36	16	<5
				<.075	5.1	262	3596	29	165	22167	10	8	58	7	156	16	143	1173	21	<5	184 71	<5	47	34	13
A_2(E	0.35	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		141	1467	15	66	12438	<5	<5	16	<5	87	7	62	342	13	<5	69 52	<5	27	10	<5
				>2	7.7	110	1085	14	49	12121	<5	<5	21	<5	81	7	57	296	11	<5	52 38	<5	30	16	<5
				.425-2	53.5	121	1273	14	53	11526	<5	<5	11	<5	66	8	47	246	12	<5	61 72	<5	26	9	<5
				.180-.425	27.7	168	1892	15	67	15673	<5	<5	25	<5	94	9	65	345	17	<5	74 74	<5	27	14	<5
				.075-.180	7.0	181	2241	19	101	15251	<5	<5	44	6	116	9	101	675	20	<5	98 69	<5	32	20	<5
				<.075	4.1	257	3883	31	173	24568	13	11	55	8	163	15	146	1127	22	<5	164 78	<5	39	29	12
A_3	0.5	BROWN WEAKLY STRUCTURED SOILS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ GRAINS ; MINOR IRON OXIDES; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		147	1683	16	41	14115	<5	<5	27	<5	91	8	67	337	13	<5	78 38	<5	32	10	<5
				>2	8.9	98	1135	16	32	8763	<5	<5	35	<5	84	7	44	216	10	<5	51 38	<5	24	13	<5
				.425-2	41.0	111	1172	13	29	11529	<5	<5	31	<5	77	8	41	227	12	<5	48 52	<5	27	8	<5
				.180-.425	33.5	152	2221	19	56	20534	<5	<5	32	<5	104	8	78	466	17	<5	110 43	<5	30	10	<5
				.075-.180	9.5	173	3284	21	84	25684	9	6	48	7	121	10	111	598	21	<5	138 67	<5	33	19	6
				<.075	7.1	242	3973	32	117	29528	12	14	69	11	181	17	138	1028	23	<5	171 53	<5	41	36	13
B_1	0.9	REDDISH - BROWN WEAKLY STRUCTURED SOILS.	QUARTZ (ROUNDED AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		158	1783	16	48	14536	<5	<5	42	<5	94	8	63	401	13	<5	75 41	<5	36	14	<5
				>2	12.9	112	1256	15	34	9567	<5	<5	31	<5	87	6	48	225	11	<5	38 31	<5	31	16	<5
				.425-2	43.5	117	1285	13	36	11983	<5	<5	34	<5	81	7	49	245	11	<5	51 22	<5	30	10	<5
				.180-.425	28.6	161	2273	18	79	21467	6	<5	51	<5	107	8	74	601	17	<5	114 59	<5	35	16	<5
				.075-.180	9.5	199	3392	22	91	27826	12	7	55	8	138	11	101	678	20	<5	151 55	<5	37	21	7
				<.075	5.5	251	4085	34	123	30548	19	14	77	14	186	17	131	980	24	<5	182 62	<5	41	38	12
B_2(T	1.6	REDDISH APEDAL B HORIZON. GRADING OCCUR INTO THE PEBBLE LAYER. (ZONE OF ILLUVIATION)	QUARTZ (ROUNDED AND SUBANGULAR); NO FELDSPAR AND BIOTITE; KAOLINITE AND OTHER MIXED LAYERED CLAY MINERALS. H.M. - MAG, ILM, LIM, GH, HEM AND ZR.	TOTAL		158	1792	16	52	15684	6	<5	46	8	97	8	54	327	14	<5	81 44	<5	39	17	<5
				>2	14.9	89	1183	16	41	14843	<5	<5	58	<5	86	8	39	206	12	<5	39 39	<5	30	15	<5
				.425-2	49.1	120	1357	14	39	12763	<5	<5	49	<5	85	7	37	228	11	<5	45 41	<5	32	16	<5
				.180-.425	25.4	181	2385	20	88	25152	8	<5	51	7	114	9	82	424	18	<5	115 55	<5	34	19	<5
				.075-.180	6.3	203	3452	22	112	34518	15	9	71	11	141	11	91	595	21	<5	158 51	<5	41	22	7
				<.075	4.3	267	4133	35	144	38562	24	17	92	19	199	18	123	880	25	<5	184 48	<5	44	41	14
P	2.2	HORIZON MARKED BY ROUNDED QUARTZ PEBBLES AND GOETHITE PELLETS. GRADING OCCUR INTO THE B_2 HORIZON.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES AND GRAINS STAINED WITH IRON OXIDES; GOETHITE PELLETS; MINOR CLAY MINERALS; NO FELDSPAR AND BIOTITE. H.M. - GH, HEM, MAG, ILM AND ZR,	TOTAL		164	1827	17	67	17549	7	<5	31	<5	91	6	57	452	16	<5	72 62	<5	37	17	<5
				>2	50.3	103	1356	15	35	10156	<5	<5	42	<5	87	<5	41	267	13	<5	20 39	<5	29	16	<5
				.425-2	30.1	145	2082	16	58	16396	6	<5	37	<5	87	6	65	328	14	<5	58 33	<5	32	14	<5
				.180-.425	11.4	198	3467	21	94	27516	9	8	39	9	104	7	99	650	22	<5	137 46	<5	32	18	<5
				.075-.180	5.4	210	3683	21	123	35841	17	13	56	11	124	9	117	787	25	<5	142 68	<5	36	22	7
				<.075	2.8	215	4291	34	156	41567	26	17	71	17	179	12	131	940	28	<5	166 82	<5	41	40	12

Description, mineralogy and trace element geochemistry of weathering profile 20. (Nature of underlying rocks unknown - probably Makhutso Granite.)

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	GEOCHEMICAL DATA (PPM)																				
						P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
		DARK BROWN, ORGANIC	ALMOST ONLY ROUNDED AND SUBANGULAR	TOTAL		122	1377	<5	119	9092	<5	<5	7	<5	93	6	46	364	10	<5	50	103	<5	29	17	<5
		RICH, ORTHIC A	QUARTZ GRAINS (SLIGHTLY STAINED WITH	>2	12.7	95	826	12	83	8847	<5	<5	<5	<5	65	5	29	223	7	<5	34	42	<5	45	<5	<5
A_1	0.15	HORIZON WITH WEAKLY	IRON OXIDES); NO FELDSPAR AND BIOTITE;	.425-2	48.4	117	1200	<5	88	7004	<5	<5	7	<5	75	5	37	271	10	<5	44	87	<5	26	7	<5
		STRUCTURED SOILS.	MINOR KAOLINITE AND OTHER CLAY	.180-.425	26.7	203	2082	<5	147	14072	<5	<5	7	<5	131	8	56	414	12	<5	96	96	<5	36	17	<5
			MINERALS. H.M- GH, HEM, MAG, ILM,	.075-.180	7.9	240	2635	<5	186	16086	6	<5	14	<5	139	11	98	832	19	<5	126	188	<5	31	29	6
			LIM AND ZR.	<.075	4.1	301	4073	17	260	24479	16	<5	32	16	183	19	138	1209	29	<5	209	143	<5	35	47	14
		LIGHT COLOURED, LOOSE	ALMOST ONLY ROUNDED AND SUBANGULAR	TOTAL		109	1257	8	111	12589	<5	<5	13	9	106	9	48	350	13	<5	53	198	<5	29	17	<5
		STRUCTURED, HORIZON OF	QUARTZ GRAINS; NO FELDSPAR AND	>2	18.2	68	493	11	103	15037	<5	<5	35	<5	55	<5	22	144	6	<5	9	176	<5	25	5	<5
A_2(E	0.3	MAXIMUM ELUVIATION.	BIOTITE; TRACES OF KAOLINITE AND	.425-2	50.8	107	1045	<5	98	8924	<5	<5	11	7	67	<5	28	213	9	<5	32	60	<5	20	6	<5
			OTHER CLAY MINERALS. H.M.- GH, MAG,	.180-.425	20.9	203	2169	12	139	19113	<5	<5	19	13	139	10	66	473	15	<5	92	209	<5	33	24	<5
			ILM, LIM AND ZR.	.075-.180	6.8	205	2575	8	163	19583	7	<5	21	15	142	11	99	803	20	<5	117	191	<5	30	32	7
				<.075	3.7	261	3953	21	208	28675	14	16	30	22	186	16	136	1185	28	<5	178	124	<5	35	47	13
		ZONE MARKED BY QUARTZ	MAINLY ROUNDED AND SUBANGULAR QUARTZ	TOTAL		122	1377	10	89	12589	<5	<5	13	<5	86	6	43	326	11	<5	78	201	<5	30	12	<5
		PEBBLES, ROCK DEBRIS	PEBBLES; GOETHITE PELLETS; MINOR	>2	45.2	75	417	24	54	19023	<5	<5	9	<5	29	<5	14	104	5	<5	<5	37	<5	18	<5	<5
P	0.45	AND IRON OXIDES.	KAOLINITE, ILLITE AND OTHER MIXED	.425-2	32.1	83	869	<5	85	6911	<5	<5	<5	<5	58	<5	25	186	6	<5	31	58	<5	28	<5	<5
			LAYERED CLAYS; NO FELDSPAR AND	.180-.425	13.6	202	2378	10	122	20408	8	<5	21	9	142	7	64	448	15	<5	99	185	<5	34	20	<5
			BIOTITE. H.M.- GH, HEM, MAG, ILM,	.075-.180	5.5	244	2995	22	148	25178	14	<5	30	14	166	10	106	817	19	<5	135	144	<5	33	35	7
			LIM AND ZR.	<.075	3.6	283	3953	33	193	35668	27	13	38	20	203	14	127	1006	24	<5	184	96	<5	47	47	11
		RED SOFT PLINTIC B	QUARTZ (ANGULAR AND SUBANGULAR)	TOTAL		126	2017	15	119	32478	9	<5	24	14	99	6	53	372	15	<5	98	40	<5	22	19	<5
		HORIZON WHICH STILL	STAINED WITH IRON OXIDES; NO FRESH	>2	38.2	71	893	12	98	44201	<5	<5	29	<5	98	<5	21	139	8	<5	71	23	<5	15	5	<5
B_2(R	0.9	PRESERVES THE GRANITIC	FELDSPAR OR BIOTITE; ENRICHED IN	.425-2	36.4	99	1856	11	114	32142	<5	<5	39	12	180	<5	45	313	11	<5	98	48	<5	28	14	<5
		STRUCTURE. (ZONE OF	KAOLINITE, ILLITE AND OTHER CLAY	.180-.425	11.2	110	3049	21	163	43172	14	6	45	24	173	10	85	572	18	<5	131	54	<5	39	33	<5
		ILLUVIATION).	MINERALS; IRON OXIDES. H.M.- HEM,	.075-.180	6.3	115	3534	28	163	42970	17	15	38	28	186	11	110	803	23	<5	151	57	<5	37	42	9
			GH, MAG, ILM, CAS, LIM AND ZR.	<.075	7.9	132	4133	44	200	51231	28	28	63	46	224	13	121	844	30	<5	176	52	<5	34	54	12
		WHITISH-GREY HORIZON	QUARTZ (ANGULAR AND SUBANGULAR);	TOTAL		78	1936	15	119	29473	11	<5	43	10	212	8	55	356	19	<5	110	36	<5	27	27	<5
		CONTAINING MUCH CLAY	ALTERED FELDSPAR AND BIOTITE;	>2	39.4	58	1389	26	135	37481	10	<5	31	<5	143	<5	36	194	12	<5	71	30	<5	31	18	<5
B_3	1.2	MINERALS. THE GRANITIC	WHITE CONCRETIONS OF MAINLY	.425-2	36.2	78	2027	10	106	30284	8	<5	42	9	217	7	48	271	18	<5	111	44	<5	26	23	<5
		STRUCTURE IS STILL PRE	KAOLINITE. H.M. - MAG, ILM, LIM,	.180-.425	10.2	96	2935	19	163	38461	18	<5	61	19	330	11	71	402	26	<5	162	51	<5	35	40	<5
		SERVED.	GH, HEM CAS, AND ZR.	.075-.180	6.9	109	2995	25	178	38362	17	<5	53	13	273	11	89	596	26	<5	173	57	<5	38	42	<5
				<.075	7.3	96	3893	29	186	45252	27	12	88	32	288	11	131	698	36	<5	158	49	<5	28	55	7
		BROWN WEATHERED	QUARTZ; KAOLINISED, ILLITISED AND	TOTAL		82	1557	10	141	22380	5	<5	47	33	406	13	71	203	25	<5	156	52	<5	36	45	<5
		BEDROCK.	HEMATITISED FELDSPARS; CHLORITISED	>2	42.2	55	820	<5	122	14939	<5	<5	21	12	322	10	44	129	10	<5	134	20	<5	50	23	<5
C	2.3	(UNCONSOLIDATED).	AND HEMATITISED BIOTITE. H.M.- HEM,	.425-2	36.8	83	1710	6	139	24157	<5	<5	49	34	429	14	69	161	22	<5	221	25	<5	52	40	<5
			MAG, CAS, ILM AND ZR.	.180-.425	10.7	87	2875	17	208	41264	22	17	93	72	440	14	108	310	48	<5	225	47	<5	56	96	<5
				.075-.180	5.5	96	2875	25	230	46859	27	21	100	77	401	13	143	424	47	<5	189	63	<5	55	98	6
				<.075	4.8	96	2875	24	238	48958	32	22	103	78	390	12	138	412	44	<5	186	44	<5	54	97	9
		SLIGHTLY WEATHERED	QUARTZ; SERICITISED AND KAOLINISED																							
		MAKHUTSO GRANITE.	POTASH FELDSPAR AND PLAGIOCLASE;																							
R	2.3		THE BIOTITE IS CHLORITISED.			109	508	<5	264	11783	<5	<5	65	30	463	43	83	160	21	<5	332	29	<5	35	37	9
			H.M. - MAG, ILM, HEM AND ZR.																							

Description, mineralogy and trace element geochemistry of weathering profile 21 on the reddish Makhutso Granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
						GEOCHEMICAL DATA (PPM)																				
A_1	0.2	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		119	1343	16	132	11297	<5	<5	7	5	142	11	56	392	12	<5	213	309	<5	44	21	5
				>2	11.3	88	843	9	84	5661	<5	<5	<5	<5	86	6	30	209	8	<5	75	39	<5	37	5	<5
				.425-2	52.1	135	1408	10	116	10161	<5	<5	7	6	135	9	43	305	12	<5	118	93	<5	36	14	<5
				.180-.425	24.4	195	2062	5	149	13176	<5	<5	5	<5	175	11	59	417	13	<5	156	100	<5	45	23	<5
				.075-.180	7.5	196	1988	10	156	14809	<5	<5	7	6	162	13	94	711	17	<5	155	122	<5	36	30	9
				<.075	4.7	253	3927	11	233	19056	13	<5	16	9	190	19	154	1313	30	<5	233	122	<5	42	49	17
A_2(E	0.4	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		113	1428	8	87	9602	<5	<5	<5	<5	132	8	52	340	11	<5	118	163	<5	40	16	<5
				>2	16.6	78	707	7	80	8424	<5	<5	<5	<5	68	6	30	176	8	<5	42	33	<5	32	7	<5
				.425-2	49.8	104	1215	11	110	9469	<5	<5	<5	<5	124	7	46	293	9	<5	99	130	<5	38	14	<5
				.180-.425	24.3	204	2421	16	154	21296	6	<5	15	15	185	12	81	513	18	<5	208	132	<5	41	31	6
				.075-.180	5.4	203	2498	14	135	18349	8	<5	13	6	167	11	102	761	19	<5	176	97	<5	37	33	9
				<.075	3.9	252	3765	27	230	29316	13	14	23	20	197	18	153	1208	28	<5	219	77	<5	45	55	20
P	0.8	ZONE MARKED BY QUARTZ PEBBLES, ROCK DEBRIS AND IRON OXIDES.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES; GOETHITE PELLETS; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		143	1548	16	105	15114	5	<5	13	12	119	9	58	367	11	<5	96	170	<5	43	20	5
				>2	55.4	80	818	9	66	7168	<5	<5	<5	<5	51	<5	25	160	7	<5	65	40	<5	37	5	<5
				.425-2	23.4	163	1752	14	132	16937	<5	<5	14	12	120	8	48	301	12	<5	113	202	<5	33	16	<5
				.180-.425	8.4	229	3330	21	144	27556	17	5	28	19	198	12	92	604	22	<5	261	131	<5	38	37	6
				.075-.180	6.4	276	3566	31	177	33284	17	17	29	31	199	14	127	871	26	<5	210	96	<5	48	48	13
				<.075	6.4	222	3776	38	192	34323	26	16	33	25	206	14	133	952	28	<5	202	70	<5	48	52	12
B_2(R	1.2	RED SOFT PLINTIC B HORIZON WHICH STILL PRESERVES THE GRANITIC STRUCTURE. (ZONE OF ILLUVIATION).	QUARTZ (ANGULAR AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; ENRICHED IN KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		180	2269	14	147	19235	10	<5	19	9	138	8	74	479	17	<5	134	34	<5	41	28	5
				>2	37.5	109	1062	13	123	14244	<5	<5	10	5	100	6	38	205	11	<5	67	25	<5	47	13	<5
				.425-2	32.2	200	2695	15	153	24420	12	<5	24	14	167	9	81	499	19	<5	154	35	<5	46	32	5
				.180-.425	16.5	226	3462	24	188	32801	16	13	32	30	213	12	103	636	25	<5	231	35	<5	50	50	10
				.075-.180	8.6	268	3566	27	202	33347	20	9	29	20	205	11	122	827	25	<5	192	48	<5	55	48	11
				<.075	5.2	281	4190	36	219	41068	28	27	47	45	228	14	135	917	32	<5	203	29	<5	45	63	13
B_3 + C	1.7	WHITISH-GREY HORIZON CONTAINING MUCH CLAY MINERALS. THE GRANITIC STRUCTURE IS STILL PRESERVED.	QUARTZ (ANGULAR AND SUBANGULAR); ALTERED FELDSPAR AND BIOTITE; GREYISH MATRIX OF PREDOMINANTLY KAOLINITE. H.M. - MAG, ILM, LIM, GH AND ZR.	TOTAL		149	2239	14	150	14423	6	<5	26	23	158	12	71	418	18	<5	159	28	<5	71	31	8
				>2	44.8	71	1161	7	114	10174	<5	<5	<5	<5	99	5	40	229	9	<5	81	25	<5	57	12	<5
				.425-2	32.3	158	2643	17	129	21220	10	<5	21	20	189	11	81	455	20	<5	167	27	<5	49	36	5
				.180-.425	10.6	179	3606	23	133	27256	21	9	36	29	226	12	110	631	26	<5	197	30	<5	52	49	7
				.075-.180	7.0	199	3552	25	153	27538	17	14	32	32	210	13	134	846	28	<5	174	46	<5	49	55	12
				<.075	5.3	187	4219	27	183	34345	28	15	30	22	218	13	149	1025	30	<5	222	26	<5	71	60	13
R	1.8	HIGHLY WEATHERED BEDROCK.	QUARTZ; KAOLINISED, SERICITISED AND HEMATITISED FELDSPARS; CHLORITISED AND HEMATITISED BIOTITE. H.M.- HEM, MAG AND ZR.			135	806	<5	148	8890	<5	<5	<5	<5	420	45	85	186	23	<5	258	16	<5	48	38	9

Description, mineralogy and trace element geochemistry of weathering profile 22 on grey Makhutso Granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
						GEOCHEMICAL DATA (PPM)																				
		DARK BROWN, ORGANIC	ALMOST ONLY ROUNDED AND SUBANGULAR	TOTAL		107	1263	7	57	14526	<5	<5	<5	<5	56	7	43	316	10	<5	47	21	<5	37	15	<5
		RICH, ORTHIC A	QUARTZ GRAINS (SLIGHTLY STAINED WITH	>2	6.2	141	1664	16	78	13336	<5	<5	<5	<5	82	8	57	414	11	<5	74	5	<5	46	17	<5
A_1	0.2	HORIZON WITH WEAKLY	IRON OXIDES); NO FELDSPAR AND BIOTITE;	.425-2	56.7	117	1167	9	36	7558	<5	<5	<5	<5	58	6	35	255	9	<5	43	77	<5	34	10	<5
		STRUCTURED SOILS.	MINOR KAOLINITE AND OTHER CLAY	.180-.425	27.2	181	1834	13	76	13015	<5	<5	<5	<5	95	8	51	349	13	<5	86	71	<5	33	18	<5
			MINERALS. H.M- GH, HEM, MAG, ILM,	.075-.180	6.3	178	1938	17	100	13310	<5	<5	<5	<5	97	9	77	624	16	<5	95	75	<5	34	23	<5
			LIM AND ZR.	<.075	3.6	292	3682	33	203	23995	14	8	12	8	140	19	132	1136	25	<5	185	22	<5	56	44	16
		LIGHT COLOURED, LOOSE	ALMOST ONLY ROUNDED AND SUBANGULAR	TOTAL		110	1359	18	67	13855	<5	<5	<5	<5	78	8	48	337	12	<5	51	22	<5	41	18	<5
		STRUCTURED, HORIZON OF	QUARTZ GRAINS; NO FELDSPAR AND	>2	4.2	95	1085	13	34	11307	<5	<5	<5	<5	61	8	43	283	9	<5	26	8	<5	43	14	5
A_2(E	0.3	MAXIMUM ELUVIATION.	BIOTITE; TRACES OF KAOLINITE AND	.425-2	54.8	118	1168	16	55	11161	<5	<5	<5	<5	59	6	35	242	9	<5	33	26	<5	38	10	<5
			OTHER CLAY MINERALS. H.M.- GH, MAG,	.180-.425	30.8	168	1835	16	65	15595	5	<5	<5	7	99	8	53	357	14	<5	68	86	<5	31	22	<5
			ILM, LIM AND ZR.	.075-.180	6.8	186	2299	21	104	19718	8	<5	<5	8	110	10	87	681	19	<5	88	77	<5	38	30	8
				<.075	3.4	279	3727	41	172	29520	18	13	14	20	150	16	130	1031	24	<5	157	8	<5	47	46	14
		BROWN WEAKLY	MAINLY ROUNDED AND SUBANGULAR QUARTZ	TOTAL		113	1609	19	30	13302	<5	<5	<5	<5	81	6	51	340	11	<5	57	20	<5	44	17	<5
		STRUCTURED	GRAINS; MINOR IRON OXIDES; MINOR	>2	7.6	64	792	14	20	7937	<5	<5	<5	<5	39	<5	27	189	8	<5	17	9	<5	28	6	<5
A_3	0.5	SOILS.	KAOLINITE, ILLITE AND OTHER MIXED	.425-2	54.2	84	1036	11	20	7526	<5	<5	<5	>5	50	<5	28	185	7	<5	22	32	<5	30	6	<5
			LAYERED CLAYS; NO FELDSPAR AND	.180-.425	27.4	158	2210	21	47	19590	8	<5	7	<5	114	7	65	431	15	<5	87	44	<5	38	24	<5
			BIOTITE. H.M.- GH, HEM, MAG, ILM,	.075-.180	6.7	209	3100	26	73	26875	13	<5	13	9	131	9	90	643	19	<5	118	28	<5	42	34	6
			LIM AND ZR.	<.075	4.1	215	3907	38	104	30627	24	14	23	17	157	12	120	914	26	<5	141	20	<5	42	47	11
		REDDISH - BROWN	QUARTZ (ROUNDED AND SUBANGULAR)	TOTAL		119	1520	18	35	13902	<5	<5	<5	<5	80	6	47	331	11	<5	53	24	<5	40	16	<5
		WEAKLY STRUCTURED	STAINED WITH IRON OXIDES; NO FRESH	>2	5.8	69	802	15	23	8201	<5	<5	<5	<5	41	<5	26	191	7	<5	11	12	<5	27	7	<5
B_1	0.6	SOILS.	FELDSPAR OR BIOTITE;	.425-2	51.9	92	1136	13	22	7724	<5	<5	<5	<5	54	<5	25	201	8	<5	22	45	<5	31	7	<5
			KAOLINITE, ILLITE AND OTHER CLAY	.180-.425	29.8	163	2214	22	51	20562	7	7	9	7	119	7	59	428	15	<5	91	71	<5	36	25	<5
			MINERALS; IRON OXIDES. H.M.- HEM,	.075-.180	7.7	211	3192	25	77	27321	14	7	15	14	136	7	83	642	19	<5	120	69	<5	43	34	7
			GH, MAG, ILM, LIM AND ZR.	<.075	4.8	221	3911	40	111	31562	24	15	24	22	162	11	117	825	25	<5	155	32	<5	42	51	12
		REDDISH APEDAL B	QUARTZ (ROUNDED AND SUBANGULAR);	TOTAL		109	1429	15	40	15799	6	<5	<5	<5	75	7	46	304	11	<5	47	26	<5	35	16	<5
		HORIZON. GRADING	NO FELDSPAR AND BIOTITE;	>2	14.3	74	903	17	20	14634	<5	<5	<5	<5	47	<5	30	202	10	<5	9	25	<5	28	9	<5
B_2(T	0.9	OCCUR INTO THE	KAOLINITE AND OTHER MIXED LAYERED	.425-2	53.7	100	1111	12	25	11312	<5	<5	<5	>5	55	<5	32	209	9	<5	23	32	<5	23	10	<5
		PEBBLE LAYER.	CLAY MINERALS. H.M. - MAG, ILM, LIM,	.180-.425	21.9	195	2428	25	68	25400	11	<5	16	19	121	9	69	427	18	<5	95	79	<5	35	29	6
		(ZONE OF	GH, HEM AND ZR.	.075-.180	6.3	245	3282	39	93	34139	17	19	23	25	143	11	93	644	21	<5	127	19	<5	43	39	9
		ILLUVIATION)		<.075	3.8	259	3891	49	127	40245	25	26	28	35	166	13	117	791	25	<5	164	<5	<5	51	50	13
		HORIZON MARKED BY	MAINLY ROUNDED AND SUBANGULAR	TOTAL		134	1883	22	40	18294	7	<5	10	<5	72	5	51	387	15	<5	51	28	<5	35	20	<5
		ROUNDED QUARTZ	QUARTZ PEBBLES AND GRAINS STAINED	>2	54.3	66	706	11	20	41540	<5	<5	<5	<5	29	<5	20	131	13	<5	<5	16	<5	52	<5	<5
P	1.5	PEBBLES AND	WITH IRON OXIDES; GOETHITE PELLETS;	.425-2	22.9	129	2003	22	47	17803	9	<5	10	<5	81	5	55	371	15	<5	57	24	<5	38	21	<5
		GOETHITE PELLETS.	MINOR CLAY MINERALS; NO FELDSPAR	.180-.425	11.8	213	3663	35	100	34832	23	12	28	21	144	8	95	629	25	<5	126	25	<5	46	43	8
		GRADING OCCUR INTO	AND BIOTITE. H.M. - GH, HEM,	.075-.180	6.7	230	3941	38	115	36997	23	15	27	18	142	9	105	747	26	<5	123	32	<5	50	44	8
		THE B_2 HORIZON.	MAG, ILM AND ZR,	<.075	4.3	231	4325	55	136	40718	29	18	31	23	153	10	114	831	27	<5	147	<5	<5	55	51	11
		BROWN HORIZON	MAINLY QUARTZ;	TOTAL		134	1889	21	82	24155	9	<5	10	10	81	6	59	379	16	<5	74	20	<5	38	24	5
		OF HIGHLY	ALTERED FELDSPAR	>2	47.9	91	1092	19	40	14444	<5	<5	<5	<5	43	<5	34	209	11	<5	24	12	<5	30	13	<5
C	1.9	WEATHERED BEDROCK.	AND BIOTITE; H.M - MAG, ILM,	.425-2	28.5	133	2082	26	78	21120	7	<5	10	9	89	7	58	371	16	<5	61	22	<5	31	25	<5
			HEM AND ZR.	.180-.425	11.3	186	3673	40	146	37566	20	20	29	28	168	10	104	649	28	<5	127	25	<5	49	49	10
				.075-.180	6.5	200	3846	45	156	39279	19	21	27	27	146	10	113	773	27	<5	129	25	<5	46	50	11
				<.075	5.8	194	4161	54	171	42122	27	29	26	26	157	11	123	830	29	<5	139	<5	<5	54	56	12

Description, mineralogy and trace element geochemistry of weathering profile 23 on grey Makhutso Granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
A_1	0.3	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		80	1194	18	49	11652	<5	<5	<5	<5	55	10	41	334	9	<5	46	20	<5	21	11	<5
				>2	6.3	111	1615	15	69	9567	<5	<5	21	<5	78	11	52	426	9	<5	69	6	<5	32	12	<5
				.425-2	45.7	87	1104	8	32	6953	<5	<5	12	<5	61	8	34	271	7	<5	39	69	<5	20	8	<5
				.180-.425	32.9	134	1767	10	62	10528	<5	<5	18	<5	99	10	49	362	10	<5	78	66	<5	19	14	<5
				.075-.180	8.1	137	1843	16	89	10752	<5	<5	19	<5	97	11	75	651	12	<5	94	69	<5	21	17	<5
				<.075	7.6	212	3591	29	194	18674	7	<5	30	7	131	21	129	1209	21	<5	207	20	<5	43	35	12
A_2(E)	0.5	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		83	1219	17	61	10568	<5	<5	15	<5	52	9	43	368	9	<5	42	21	<5	19	13	<5
				>2	7.4	75	1017	14	31	9267	<5	<5	22	<5	66	10	39	302	8	<5	34	7	<5	21	9	<5
				.425-2	43.1	88	1147	10	47	9487	<5	<5	13	<5	62	8	35	272	8	<5	36	31	<5	19	7	<5
				.180-.425	34.9	123	1752	15	58	11521	<5	<5	17	<5	93	9	50	383	11	<5	59	81	<5	17	13	<5
				.075-.180	8.2	139	2237	19	84	15461	<5	<5	20	6	94	10	81	711	12	<5	78	69	<5	22	20	7
				<.075	6.4	198	3751	39	154	23812	8	6	32	12	136	18	131	1211	20	<5	164	15	<5	37	36	12
A_3	0.7	BROWN WEAKLY STRUCTURED SOILS.	MAINLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; MINOR IRON OXIDES; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		87	1486	19	51	10782	<5	<5	16	<5	61	11	49	351	10	<5	49	20	<5	23	12	<5
				>2	9.2	67	1025	15	35	8563	<5	<5	23	<5	69	9	31	202	8	<5	29	9	<5	15	5	<5
				.425-2	40.4	77	1068	10	42	9651	<5	<5	15	<5	71	8	33	195	8	<5	34	34	<5	19	6	<5
				.180-.425	35.2	124	2154	18	51	15421	<5	<5	18	<5	109	10	59	445	11	<5	75	55	<5	21	14	<5
				.075-.180	8.1	166	2967	24	86	21861	6	<5	22	7	116	12	88	649	15	<5	113	31	<5	24	21	5
				<.075	7.1	189	3791	38	139	24592	10	7	33	14	148	22	119	1098	23	<5	167	19	<5	38	35	10
B_1	0.9	REDDISH - BROWN WEAKLY STRUCTURED SOILS.	QUARTZ (ROUNDED AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		95	1501	18	40	11516	<5	<5	18	<5	74	11	48	339	11	<5	50	15	<5	23	12	<5
				>2	10.2	81	956	14	27	8674	<5	<5	25	<5	70	8	28	189	7	<5	19	9	<5	16	6	<5
				.425-2	38.1	87	1093	12	27	8951	<5	<5	14	<5	69	8	23	199	9	<5	24	41	<5	18	6	<5
				.180-.425	35.4	141	2056	19	49	16567	<5	<5	19	<5	111	10	61	418	12	<5	88	61	<5	23	14	<5
				.075-.180	8.2	172	3092	23	78	22526	6	6	26	8	121	14	77	637	15	<5	119	59	<5	24	22	6
				<.075	7.1	191	3854	39	114	25848	12	7	37	15	161	24	117	951	23	<5	166	22	<5	37	37	11
B_2(T)	1.2	REDDISH APEDAL B HORIZON. GRADING OCCUR INTO THE PEBBLE LAYER. (ZONE OF ILLUVIATION)	QUARTZ (ROUNDED AND SUBANGULAR); NO FELDSPAR AND BIOTITE; KAOLINITE AND OTHER MIXED LAYERED CLAY MINERALS. H.M. - MAG, ILM, LIM, GH, HEM AND ZR.	TOTAL		94	1521	18	45	12984	<5	<5	20	<5	79	12	49	306	11	<5	49	24	<5	24	13	<5
				>2	11.4	82	941	17	24	10102	<5	<5	26	<5	57	9	32	214	9	<5	16	17	<5	18	7	<5
				.425-2	37.4	91	1010	11	29	9471	<5	<5	15	<5	65	9	29	206	8	<5	21	29	<5	17	8	<5
				.180-.425	36.1	152	1976	24	71	19184	<5	<5	21	6	117	11	61	434	14	<5	89	68	<5	23	15	<5
				.075-.180	8.6	191	3152	36	89	27456	7	7	29	12	132	16	89	672	17	<5	121	77	<5	26	24	8
				<.075	6.5	205	3876	45	117	32894	14	12	41	24	154	27	118	846	23	<5	172	10	<5	41	37	11
P	1.9	HORIZON MARKED BY ROUNDED QUARTZ PEBBLES AND GOETHITE PELLETS. GRADING OCCUR INTO THE B_2 HORIZON.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES AND GRAINS STAINED WITH IRON OXIDES; GOETHITE PELLETS; MINOR CLAY MINERALS; NO FELDSPAR AND BIOTITE. H.M. - GH, HEM, MAG, ILM AND ZR.	TOTAL		111	1914	20	47	15672	<5	<5	29	<5	69	12	50	372	13	<5	47	31	<5	26	15	<5
				>2	51.6	67	956	10	28	9846	<5	<5	27	<5	38	9	25	151	12	<5	<5	17	<5	13	6	<5
				.425-2	26.2	105	2052	19	46	15216	<5	<5	14	<5	61	8	49	392	14	<5	48	29	<5	21	13	<5
				.180-.425	8.6	151	3267	30	91	27814	7	<5	19	7	129	10	89	672	19	<5	119	24	<5	40	32	<5
				.075-.180	7.5	163	3756	35	111	31469	8	6	27	10	131	16	98	771	21	<5	118	64	<5	42	33	7
				<.075	6.1	178	4084	52	129	33512	16	9	39	16	146	25	113	904	24	<5	155	7	<5	43	38	10
PAL-COL	2.3	BROWN HORIZON OF WEAKLY STRUCTURED SOILS.	MAINLY QUARTZ (ROUNDED AND SUBANGULAR); NO FELDSPAR OR BIOTITE; KAOLINITE AND MIXED LAYERED CLAY MINERALS; IRON OXIDES. H.M. - MAG, ILM, HEM AND ZR.	TOTAL		121	1656	17	71	12942	6	<5	23	<5	80	12	51	351	12	<5	44	36	<5	24	13	<5
				>2	12.2	81	1026	14	42	9572	<5	<5	27	<5	62	10	31	297	10	<5	36	27	<5	21	7	<5
				.425-2	39.2	121	1543	11	53	10431	<5	<5	17	<5	64	9	52	285	10	<5	41	28	<5	22	8	<5
				.180-.425	33.3	173	1954	16	55	16519	6	<5	24	6	116	12	94	401	18	<5	51	47	<5	31	17	6
				.075-.180	8.1	198	3156	20	81	24678	7	6	31	9	124	16	101	676	20	<5	81	85	<5	33	26	8
				<.075	7.2	238	3985	41	149	27819	14	11	49	16	161	28	118	1152	25	<5	174	27	<5	42	37	10

Description, mineralogy and trace element geochemistry of weathering profile 24. (Nature of underlying rocks unknown).

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	GEOCHEMICAL DATA (PPM)																				
						P	TI	V	Mn	Fe	Co	NI	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
A_1	0.1	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		145	1705	13	187	11323	<5	<5	7	<5	213	16	55	467	20	<5	209	172	<5	23	20	<5
				>2	25.5	87	839	6	127	6595	<5	<5	16	<5	167	8	25	181	11	<5	83	768	<5	45	7	<5
				.425-2	37.2	148	1457	<5	164	17098	<5	<5	<5	<5	112	13	41	336	15	<5	180	76	<5	33	18	<5
				.180-.425	18.9	238	2313	12	238	13634	<5	65	11	6	222	22	68	544	24	<5	333	198	<5	42	35	<5
				.075-.180	11.5	355	2778	8	287	13759	<5	<5	11	6	216	24	91	849	24	<5	363	139	<5	29	33	7
				<.075	6.9	363	4055	20	403	18535	6	5	12	7	226	34	164	1649	35	<5	403	109	<5	42	48	21
A_2(E)	0.2	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		121	1399	20	110	9876	<5	<5	7	<5	113	16	59	466	19	<5	193	200	<5	20	20	<5
				>2	22.2	96	654	10	109	7021	<5	<5	17	<5	143	18	22	231	10	<5	171	631	<5	19	6	<5
				.425-2	40.5	139	1212	6	114	7134	<5	<5	<5	<5	206	12	47	319	16	<5	195	98	<5	23	7	<5
				.180-.425	17.5	201	2256	14	141	12300	<5	<5	6	6	283	19	77	531	25	<5	301	201	<5	27	18	6
				.075-.180	11.9	197	2273	14	142	12101	<5	<5	13	7	251	17	98	782	26	<5	273	153	<5	21	21	7
				<.075	7.9	239	3798	21	183	19536	10	9	16	9	273	23	163	1390	39	<5	331	121	<5	23	37	15
P	0.4	ZONE MARKED BY QUARTZ PEBBLES, ROCK DEBRIS AND IRON OXIDES.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES; GOETHITE PELLETS; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		126	1375	12	138	18262	<5	<5	20	15	252	12	49	322	18	<5	139	289	<5	33	20	<5
				>2	58.4	61	594	7	113	9274	<5	<5	7	<5	144	6	19	110	10	<5	27	222	<5	44	6	<5
				.425-2	19.4	113	1334	7	145	12169	<5	<5	13	8	113	12	43	287	17	<5	129	154	<5	32	21	7
				.180-.425	12.9	242	2637	11	202	23743	<5	<5	22	18	241	21	87	618	23	<5	321	154	<5	48	41	8
				.075-.180	5.5	251	3019	22	182	23990	9	84	29	24	234	21	115	953	27	<5	304	170	<5	33	38	11
				<.075	3.8	293	4039	26	225	29591	17	19	45	37	252	25	159	1331	35	<5	336	133	<5	31	51	17
B_2(R)	0.7	RED SOFT PLINTIC B HORIZON WHICH STILL PRESERVES THE GRANITIC STRUCTURE. (ZONE OF ILLUVIATION).	QUARTZ (ANGULAR AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; ENRICHED IN KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		137	1994	19	148	18376	8	5	24	6	152	14	63	450	21	<5	177	29	<5	38	32	10
				>2	45.5	79	1165	11	132	10110	<5	<5	9	<5	75	6	32	184	12	<5	84	29	<5	41	9	<5
				.425-2	33.2	149	2335	11	160	18646	6	<5	21	8	161	13	71	489	21	<5	218	29	<5	37	25	<5
				.180-.425	11.3	228	3572	21	177	29164	16	23	44	26	252	20	113	804	29	<5	346	37	<5	37	45	9
				.075-.180	5.9	248	3629	26	182	30252	16	25	40	23	240	19	127	996	28	<5	319	51	<5	28	43	11
				<.075	4.1	222	3971	32	214	34683	24	22	50	31	246	21	151	1141	31	<5	317	36	<5	31	53	14
B_3 + C	1.2	WHITISH-GREY HORIZON CONTAINING MUCH CLAY MINERALS. THE GRANITIC STRUCTURE IS STILL PRESERVED.	QUARTZ (ANGULAR AND SUBANGULAR); ALTERED FELDSPAR AND BIOTITE; GREYISH MATRIX OF PREDOMINANTLY KAOLINITE. H.M. - MAG, ILM, LIM, GH AND ZR.	TOTAL		102	1907	18	119	15763	8	<5	26	16	159	15	66	379	22	<5	183	28	<5	20	27	<5
				>2	38.8	85	1564	12	137	10213	<5	<5	14	8	112	11	52	261	17	<5	119	28	<5	41	20	6
				.425-2	37.7	129	2672	19	173	16485	7	5	30	21	202	19	79	447	25	<5	261	29	<5	40	33	6
				.180-.425	10.4	145	3369	35	169	22390	19	20	42	31	278	24	107	614	29	<5	328	39	<5	42	52	7
				.075-.180	6.8	148	3550	37	175	23163	16	22	51	37	265	23	125	873	32	<5	315	47	<5	32	55	10
				<.075	6.3	147	4196	37	194	28986	25	29	50	39	265	24	156	1143	38	<5	302	30	<5	34	62	15
R	1.5	HIGHLY WEATHERED BEDROCK.	QUARTZ; KAOLINISED, SERICITISED AND HEMATITISED FELDSPARS; CHLORITISED AND HEMATITISED BIOTITE. H.M.- HEM, MAG AND ZR.			120	1313	12	176	7225	<5	<5	<5	<5	362	66	110	225	16	<5	559	20	<5	61	26	5

Description, mineralogy and trace element geochemistry of weathering profile 25 on the grey Makhutso Granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
						GEOCHEMICAL DATA (PPM)																				
A_1	0.15	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		97	1754	16	308	14308	7	<5	<5	<5	151	19	58	524	20	<5	243	52	<5	52	27	6
				>2	14.7	44	730	5	10	3822	<5	<5	<5	<5	76	8	20	200	9	<5	104	17	<5	24	<5	<5
				.425-2	42.8	108	1413	6	61	9933	<5	<5	<5	<5	136	14	42	341	15	<5	199	52	<5	33	21	<5
				.180-.425	26.9	176	2603	11	86	15612	<5	<5	<5	<5	223	20	71	587	26	<5	337	97	<5	33	37	5
				.075-.180	10.3	166	2636	17	133	19385	9	<5	<5	<5	202	22	104	1050	28	<5	313	101	<5	35	37	10
				<.075	5.3	296	4058	20	232	22822	11	9	<5	8	219	30	166	1645	38	<5	390	63	<5	50	51	<5
A_2(E	0.3	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		86	1671	16	48	15263	<5	<5	<5	<5	151	16	61	497	20	<5	211	51	<5	36	32	7
				>2	18.3	48	698	7	131	6251	<5	<5	<5	<5	82	19	21	181	9	<5	190	29	<5	33	5	<5
				.425-2	50.8	93	1626	6	10	9306	<5	<5	<5	<5	143	12	48	402	17	<5	210	59	<5	25	18	<5
				.180-.425	21.8	148	2582	16	53	20200	<5	<5	<5	<5	224	20	80	645	26	<5	333	93	<5	40	41	6
				.075-.180	5.7	124	2609	12	40	16249	8	<5	<5	<5	191	17	101	1007	25	<5	294	94	<5	34	34	7
				<.075	5.2	203	4167	12	94	21417	13	<5	7	<5	212	24	169	1667	38	<5	351	71	<5	39	49	19
P	0.4	ZONE MARKED BY QUARTZ PEBBLES, ROCK DEBRIS AND IRON OXIDES.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES; GOETHITE PELLETS; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		66	1349	16	10	10436	<5	<5	<5	<5	128	11	43	373	14	<5	192	45	<5	21	16	<5
				>2	60.6	27	543	11	10	4125	<5	<5	<5	<5	61	6	13	131	8	<5	89	25	<5	14	<5	<5
				.425-2	19.0	63	1082	9	64	10632	<5	<5	<5	<5	107	11	33	267	13	<5	146	30	<5	42	10	<5
				.180-.425	10.3	126	2673	16	29	20327	8	<5	<5	<5	217	17	83	652	27	<5	325	124	<5	32	40	<5
				.075-.180	5.9	228	3473	26	94	35967	18	17	16	21	207	17	114	930	30	<5	274	72	<5	41	43	10
				<.075	4.2	220	3975	23	102	30513	18	15	20	20	225	22	153	1328	35	<5	333	59	<5	41	48	15
B_2(R	0.9	RED SOFT PLINTIC B HORIZON WHICH STILL PRESERVES THE GRANITIC STRUCTURE. (ZONE OF ILLUVIATION).	QUARTZ (ANGULAR AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; ENRICHED IN KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		93	1864	19	51	21624	14	<5	8	8	97	11	60	422	21	<5	119	31	<5	33	23	<5
				>2	51.2	81	1399	14	37	14933	9	<5	<5	<5	69	7	38	302	15	<5	95	22	<5	25	13	<5
				.425-2	29.3	122	2303	11	77	19809	12	<5	6	<5	128	10	61	464	20	<5	174	43	<5	33	21	<5
				.180-.425	8.1	180	3229	26	87	32927	19	13	15	18	207	17	103	775	30	<5	280	42	<5	36	46	7
				.075-.180	6.3	191	3590	17	99	30516	20	6	16	19	230	18	125	1072	32	<5	342	38	<5	43	42	10
				<.075	5.1	218	3889	37	109	39168	29	25	28	24	210	16	129	1186	30	<5	280	26	<5	44	46	14
B_3	1.4	WHITISH-GREY HORIZON CONTAINING MUCH CLAY MINERALS. THE GRANITIC STRUCTURE IS STILL PRESERVED.	QUARTZ (ANGULAR AND SUBANGULAR); ALTERED FELDSPAR AND BIOTITE; WHITE CONCRETIONS OF MAINLY KAOLINITE. H.M. - MAG, ILM, LIM, GH, HEM AND ZR.	TOTAL		94	1972	14	43	16007	10	<5	<5	<5	168	14	65	401	21	<5	280	30	<5	50	21	<5
				>2	36.4	71	1168	<5	47	9973	<5	<5	<5	<5	113	9	37	204	12	<5	181	13	<5	30	17	<5
				.425-2	34.1	97	1769	12	61	16594	6	<5	<5	<5	179	16	58	335	21	<5	296	33	<5	47	20	<5
				.180-.425	15.7	172	3594	15	74	27737	17	<5	14	9	256	18	110	708	33	<5	398	39	<5	45	43	6
				.075-.180	7.2	191	3590	17	89	27516	20	6	10	7	230	18	125	1002	32	<5	342	38	<5	43	42	10
				<.075	6.6	202	3977	32	102	32973	23	28	21	24	232	20	142	1037	35	<5	313	32	<5	44	50	13
C	1.5	BROWN WEATHERED BEDROCK. (UNCONSOLIDATED).	QUARTZ; KAOLINISED, ILLITISED AND HEMATITISED FELDSPARS; CHLORITISED AND HEMATITISED BIOTITE. H.M.- HEM, MAG, ILM AND ZR.			87	1710	6	154	14133	11	<5	<5	<5	303	58	140	265	29	<5	633	22	<5	51	35	<5
R	1.5	SLIGHTLY WEATHERED MAKHUTSO GRANITE.	QUARTZ; SERICITISED AND KAOLINISED POTASH FELDSPAR AND PLAGIOCLASE; THE BIOTITE IS CHLORITISED. H.M. - MAG, ILM, HEM AND ZR.			72	1407	<5	100	8890	<5	<5	<5	<5	348	83	211	227	27	<5	726	23	<5	29	35	6

Description, mineralogy and trace element geochemistry of weathering profile 26 on the grey Makhutso Granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	GEOCHEMICAL DATA (PPM)																				
						P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
A_1	0.15	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		115	1598	14	120	13043	<5	<5	<5	<5	99	12	43	460	15	<5	118	109	<5	18	20	<5
				>2	13.4	80	919	7	37	8374	<5	<5	<5	<5	47	<5	19	236	8	<5	53	22	<5	17	<5	<5
				.425-2	43.4	120	1381	9	81	9625	<5	<5	<5	<5	85	9	30	308	12	<5	113	64	<5	14	10	<5
				.180-.425	26.9	189	2269	16	146	15436	<5	<5	<5	<5	144	14	51	511	17	<5	190	68	<5	31	21	8
				.075-.180	10.4	240	2605	12	152	16335	<5	<5	5	5	127	16	71	834	20	<5	197	70	<5	25	23	8
				<.075	5.4	300	4249	14	250	20114	12	<5	12	5	148	23	121	1422	30	<5	275	70	<5	17	38	16
A_2(E	0.3	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		81	1599	21	52	10125	<5	<5	<5	<5	98	11	44	467	16	<5	132	62	<5	7	19	5
				>2	13.9	57	776	10	52	7826	<5	<5	<5	<5	45	5	19	215	7	<5	40	12	<5	19	<5	<5
				.425-2	45.8	100	1422	7	56	7917	<5	<5	<5	<5	84	7	31	326	10	<5	114	38	<5	21	7	<5
				.180-.425	26.2	176	2475	15	85	16400	<5	<5	<5	<5	143	13	55	529	18	<5	211	75	<5	25	20	<5
				.075-.180	8.9	171	2673	14	83	14129	<5	<5	<5	<5	124	13	68	792	19	<5	200	62	<5	20	21	7
				<.075	5.2	224	4007	22	147	22545	13	17	16	15	149	19	122	1402	29	<5	250	62	<5	21	39	16
P	0.6	ZONE MARKED BY QUARTZ PEBBLES, ROCK DEBRIS AND IRON OXIDES.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES; GOETHITE PELLETS; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		76	1159	9	55	11782	<5	<5	<5	<5	66	8	32	324	8	<5	53	45	<5	26	10	<5
				>2	44.4	77	648	19	36	13083	<5	<5	<5	<5	27	<5	13	142	7	<5	26	28	<5	22	<5	<5
				.425-2	30.4	108	1529	10	47	12302	<5	<5	<5	<5	76	7	32	320	10	<5	79	25	<5	23	9	<5
				.180-.425	12.5	191	2880	22	56	20233	7	9	9	<5	137	10	63	598	17	<5	185	51	<5	25	23	<5
				.075-.180	7.3	219	3345	28	108	26347	11	44	15	14	137	13	92	990	22	<5	192	47	<5	29	30	10
				<.075	5.4	228	4043	35	122	30458	21	8	26	12	154	14	109	1122	26	<5	235	32	<5	26	37	10
B_2(R	1.0	RED SOFT PLINTIC B HORIZON WHICH STILL PRESERVES THE GRANITIC STRUCTURE. (ZONE OF ILLUVIATION).	QUARTZ (ANGULAR AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; ENRICHED IN KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		130	1950	21	48	21395	5	<5	6	<5	61	6	39	396	14	<5	69	36	<5	7	14	<5
				>2	37.5	92	890	15	35	13255	<5	<5	<5	<5	28	<5	17	176	8	<5	<5	15	<5	22	5	<5
				.425-2	35.3	174	2298	11	74	19995	<5	<5	6	<5	79	6	43	426	15	<5	114	46	<5	20	14	<5
				.180-.425	12.4	223	3316	34	116	30353	11	20	15	14	143	12	78	734	21	<5	194	59	<5	33	32	7
				.075-.180	8.4	245	3840	33	97	31661	17	55	18	9	134	11	93	1052	25	<5	199	42	<5	28	33	9
				<.075	6.4	262	4232	39	158	37292	31	98	29	26	148	13	108	1056	27	<5	193	26	<5	23	41	12
B_3	1.4	WHITISH-GREY HORIZON CONTAINING MUCH CLAY MINERALS. THE GRANITIC STRUCTURE IS STILL PRESERVED.	QUARTZ (ANGULAR AND SUBANGULAR); ALTERED FELDSPAR AND BIOTITE; WHITE CONCRETIONS OF MAINLY KAOLINITE. H.M. - MAG, ILM, LIM, GH, HEM AND ZR.	TOTAL		126	1701	16	42	16894	6	10	12	10	126	10	38	342	17	<5	138	29	<5	24	23	5
				>2	54.9	72	1116	15	35	12869	<5	<5	<5	<5	64	<5	20	183	10	<5	68	16	<5	25	10	<5
				.425-2	20.3	112	1982	17	63	20422	<5	10	12	9	160	10	38	288	15	<5	193	44	<5	35	23	<5
				.180-.425	8.6	133	3113	20	104	30046	14	5	23	8	265	17	66	529	24	<5	323	44	<5	37	45	7
				.075-.180	8.3	137	2929	33	103	30371	14	29	19	16	205	15	82	850	22	<5	236	34	<5	31	41	9
				<.075	7.9	141	3357	35	129	32668	26	84	30	18	216	13	94	882	24	<5	255	26	<5	33	49	10
C	1.5	BROWN WEATHERED BEDROCK. (UNCONSOLIDATED).	QUARTZ; KAOLINISED, ILLITISED AND HEMATITISED FELDSPARS; CHLORITISED AND HEMATITISED BIOTITE. H.M.- HEM, MAG, ILM AND ZR.			112	1550	<5	74	13834	<5	<5	10	<5	392	18	44	234	18	<5	346	25	<5	34	37	5
R	1.5	SLIGHTLY WEATHERED MAKHUTSO GRANITE.	QUARTZ; SERICITISED AND KAOLINISED POTASH FELDSPAR AND PLAGIOCLASE; THE BIOTITE IS CHLORITISED. H.M. - MAG, ILM, HEM AND ZR.			113	1323	<5	115	14329	<5	<5	7	10	427	56	76	193	25	<5	441	22	<5	27	37	7

Description, mineralogy and trace element geochemistry of weathering profile 27 on the grey Makhutso Granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
A_1	0.15	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		121	1637	25	139	16554	<5	<5	23	15	69	11	49	468	15	<5	74	141	<5	58	21	8
				>2	21.2	99	1055	11	89	10211	<5	<5	14	5	44	6	24	257	8	<5	31	32	<5	56	6	<5
				.425-2	29.1	117	1353	13	141	1241	<5	<5	17	13	53	8	30	294	11	<5	56	94	<5	68	9	<5
				.180-.425	26.4	173	2092	13	172	16175	<5	<5	28	11	82	8	46	405	16	<5	99	111	<5	63	16	<5
				.075-.180	14.6	208	2496	17	203	18613	<5	<5	30	20	89	14	79	854	20	<5	116	125	<5	69	27	11
				<.075	8.7	287	4320	36	310	28177	17	9	67	28	134	21	131	1466	31	<5	215	166	<5	86	44	18
A_2(E	0.3	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		109	1682	13	80	13365	<5	<5	33	11	64	8	40	393	14	<5	69	111	<5	64	21	<5
				>2	25.4	100	1298	12	75	13557	<5	<5	22	12	52	7	30	288	12	<5	37	159	<5	84	14	<5
				.425-2	32.3	69	821	10	48	10337	<5	<5	9	<5	34	<5	17	180	<5	<5	23	111	<5	62	<5	<5
				.180-.425	29.4	168	2519	19	116	21253	<5	<5	40	25	91	10	61	497	19	<5	124	133	<5	61	24	5
				.075-.180	8.5	154	2618	17	110	18504	6	<5	40	11	89	11	81	872	19	<5	129	119	<5	62	25	9
				<.075	4.4	231	3905	35	180	29014	11	15	58	31	124	17	122	1347	28	<5	179	109	<5	80	38	17
P	0.6	ZONE MARKED BY QUARTZ PEBBLES, ROCK DEBRIS AND IRON OXIDES.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES; GOETHITE PELLETS; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		109	1372	29	64	27345	7	<5	44	15	49	7	32	301	12	<5	41	38	<5	61	16	5
				>2	70.4	146	1150	99	499	74479	22	<5	127	14	38	6	23	192	8	<5	117	<5	<5	148	25	13
				.425-2	11.8	119	1578	20	97	22155	<5	<5	40	16	56	7	34	312	11	<5	56	16	<5	105	14	<5
				.180-.425	8.3	190	3286	34	126	33255	16	<5	84	31	112	11	76	683	22	<5	143	40	<5	77	34	8
				.075-.180	6.6	245	3632	36	147	36827	13	15	81	42	120	12	88	866	23	<5	171	97	<5	74	34	11
				<.075	2.9	223	4210	55	171	46418	28	22	125	50	148	14	108	1026	28	<5	188	62	<5	90	47	13
B_2(R	1.4	RED SOFT PLINTIC B HORIZON WHICH STILL PRESERVES THE GRANITIC STRUCTURE. (ZONE OF ILLUVIATION).	QUARTZ (ANGULAR AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; ENRICHED IN KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		87	2333	26	67	24048	8	<5	56	7	55	6	40	376	15	<5	59	34	<5	41	16	5
				>2	46.7	98	1339	26	88	23506	<5	<5	45	11	39	5	23	222	10	<5	30	29	<5	54	8	<5
				.425-2	28.6	123	2350	25	107	28473	<5	<5	62	10	61	7	41	376	14	<5	81	26	<5	73	16	5
				.180-.425	9.9	188	3606	47	183	43284	20	15	90	43	121	13	86	776	26	<5	150	45	<5	78	44	13
				.075-.180	8.3	201	4029	34	161	40586	19	11	99	33	119	11	94	989	25	<5	161	59	<5	78	37	12
				<.075	6.5	212	4596	57	220	50269	23	28	115	56	142	16	109	1086	31	<5	184	61	<5	86	49	17
B_3 + C	1.6	WHITISH-GREY HORIZON CONTAINING MUCH CLAY MINERALS. THE GRANITIC STRUCTURE IS STILL PRESERVED.	QUARTZ (ANGULAR AND SUBANGULAR); ALTERED FELDSPAR AND BIOTITE; WHITE CONCRETIONS OF MAINLY KAOLINITE. H.M. - MAG, ILM, LIM, GH, HEM AND ZR.	TOTAL		94	2238	20	67	23262	7	<5	77	25	120	17	53	312	22	<5	186	19	<5	64	30	10
				>2	39.7	64	1144	18	41	16413	<5	<5	52	<5	50	6	24	203	11	<5	66	24	<5	53	11	<5
				.425-2	26.8	79	1904	14	118	17387	<5	<5	67	22	92	12	36	268	18	<5	154	23	<5	70	22	<5
				.180-.425	14.3	103	3212	25	159	31389	13	<5	134	30	203	22	68	478	27	<5	337	25	<5	92	48	5
				.075-.180	8.5	116	3260	32	150	34924	13	20	124	42	180	21	83	702	30	<5	291	44	<5	69	41	10
				<.075	10.7	105	3257	32	129	34471	24	12	187	51	180	19	94	779	32	<5	256	48	<5	71	41	8

Description, mineralogy and trace element geochemistry of weathering profile 28 on the grey Makhutso Granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	GEOCHEMICAL DATA (PPM)																				
						P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
A_1	0.15	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		130	1734	21	101	13991	<5	<5	8	15	84	12	45	521	16	<5	135	127	<5	21	16	<5
				>2	11.7	87	820	29	32	15070	<5	<5	5	<5	34	5	15	197	9	<5	53	32	<5	28	<5	<5
				.425-2	45.4	131	1552	12	76	11428	5	<5	6	<5	63	8	29	340	13	<5	100	120	<5	24	8	<5
				.180-.425	22.0	175	2203	9	113	11854	<5	<5	<5	<5	119	12	45	470	16	<5	218	185	<5	34	15	<5
				.075-.180	13.3	207	2631	17	117	14973	8	<5	10	10	122	15	76	920	22	<5	227	143	<5	24	21	6
				<.075	7.6	310	4615	12	249	21919	17	<5	18	10	148	23	115	1442	31	<5	324	76	<5	35	37	12
A_2(E	0.3	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM AND ZR.	TOTAL		88	1919	18	43	13498	10	<5	10	<5	85	10	44	535	18	6	136	165	10	10	15	<5
				>2	17.1	109	1160	26	166	16717	<5	<5	7	<5	44	6	23	279	11	<5	92	154	<5	46	7	<5
				.425-2	42.6	103	1439	12	17	8099	<5	<5	<5	<5	62	6	29	353	11	<5	87	49	<5	34	5	<5
				.180-.425	26.6	168	2481	8	78	15608	8	<5	12	11	125	12	50	538	19	<5	211	200	<5	22	19	5
				.075-.180	9.4	178	3027	8	84	14246	7	<5	8	<5	122	14	79	987	22	<5	236	99	<5	24	23	5
				<.075	4.3	204	4196	17	168	22978	11	8	19	15	139	21	121	1563	30	<5	279	80	<5	22	38	14
P	0.6	ZONE MARKED BY QUARTZ PEBBLES, ROCK DEBRIS AND IRON OXIDES.	MAINLY ANGULAR AND SUBANGULAR QUARTZ PEBBLES; GOETHITE PELLETS; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM AND ZR.	TOTAL		101	1700	28	68	21686	9	<5	17	8	71	8	39	444	15	<5	111	180	<5	20	13	5
				>2	61.3	118	827	32	33	23799	5	<5	5	<5	25	<5	62	160	7	<5	29	16	<5	26	<5	<5
				.425-2	18.4	101	1489	18	35	12484	<5	<5	8	5	54	5	26	292	12	<5	83	209	<5	32	6	<5
				.180-.425	8.6	158	3046	14	41	19179	9	<5	21	10	129	10	61	651	22	<5	221	170	<5	25	21	<5
				.075-.180	6.2	187	3489	19	103	25164	8	5	15	13	134	14	91	1081	24	<5	240	80	<5	29	30	8
				<.075	5.5	203	4705	20	93	28801	22	8	32	17	148	15	108	1283	32	<5	264	94	<5	21	38	9
B_2(R	1.2	RED SOFT PLINTIC B HORIZON WHICH STILL PRESERVES THE GRANITIC STRUCTURE. (ZONE OF ILLUVIATION).	QUARTZ (ANGULAR AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; ENRICHED IN KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM AND ZR.	TOTAL		100	2573	22	120	24838	12	<5	16	8	90	9	52	591	19	<5	156	70	<5	32	20	<5
				>2	53.5	87	1350	26	71	20663	5	<5	12	7	41	5	22	242	11	<5	54	31	<5	32	9	<5
				.425-2	26.7	102	2685	20	107	22772	14	<5	22	10	89	7	46	491	19	<5	139	45	<5	31	17	<5
				.180-.425	8.8	144	3607	29	172	31291	16	7	28	26	138	12	71	738	25	<5	233	51	<5	43	30	5
				.075-.180	5.4	153	3909	16	136	27262	19	<5	25	12	129	12	91	1091	26	<5	214	63	<5	30	32	6
				<.075	5.6	174	4757	31	218	36193	25	17	39	34	142	15	106	1242	33	<5	259	47	<5	30	41	11
B_3	1.9	WHITISH-GREY HORIZON CONTAINING MUCH CLAY MINERALS. THE GRANITIC STRUCTURE IS STILL PRESERVED.	QUARTZ (ANGULAR AND SUBANGULAR); ALTERED FELDSPAR AND BIOTITE; WHITE CONCRETIONS OF MAINLY KAOLINITE. H.M. - MAG, ILM, LIM, GH, HEM AND ZR.	TOTAL		101	2441	26	113	23765	11	<5	21	14	149	14	58	571	21	<5	323	60	<5	46	23	<5
				>2	36.4	89	1183	29	80	22534	<5	<5	16	<5	107	8	25	169	11	<5	303	22	<5	93	11	<5
				.425-2	34.1	89	1994	28	103	24906	<5	<5	22	13	171	14	42	318	16	<5	408	41	<5	62	20	<5
				.180-.425	11.4	132	3365	20	151	26815	13	<5	30	12	191	14	71	627	24	<5	398	44	<5	53	28	<5
				.075-.180	9.8	145	3540	17	133	22406	10	<5	20	12	148	16	95	1056	28	<5	312	55	<5	38	33	9
				<.075	8.3	164	5110	11	193	24646	16	<5	23	6	153	18	127	1519	37	<5	333	41	<5	44	43	13
C	2.1	BROWN WEATHERED BEDROCK. (UNCONSOLIDATED).	QUARTZ; KAOLINISED, ILLITISED AND HEMATITISED FELDSPARS; CHLORITISED AND HEMATITISED BIOTITE. H.M.- HEM, MAG, ILM AND ZR.	TOTAL		99	1942	15	111	2562	6	<5	16	8	192	25	72	389	21	<5	420	45	<5	23	23	<5
				>2	31.5	101	963	19	76	23567	<5	<5	13	<5	143	14	37	78	10	<5	403	13	<5	56	12	<5
				.425-2	27.1	89	1562	18	93	25162	<5	<5	19	6	201	22	58	173	17	<5	513	35	<5	37	19	<5
				.180-.425	23.9	135	2943	10	142	27102	11	<5	25	6	232	21	83	456	23	<5	501	37	<5	34	27	<5
				.075-.180	8.3	149	3156	8	131	23562	8	<5	16	7	178	25	102	852	27	<5	415	45	<5	21	31	9
				<.075	9.2	172	4652	6	178	25512	11	<5	17	<5	185	29	135	1256	35	<5	443	36	<5	35	39	12
R	2.1	WEATHERED MAKHUTSO GRANITE.	QUARTZ; SERICITISED AND KAOLINISED POTASH FELDSPAR AND PLAGIOCLASE; THE BIOTITE IS CHLORITISED. H.M. - MAG, ILM, HEM AND ZR.			100	1060	<5	103	3324	<5	<5	<5	<5	259	69	95	215	22	<5	580	27	<5	21	23	5

Description, mineralogy and trace element geochemistry of weathering profile 29 on the grey Makhutso Granite.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
						GEOCHEMICAL DATA (PPM)																				
		DARK BROWN, ORGANIC	ALMOST ONLY ROUNDED AND SUBANGULAR	TOTAL		98	1642	18	99	19541	<5	<5	<5	<5	153	15	53	578	17	<5	233	44	<5	36	25	6
		RICH, ORTHIC A	QUARTZ GRAINS (SLIGHTLY STAINED WITH	>2	14.4	71	1001	11	20	14196	<5	<5	<5	<5	97	8	30	319	10	<5	142	35	<5	34	9	<5
A_1	0.05	HORIZON WITH WEAKLY	IRON OXIDES); NO FELDSPAR AND BIOTITE;	.425-2	39.9	101	1214	5	53	11551	<5	<5	<5	<5	120	11	31	332	12	<5	173	29	<5	36	12	<5
		STRUCTURED SOILS.	MINOR KAOLINITE AND OTHER CLAY	.180-.425	28.3	131	2075	<5	106	16251	<5	<5	<5	<5	192	15	56	596	19	<5	312	77	<5	31	24	<5
			MINERALS. H.M- GH, HEM, MAG, ILM	.075-.180	11.9	153	2099	11	141	17740	<5	<5	<5	<5	188	17	79	978	19	<5	356	65	<5	38	24	7
			AND ZR.	<.075	5.5	179	3180	13	191	16750	<5	<5	<5	<5	216	24	130	1717	25	<5	494	41	<5	39	35	15
		LIGHT COLOURED, LOOSE	ALMOST ONLY ROUNDED AND SUBANGULAR	TOTAL		90	1632	16	30	17342	5	<5	<5	<5	147	12	50	555	16	<5	235	44	<5	22	18	5
		STRUCTURED, HORIZON OF	QUARTZ GRAINS; NO FELDSPAR AND	>2	16.6	68	894	13	30	22583	5	<5	<5	<5	90	8	26	262	10	<5	143	29	<5	39	8	<5
A_2(E)	0.1	MAXIMUM ELUVIATION.	BIOTITE; TRACES OF KAOLINITE AND	.425-2	40.2	82	1336	<5	28	10735	<5	<5	<5	<5	126	10	36	388	13	<5	192	39	<5	27	9	<5
			OTHER CLAY MINERALS. H.M.- GH, MAG,	.180-.425	29.1	124	2109	10	82	19923	<5	<5	<5	<5	196	15	62	652	19	<5	325	83	<5	35	27	6
			ILM AND ZR.	.075-.180	9.4	126	2165	<5	30	13456	<5	<5	<5	<5	183	15	73	902	20	<5	366	89	<5	20	24	5
				<.075	4.7	172	3137	16	105	20349	7	6	<5	7	222	22	122	1489	26	<5	475	55	<5	37	36	15
		ZONE MARKED BY QUARTZ	MAINLY ANGULAR AND SUBANGULAR QUARTZ	TOTAL		94	1641	11	33	20516	<5	<5	7	<5	153	11	48	515	9	<5	221	34	<5	31	18	7
		PEBBLES, ROCK DEBRIS	PEBBLES; GOETHITE PELLETS; MINOR	>2	51.5	51	821	6	35	23512	<5	<5	<5	<5	89	9	20	246	15	<5	136	45	<5	39	9	<5
P	0.2	AND IRON OXIDES.	KAOLINITE, ILLITE AND OTHER MIXED	.425-2	27.8	83	1534	6	31	12735	<5	<5	<5	7	134	11	39	351	15	<5	197	54	<5	40	12	<5
			LAYERED CLAYS; WEATHERED ROCK	.180-.425	10.4	184	2751	10	91	21516	<5	<5	7	6	197	17	81	631	19	<5	340	93	<5	56	31	7
			DEBRIS. H.M.- GH, HEM, MAG, ILM	.075-.180	6.1	201	3215	19	34	17345	9	<5	12	<5	179	15	109	852	25	<5	385	83	<5	41	36	11
			AND ZR.	<.075	6.2	221	3956	22	111	23515	16	7	16	9	201	24	161	1276	32	<5	501	60	<5	37	42	17
		BROWN-RED HORIZON	QUARTZ (ANGULAR AND SUBANGULAR)	TOTAL		64	1945	6	120	37348	14	<5	<5	13	239	12	55	523	22	<5	610	<5	<5	34	28	5
		CONTAINING HIGHLY	STAINED WITH IRON OXIDES; ALTERED	>2	32.5	64	1953	8	123	36421	13	<5	<5	15	240	15	49	462	24	<5	593	<5	<5	33	27	<5
B(R)	0.4	WEATHERED BEDROCK	FELDSPAR AND BIOTITE; GREYISH	.425-2	31.2	83	1740	8	141	31056	8	<5	<5	17	186	12	53	447	19	<5	392	10	<5	34	26	5
+ C		MATERIAL.	MATRIX OF KAOLINITE, ILLITE AND	.180-.425	18.2	94	2349	7	129	31290	11	<5	<5	17	209	13	65	591	21	<5	417	<5	<5	31	31	<5
			OTHER CLAY MINERALS; IRON OXIDES.	.075-.180	9.3	115	2133	15	145	28553	8	<5	<5	12	255	18	84	881	20	<5	585	9	<5	32	32	8
			H.M. - HEM, GH, MAG, ILM AND ZR.	<.075	8.8	107	2220	17	143	33165	17	8	<5	18	337	19	90	913	20	<5	817	<5	<5	38	36	6
		WEATHERED	QUARTZ; ALTERED FELDSPARS AND																							
		GRANOPHYRE.	BIOTITE.																							
R	0.4		H.M.- HEM, MAG AND ZR.			46	1606	<5	114	24178	<5	<5	<5	34	301	49	85	476	18	<5	1159	<5	<5	29	29	7

Description, mineralogy and trace element geochemistry of weathering profile 30 on the Stavoren Granophyre.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m).	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
						GEOCHEMICAL DATA (PPM)																				
A_1	0.2	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM AND ZR.	TOTAL		144	5955	28	158	21433	10	<5	31	52	87	11	55	456	17	<5	83	211	16	102	27	6
				>2	17.1	123	1211	18	93	28183	6	<5	53	42	80	10	33	248	12	<5	71	60	17	159	36	<5
				.425-2	43.7	156	1565	19	153	16287	6	<5	25	36	69	9	39	328	14	<5	69	101	<5	113	18	<5
				.180-.425	26.2	215	2384	21	186	21173	12	<5	38	39	95	11	59	495	19	<5	117	145	<5	118	26	<5
				.075-.180	8.4	255	2812	23	219	24776	10	<5	38	46	100	14	85	823	22	<5	117	136	<5	105	29	9
				<.075	4.6	285	3746	34	310	28249	19	5	59	59	137	21	118	1138	25	<5	184	103	<5	138	40	13
A_2(E	0.3	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM AND ZR.	TOTAL		105	1548	24	91	32697	14	<5	27	58	109	7	48	401	13	<5	88	201	8	112	19	5
				>2	23.1	99	1298	15	102	34923	10	<5	47	103	135	7	38	229	17	<5	74	58	12	251	17	<5
				.425-2	46.2	124	1616	12	75	14733	<5	<5	28	24	67	7	41	348	14	<5	65	152	25	115	14	<5
				.180-.425	21.3	196	2445	25	109	23676	10	<5	37	43	91	10	62	521	20	<5	95	173	<5	104	28	5
				.075-.180	5.7	209	2796	19	91	21192	11	<5	44	33	92	10	78	805	21	<5	122	131	<5	88	26	5
				<.075	3.7	277	3904	31	167	31710	18	13	58	65	134	16	118	1166	28	<5	167	113	<5	114	42	13
P	0.6	ZONE MARKED BY QUARTZ PEBBLES, ROCK DEBRIS AND IRON OXIDES.	MAINLY ROUNDED AND SUBANGULAR QUARTZ PEBBLES; GOETHITE PELLETS; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM AND ZR.	TOTAL		111	1578	17	203	28927	8	<5	86	131	176	8	51	351	17	<5	151	47	6	104	23	<5
				>2	64.3	121	1376	20	599	54907	15	<5	147	235	315	8	63	233	20	<5	218	18	10	239	27	<5
				.425-2	16.7	126	1579	14	119	18701	<5	<5	63	59	91	7	40	298	13	<5	69	175	<5	102	14	<5
				.180-.425	7.7	195	2666	19	111	24568	12	<5	79	46	102	9	65	529	20	<5	116	140	<5	110	28	<5
				.075-.180	6.0	205	2942	25	119	27307	14	5	79	56	109	11	88	845	23	<5	125	121	<5	101	33	9
				<.075	5.3	253	3969	33	164	35661	21	9	93	74	158	14	113	1053	26	<5	187	80	<5	123	45	9
B_2(R	1.2	RED SOFT PLINTIC B HORIZON WHICH STILL PRESERVES THE GRANITIC STRUCTURE. (MAXIMUM CLAY AND IRON ACCUMULATION).	QUARTZ (ANGULAR AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; ENRICHED IN KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM AND ZR.	TOTAL		109	1608	15	542	36510	10	<5	199	203	242	8	67	302	19	<5	170	36	<5	286	25	<5
				>2	63.9	96	1249	9	873	40850	10	<5	193	289	312	10	72	230	21	<5	258	30	<5	341	25	<5
				.425-2	21.3	112	1768	17	353	24515	9	<5	162	149	183	7	54	319	19	<5	159	80	<5	186	20	<5
				.180-.425	6.4	179	2615	31	219	33219	13	7	162	114	169	11	76	563	23	<5	162	122	<5	150	35	6
				.075-.180	4.7	236	3225	29	176	33848	15	<5	179	92	160	10	87	741	22	<5	175	85	<5	121	34	6
				<.075	3.7	256	3623	38	227	42586	23	20	191	131	214	15	109	912	27	<5	189	80	<5	138	46	11
B_3	1.4	HORIZON CONTAINING REDDISH UNCONSOLIDATED WEATHERED BEDROCK WITH GREEN AND WHITE CONCRETIONS OF CLAY MINERALS.	QUARTZ (ANGULAR AND SUBANGULAR); ALTERED FELDSPAR AND BIOTITE. H.M.- HEM, GH, MAG, ILM AND ZR.	TOTAL		63	1547	13	442	22895	6	<5	127	358	336	11	77	300	29	<5	231	31	<5	135	40	<5
				>2	61.9	39	1244	6	644	16789	<5	<5	125	380	346	7	69	232	22	<5	269	21	<5	184	22	<5
				.425-2	26.2	66	1733	7	291	19142	8	<5	121	343	315	9	68	284	31	<5	201	59	<5	106	31	<5
				.180-.425	3.8	83	1914	17	254	24561	12	<5	132	387	375	9	56	364	29	<5	232	85	<5	120	51	<5
				.075-.180	3.8	121	1849	12	230	29527	11	<5	137	354	344	11	100	499	25	<5	239	50	<5	118	56	<5
				<.075	4.3	94	1437	15	208	22994	11	<5	141	312	325	10	111	524	20	<5	250	45	<5	124	52	<5
C	1.6	RED UNCONSOLIDATED WEATHERED BEDROCK. GRANITIC STRUCTURE STILL PRESERVED.	QUARTZ; KAOLINISED, ILLITISED AND HEMATITISED FELDSPARS; CHLORITISED AND HEMATITISED BIOTITE. H.M.- HEM, MAG, ILM AND ZR.	TOTAL		34	1443	10	151	22521	5	<5	130	322	367	5	80	255	22	<5	240	24	<5	81	31	<5

Description, mineralogy and trace element geochemistry of weathering profile 31 on altered (chloritised) Makhutso Granite next to a sulphide rich quartz vein.

APPENDIX A: (CONTINUED)

WEATHERING HORIZON	DEPTH TO LOWER BOUNDARY OF ZONE (m)	DESCRIPTION	MINERALOGY	GRAIN SIZE (mm).	WEIGHT %	GEOCHEMICAL DATA (PPM)																				
						P	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	Sn	W	Pb	Th	U
A_1	0.15	DARK BROWN, ORGANIC RICH, ORTHIC A HORIZON WITH WEAKLY STRUCTURED SOILS.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS (SLIGHTLY STAINED WITH IRON OXIDES); NO FELDSPAR AND BIOTITE; MINOR KAOLINITE AND OTHER CLAY MINERALS. H.M- GH, HEM, MAG, ILM, LIM, ZR AND CAS.	TOTAL		266	3114	41	111	38467	31	15	101	41	216	10	87	359	27	<5	146	221	<5	58	38	<5
				>2	20.3	240	3833	47	126	53154	39	30	148	65	280	10	86	266	31	<5	174	91	<5	77	46	<5
				.425-2	38.5	244	3354	36	119	40565	27	14	107	42	219	9	74	278	25	<5	154	132	<5	70	36	<5
				.180-.425	32.4	240	2815	24	111	29374	19	<5	72	27	174	8	79	355	21	<5	135	256	<5	57	27	<5
				.075-.180	5.6	301	3713	33	171	37068	26	10	90	35	210	11	111	614	27	<5	178	180	<5	72	40	6
				<.075	3.2	314	4372	44	193	41264	30	18	109	46	239	15	123	678	33	<5	196	166	<5	79	49	9
A_2(E)	0.3	LIGHT COLOURED, LOOSE STRUCTURED, HORIZON OF MAXIMUM ELUVIATION.	ALMOST ONLY ROUNDED AND SUBANGULAR QUARTZ GRAINS; NO FELDSPAR AND BIOTITE; TRACES OF KAOLINITE AND OTHER CLAY MINERALS. H.M.- GH, MAG, ILM, LIM, ZR AND CAS.	TOTAL		91	1491	22	59	17485	8	<5	23	13	114	8	64	399	16	<5	75	475	<5	26	21	<5
				>2	14.8	74	928	18	47	28675	10	<5	30	28	201	6	41	179	15	<5	81	700	<5	32	21	<5
				.425-2	31.8	96	1263	11	24	11882	<5	<5	18	9	90	7	44	259	14	<5	56	350	<5	23	15	<5
				.180-.425	34.3	109	1419	12	39	14407	<5	<5	23	12	100	7	55	311	16	<5	63	405	<5	17	18	<5
				.075-.180	12.6	187	2455	7	81	16785	8	<5	27	14	124	10	92	641	21	<5	105	332	<5	28	30	6
				<.075	6.5	240	4075	26	178	28535	15	9	47	29	191	16	162	1254	32	<5	206	315	<5	41	57	14
P	0.45	ZONE MARKED BY QUARTZ PEBBLES, ROCK DEBRIS AND IRON OXIDES. PIECES OF VLAKLAAGTE GRANITE ARE RECOGNISED.	MAINLY ANGULAR AND SUBANGULAR QUARTZ PEBBLES; GOETHITE PELLETS; MINOR KAOLINITE, ILLITE AND OTHER MIXED LAYERED CLAYS; NO FELDSPAR AND BIOTITE. H.M.- GH, HEM, MAG, ILM, LIM, ZR AND CAS.	TOTAL		120	1800	36	45	40000	10	<5	40	24	124	7	100	450	19	<5	80	950	<5	20	40	<5
				>2	64.2	132	1200	52	33	44000	12	<5	35	6	118	<5	70	200	13	<5	45	800	<5	17	28	<5
				.425-2	18.4	110	1400	26	31	26100	9	<5	29	20	120	<5	67	250	16	<5	64	550	<5	15	25	<5
				.180-.425	7.4	113	2400	29	29	28200	13	<5	36	21	130	<5	85	410	17	<5	110	600	<5	13	30	<5
				.075-.180	5.4	170	3100	33	44	35300	18	16	39	36	150	7	130	710	23	<5	120	610	<5	17	46	<5
				<.075	4.6	192	3200	60	49	42600	30	21	53	40	200	8	134	670	25	<5	140	605	<5	19	52	<5
B_2(R)	0.7	RED SOFT PLINTIC B HORIZON WHICH STILL PRESERVES THE GRANITIC STRUCTURE. GREISEN VEINS ARE ARE STILL PRESENT.	QUARTZ (ANGULAR AND SUBANGULAR) STAINED WITH IRON OXIDES; NO FRESH FELDSPAR OR BIOTITE; ENRICHED IN KAOLINITE, ILLITE AND OTHER CLAY MINERALS; IRON OXIDES. H.M.- HEM, GH, MAG, ILM, LIM, ZR AND CAS.	TOTAL		104	1617	22	41	21631	13	<5	42	21	168	6	68	359	17	<5	79	273	<5	24	28	<5
				>2	57.2	61	1797	15	30	14687	<5	<5	16	21	184	<5	44	160	12	<5	50	193	<5	20	16	<5
				.425-2	25.3	122	1797	15	34	21681	11	<5	44	23	169	<5	65	314	15	<5	81	299	<5	27	22	<5
				.180-.425	8.5	165	2336	22	45	27276	17	<5	63	24	169	7	81	449	19	<5	96	340	<5	32	30	<5
				.075-.180	4.9	218	3174	30	81	34970	21	8	82	34	202	9	103	659	22	<5	135	228	<5	35	42	<5
				<.075	4.1	235	3833	4:	111	43362	31	21	108	48	259	12	129	789	28	<5	166	188	<5	45	55	7
B_3	0.9	WHITISH-GREY HORIZON CONTAINING MUCH CLAY MINERALS. THE GRANITIC STRUCTURE IS STILL PRESERVED AND THE GREISEN VEINS LESS ALTERED.	QUARTZ (ANGULAR AND SUBANGULAR); ALTERED FELDSPAR AND BIOTITE. KAOLINITE IS ENRICHED IN THIS ZONE. H.M. - MAG, ILM, LIM, GH, HEM, ZR AND CAS,	TOTAL		120	1820	21	40	19000	13	<5	40	24	350	10	75	300	20	<5	95	250	<5	25	34	<5
				>2	58.1	136	1460	30	31	11000	11	<5	48	27	500	9	66	210	22	<5	80	170	<5	21	34	<5
				.425-2	21.4	120	1765	11	30	20200	10	<5	42	20	410	7	63	260	19	<5	71	260	<5	14	24	<5
				.180-.425	8.1	175	2490	14	36	14100	9	<5	45	36	360	10	78	380	17	<5	73	260	<5	17	27	<5
				.075-.180	7.7	235	3634	29	38	21200	13	8	65	42	299	11	111	454	20	<5	130	241	<5	19	37	6
				<.075	4.7	240	3843	45	52	27300	16	20	74	64	380	14	125	510	25	<5	162	212	<5	23	53	10
C	1.6	REDDISH-BROWN WEATHERED BEDROCK. GREISEN VEINS ARE CUTTING THROUGH THE UNCONSOLIDATED MATERIAL.	QUARTZ; KAOLINISED, ILLITISED AND HEMATITISED FELDSPARS; CHLORITISED AND HEMATITISED BIOTITE. H.M.- HEM, MAG, ILM, ZR AND CAS.	TOTAL		115	2036	21	89	25178	13	<5	40	23	411	10	88	233	20	<5	101	185	<5	29	40	<5
				>2	61.8	96	1257	9	42	13888	6	<5	23	24	354	<5	54	232	16	<5	60	104	<5	28	24	<5
				.425-2	15.8	135	2036	13	89	25178	11	<5	43	47	436	7	83	382	20	<5	98	166	<5	36	37	<5
				.180-.425	7.3	213	3414	30	133	40565	18	14	80	64	473	9	105	312	25	<5	160	229	<5	40	50	<5
				.075-.180	9.4	231	3414	35	126	40565	21	17	78	51	447	10	123	406	24	<5	156	180	<5	47	59	7
				<.075	5.7	231	3776	51	141	45460	28	25	92	61	488	11	132	438	23	<5	170	145	<5	45	65	6
R	1.6	HIGHLY WEATHERED GREYISH-RED MAKHUTSO GRANITE	QUARTZ; SERICITISED AND KAOLINISED POTASH FELDSPAR AND PLAGIOCLASE; THE BIOTITE IS CHLORITISED. H.M. - MAG, ILM, HEM, ZR AND CAS.			90	486	6	64	24479	<5	<5	50	41	504	11	90	110	15	<5	108	150	<5	34	23	<5

Description, mineralogy and trace element geochemistry of weathering profile 32 on reddish-grey Makhutso Granite with greisen veins cutting through the granite.

APPENDIX B: MAJOR AND TRACE ELEMENT DATA FOR THE DIFFERENT ROCK-TYPES.

SAMPLE No.	A		B			C		D	E							F	
ELEMENT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SiO_2	74.96	78.28	75.72	77.28	75.43	77.63	77.35	72.60	73.35	72.92	74.05	73.76	74.17	75.10	73.89	74.00	75.00
TiO_2	0.23	0.22	0.19	0.16	0.17	0.10	0.10	0.20	0.23	0.21	0.19	0.19	0.22	0.21	0.21	0.22	0.20
Al_2O_3	10.94	10.99	11.96	11.21	12.15	10.80	11.38	12.23	12.06	12.66	12.32	12.15	12.69	12.24	12.32	12.19	11.69
Fe_2O_3	2.28	2.25	0.48	0.34	0.46	0.44	0.91	1.53	0.51	0.48	0.53	1.17	0.80	0.57	0.28	0.43	0.36
FeO	1.36	1.20	0.68	0.68	0.60	1.27	1.18	5.48	2.27	2.30	1.75	1.85	1.49	1.73	2.12	2.24	2.11
MnO	0.01	0.02	0.02	0.01	0.01	0.01	0.04	0.20	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.02
MgO	0.01	0.01	0.10	0.08	0.19	0.01	0.09	0.15	0.20	0.14	0.20	0.17	0.07	0.20	0.15	0.11	0.15
CaO	0.67	0.47	1.02	0.82	0.99	0.38	0.25	0.06	1.06	0.96	0.97	0.87	0.59	0.94	0.88	0.81	0.85
Na_2O	3.42	3.52	3.88	3.56	3.98	2.75	2.72	0.01	3.14	3.16	3.47	3.24	3.54	3.16	3.79	3.10	3.30
K_2O	5.47	2.55	5.32	5.08	5.38	5.31	5.04	5.43	5.64	5.62	5.36	5.40	5.34	5.20	5.28	5.53	5.26
P_2O_5	0.01	0.01	0.02	0.04	0.03	0.01	0.01	0.01	0.03	0.04	0.27	0.03	0.04	0.02	0.02	0.02	0.01
Cr_2O_3	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03
H_2O^+	0.43	0.37	0.39	0.36	0.36	0.62	0.69	1.85	0.83	0.84	0.77	0.55	0.85	0.55	0.75	0.80	0.69
H_2O^-	0.16	0.09	0.16	0.21	0.22	0.14	0.12	0.06	0.07	0.11	0.07	0.11	0.13	0.05	0.15	0.12	0.11
Total	99.96	99.99	99.95	99.85	99.98	99.49	99.89	99.82	99.41	99.47	99.97	99.51	99.95	99.99	99.86	99.60	99.78
Li	2	15	10	8	7	8	9	36	34	31	33	24	20	33	32	23	21
Be	2	2	6	6	6	7	8	10	9	8	6	6	5	7	5	8	8
B	ND	ND	18	8	23	3	30	20	60	55	75	35	ND	30	33	3	3
F	830	1050	330	230	400	1530	1000	1090	1730	1300	1230	1450	1000	1030	1430	1530	1350
V	5	5	6	7	7	5	5	10	5	5	6	7	5	5	5	5	5
Co	5	5	5	5	5	5	5	7	5	5	5	5	5	5	5	5	6
Ni	5	17	5	11	5	10	5	28	16	5	14	12	7	12	5	7	17
Cu	5	5	5	5	5	240	263	90	5	102	33	5	5	12	5	41	5
Zn	117	26	5	5	5	129	199	188	5	5	9	5	10	5	5	5	6
Rb	229	251	263	262	272	363	326	1179	480	485	442	449	436	433	432	490	443
Sr	58	61	71	73	73	43	38	31	97	88	94	93	96	91	86	55	61
Y	106	123	112	132	115	83	75	59	88	67	83	76	151	82	90	114	120
Zr	526	492	235	221	237	160	160	240	257	254	261	242	255	258	264	333	322
Nb	17	18	22	22	21	21	21	21	23	23	24	23	20	23	22	28	30
Mo	5	5	5	5	5	5	5	5	112	96	5	5	5	5	5	45	68
Ba	1075	1165	582	567	612	332	457	347	498	491	511	490	519	504	513	402	282
Sn	5	12	25	26	5	29	19	260	36	31	29	28	9	28	19	47	38
W	5	5	5	5	5	28	9	19	5	5	5	5	5	5	5	5	5
Pb	29	21	30	30	23	54	54	37	32	25	28	28	26	25	26	30	31
Th	27	30	37	44	32	47	44	45	31	32	31	30	25	31	24	74	78
U	7	10	8	13	7	13	14	16	11	8	15	17	14	14	7	15	21

APPENDIX B: (CONTINUED)

	G						H				I		J		K
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
SiO_2	76.70	76.47	72.89	76.76	75.55	74.52	53.68	59.92	71.00	66.42					
TiO_2	0.06	0.05	0.20	0.09	0.18	0.21	0.03	0.06	0.14	0.06					
Al_2O_3	11.42	11.72	12,87	11.02	11.70	12.30	27.22	22.74	15.64	17.88					
Fe_2O_3	2.17	1.63	3.41	0.91	1.70	0.64	3.00	2.26	1.64	2.82					
FeO	0.64	0.67	0.01	0.80	1.06	1.63	2.30	2.36	1.65	2.28					
MnO	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.01					
MgO	0.08	0.10	0.12	0.01	0.14	0.19	0.41	0.21	0.13	0.19					
CaO	0.05	0.03	0.09	0.50	0.23	0.78	0.02	0.02	0.02	0.03					
Na_2O	0.01	0.01	0.86	2.24	1.58	3.23	0.01	0.01	0.01	0.01					
K_2O	7.24	7.76	7.49	6.53	6.53	5.09	9.15	8.44	6.63	7.39					
P_2O_5	0.01	0.01	0.02	0.01	0.02	0.05	0.01	0.01	0.01	0.01					
Cr_2O_3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01					
H_2O^+	1.15	1.18	1.16	0.61	1.06	0.66	3.48	3.00	2.21	2.57					
H_2O^-	0.18	0.09	0.29	0.08	0.15	0.13	0.04	0.10	0.07	0.05					
TOTAL	99.73	99.74	99.43	99.58	99.92	99.47	99.37	99.15	99.17	99.73					
Li	8	7	11	11	16	23	39	40	32	20					
Be	5	10	4	7	4	5	160	90	4	360					
B	97	75	30	90	ND	ND	93	18	5	65					
F	570	500	700	2170	1370	1100	4450	5700	2950	2550					
V	5	5	5	5	5	5	25	21	20	23	5	16	25	53	5
CO	5	5	5	5	5	5	15	12	6	12	5	5	25	73	28
Ni	11	10	7	5	8	14	35	21	19	29	5	5	35	71	28
Cu	14	12	262	338	295	55	5	5	36	5	5	8	980	1560	147
Zn	8	8	43	212	36	15	11	5	5	16	5	5	250	50	1592
Rb	718	745	661	546	594	491	1986	1742	685	1550	184	169	256	146	226
Sr	19	20	27	33	51	75	27	23	15	22	26	23	5	11	5
Y	131	128	71	96	104	78	85	121	56	94	30	25	5	25	34
Zr	163	163	256	182	237	259	138	143	216	169	41	35	5	5	135
Nb	31	31	18	29	24	24	6	33	9	13	5	9	5	6	19
Mo	5	7	5	107	5	7	5	5	5	5	45	25	5	5	5
Ba	341	339	549	382	495	490	351	293	255	229	152	131	250	1055	33
Sn	50	49	14	124	58	19	751	513	2301	461	292	459	53	22	20
W	5	5	19	28	27	5	5	5	5	5	5	5	70	80	21
Pb	71	77	17	88	56	32	31	24	21	47	26	36	50	250	155
Th	42	44	34	54	33	31	50	47	30	53	11	7	618	621	43
U	29	29	11	20	12	14	11	16	5	8	9	5	5	16	18

LEGEND

A - Stavoren Granophyre
B - Grey Makhutso Granite
C - Red Makhutso Granite
D - Greisen from Makhutso Granite
E - Grey Vlaklaagte granite
F - Granite aplite
G - Red Vlaklaagte granite
H - Greisen from Vlaklaagte granite
I - Quartz-pegmatite veins associated with greisens
J - Quartz-pegmatite veins from sulphide rich zone
K - Epithermal altered Makhutso Granite in sulphide rich zone.

APPENDIX C: MAJOR AND TRACE ELEMENT DATA FOR THE ZONES IN THE BEDROCK MATERIAL.

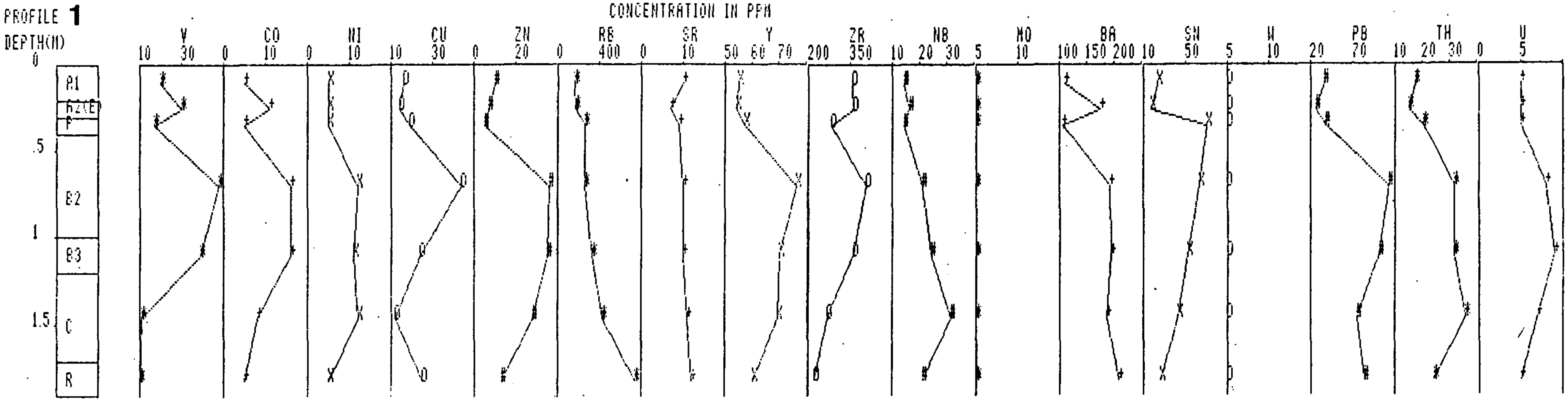
ELEMENT	WEATHERING ZONES			
	R4	R3	R2	R1
SiO_2	74.17	73.87	74.60	74.19
TiO_2	0.22	0.21	0.23	0.24
Al_2O_3	12.69	12.44	12.87	12.19
Fe_2O_3	0.80	1.73	1.39	1.97
FeO	1.49	0.70	0.67	0.68
MnO	0.01	0.01	0.01	0.01
MgO	0.07	0.03	0.12	0.01
CaO	0.59	0.32	0.19	0.09
Na_2O	3.54	3.36	1.93	1.00
K_2O	5.34	5.33	5.47	6.53
P_2O_5	0.04	0.03	0.03	0.02
Cr_2O_3	0.01	0.01	0.04	0.01
H_2O^+	0.85	1.08	1.66	2.11
H_2O^-	0.13	0.23	0.41	0.44
TOTAL	99.95	99.35	99.62	99.49
Li	20	20	20	20
Be	6	6	4	3
F	1000	600	470	370
V	<5	<5	<5	7
Co	<5	6	<5	6
Ni	7	17	5	22
Cu	<5	<5	12	39
Zn	10	10	13	15
Rb	436	571	575	630
Sr	96	94	68	50
Y	151	109	89	83
Zr	255	257	273	295
Nb	20	21	22	23
Mo	<5	<5	<5	<5
Ba	519	607	651	778
Sn	10	14	16	18
W	<5	<5	<5	<5
Pb	26	46	60	82
Th	25	32	32	33
U	14	16	16	17

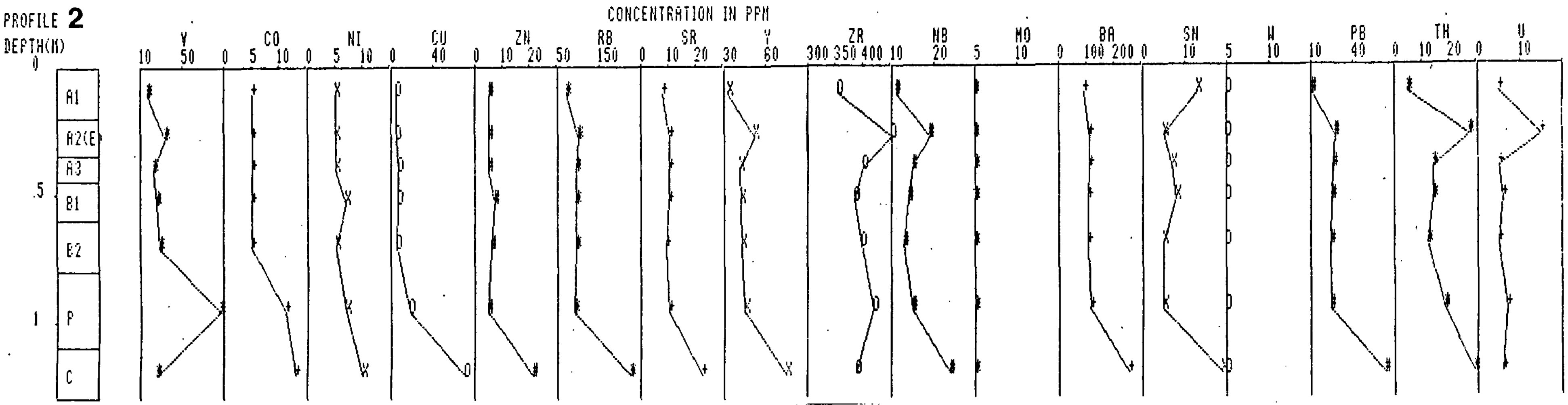
APPENDIX D: MAJOR ELEMENT DATA FOR PROFILES 9 AND 11.

	9							11							
HORIZON / ELEMENT	A_1	A_2	P	B_2	B_3	C	R	A_1	A_2	A_3	B_1	B_2	P	C	R
SiO_2	90.94	87.29	81.37	73.87	75.28	79.00	74.47	88.43	87.83	79.92	78.73	74.99	66.57	66.64	74.01
TiO_2	0.23	0.24	0.29	0.27	0.24	0.14	0.09	0.28	0.23	0.39	0.29	0.45	0.43	0.33	0.28
Al_2O_3	3.76	5.50	7.80	12.69	14.20	12.94	11.78	4.45	5.13	9.67	10.78	12.87	12.78	15.19	12.87
Fe_2O_3	0.01	0.94	3.72	4.60	3.60	3.10	2.72	0.01	0.04	1.24	1.66	2.81	10.03	2.38	1.09
FeO	1.50	1.83	1.47	1.81	1.10	1.03	1.06	1.48	1.53	1.58	1.50	1.12	1.47	1.49	1.49
MnO	0.02	0.01	0.02	0.03	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.02
MgO	0.02	0.04	0.06	0.16	0.16	0.08	0.12	0.04	0.02	0.07	0.10	0.10	0.01	0.10	0.09
CaO	0.05	0.03	0.03	0.02	0.03	0.04	0.25	0.05	0.04	0.03	0.20	0.03	0.03	0.04	0.53
Na_2O	0.01	0.01	0.01	0.01	0.01	0.01	1.68	0.01	0.01	0.01	0.01	0.01	0.01	0.01	3.52
K_2O	0.58	0.68	1.57	1.46	1.72	1.50	5.43	1.44	1.51	1.55	1.45	1.69	1.43	2.99	5.14
P_2O_5	0.02	0.02	0.03	0.03	0.02	0.01	0.01	0.02	0.02	0.01	0.02	0.03	0.06	0.04	0.03
Cr_2O_3	0.03	0.05	0.06	0.03	0.03	0.03	0.01	0.05	0.05	0.04	0.05	0.02	0.11	0.02	0.01
H_2O +	1.78	2.38	2.77	3.64	3.22	1.76	1.14	1.91	2.00	3.66	4.00	4.52	5.36	4.47	0.85
H_2O–	0.20	0.39	0.46	0.74	0.30	0.16	1.10	0.38	0.39	0.57	0.70	0.81	1.26	5.37	0.04
CO_2	0.48	0.22	0.15	0.23	0.06	0.03	-	0.64	0.46	0.30	0.26	0.12	0.11	0.05	-
TOTAL	99.63	99.63	99.81	99.59	100.00	99.86	99.88	99.20	99.27	99.05	99.76	99.58	99.69	99.15	99.97

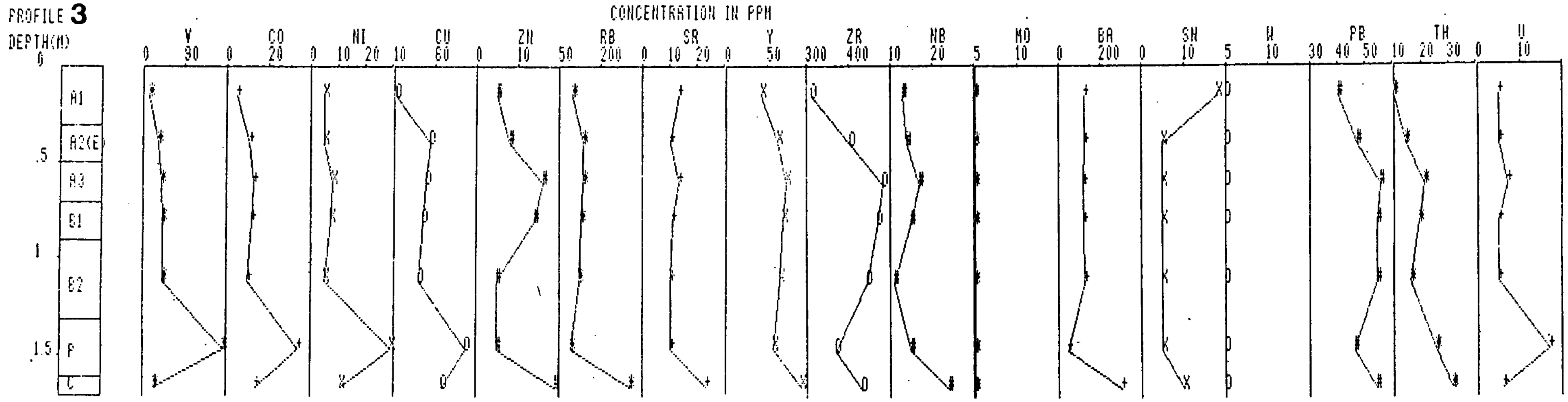
APPENDIX E: THE TRACE ELEMENT DISPERSION PATTERNS IN 32 SOIL PROFILES (bulk samples).

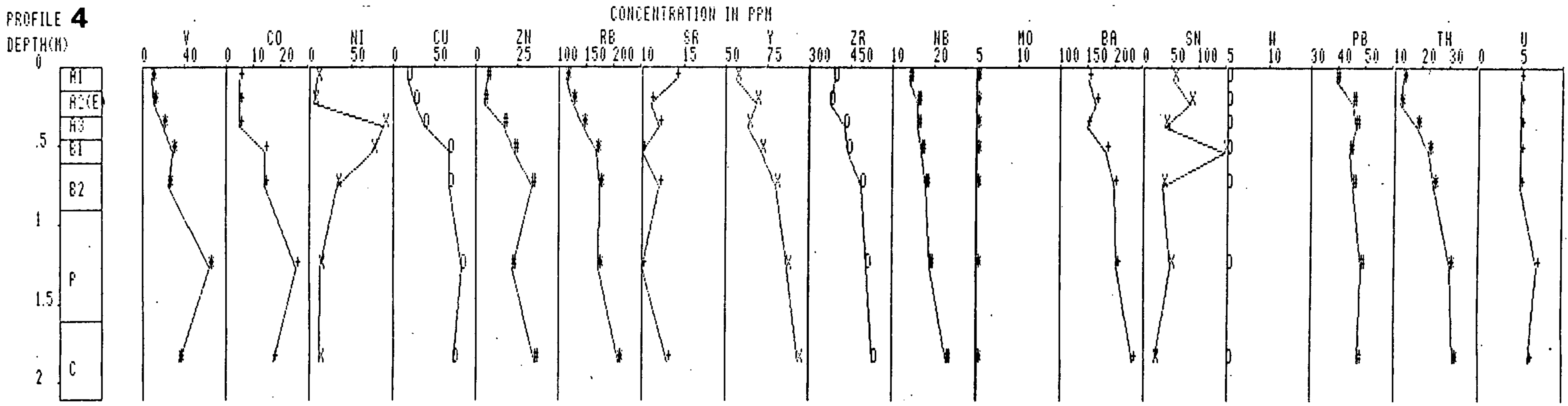
APPENDIX E: (CONTINUED)



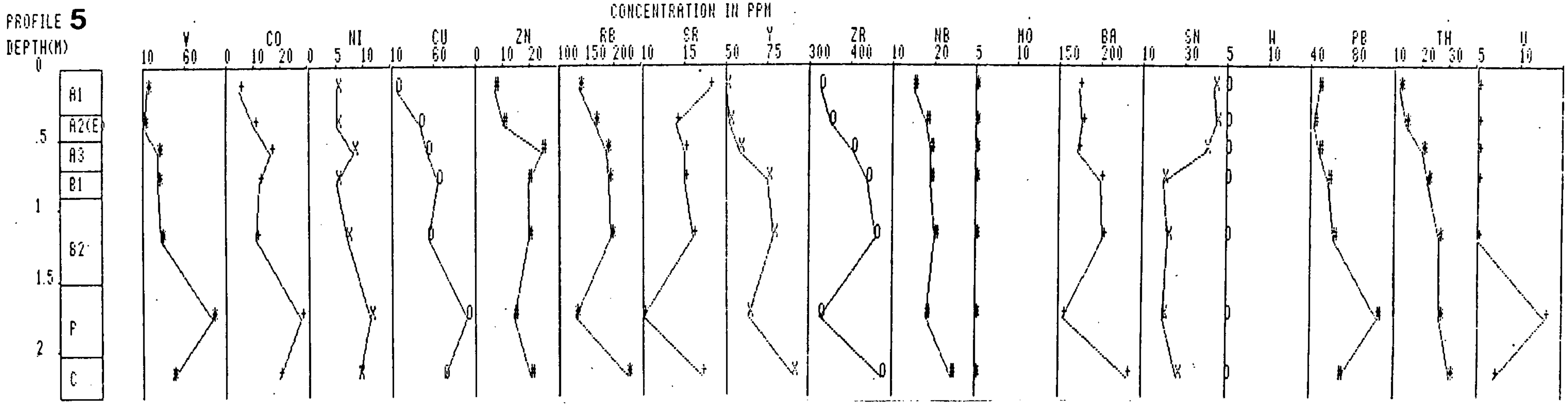


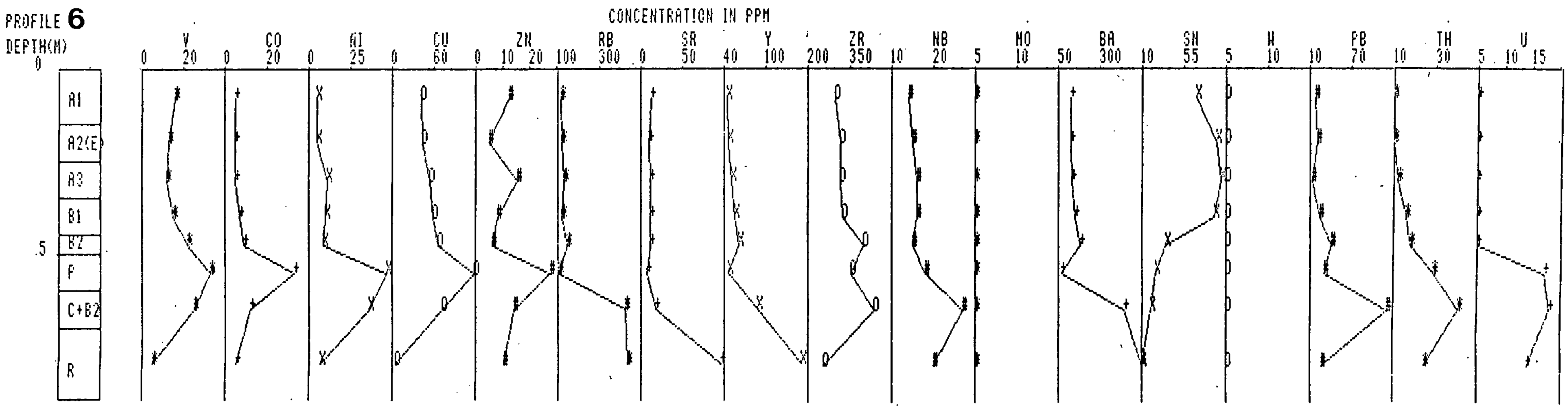
APPENDIX E: (CONTINUED)



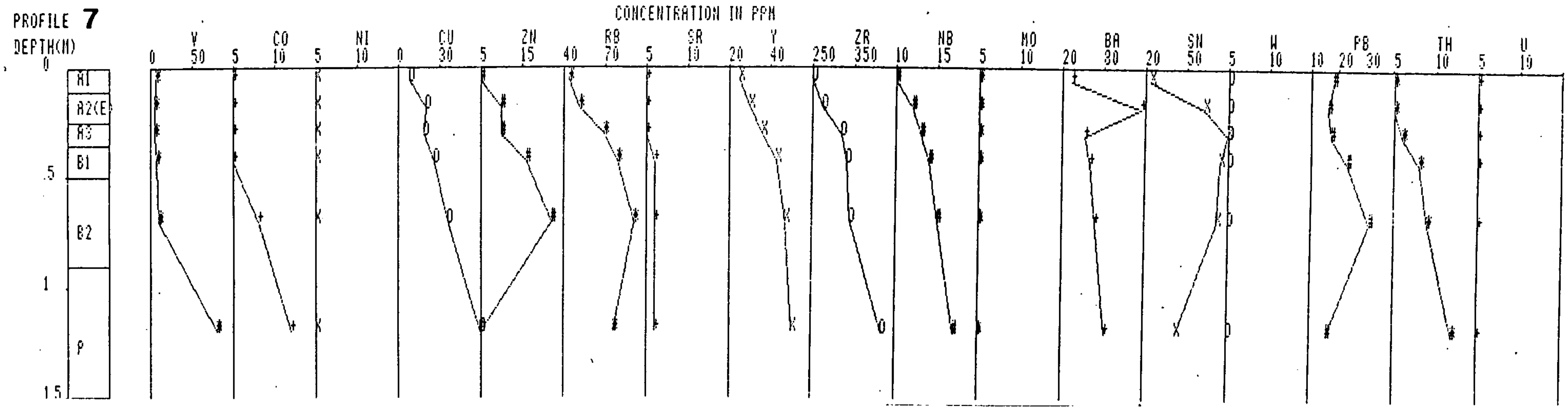


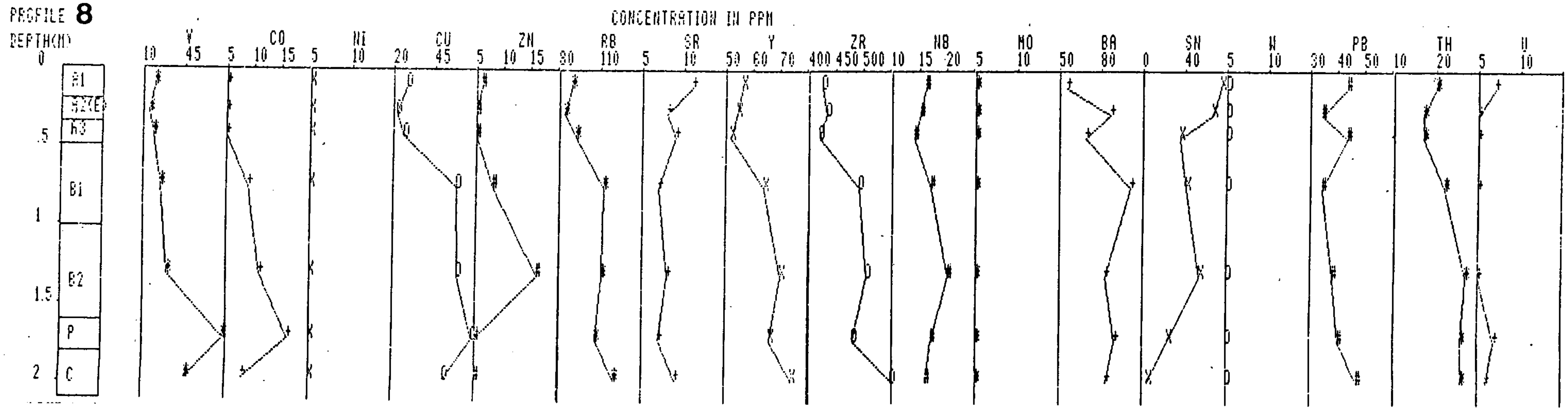
APPENDIX E: (CONTINUED)



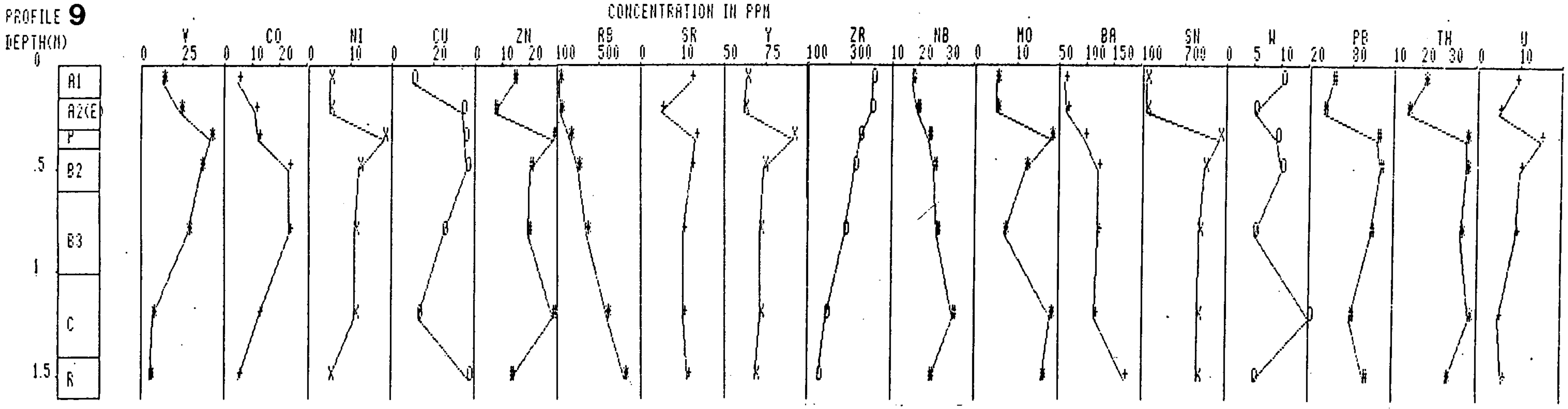


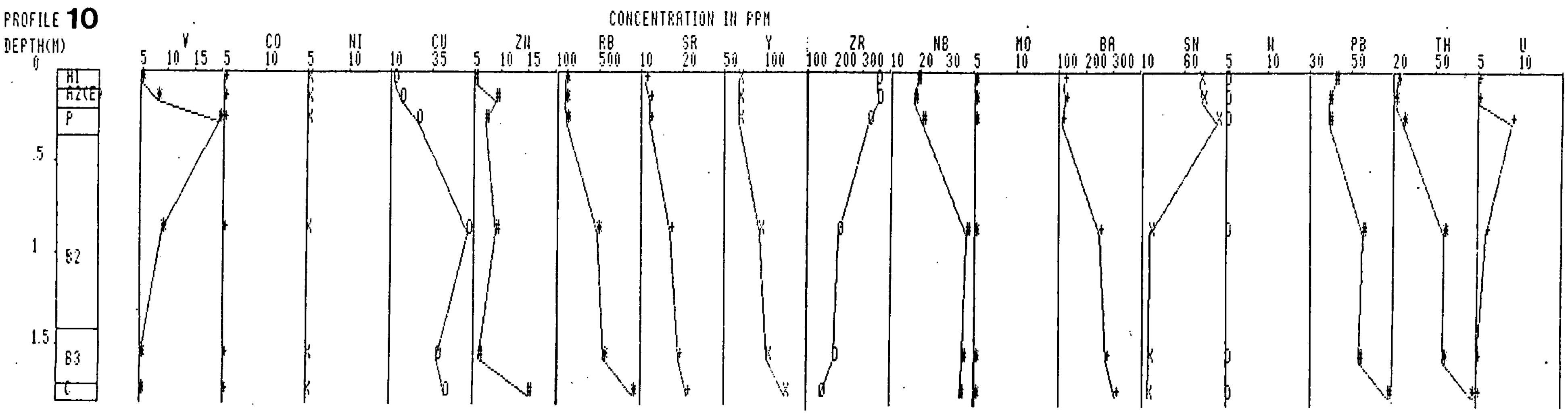
APPENDIX E: (CONTINUED)



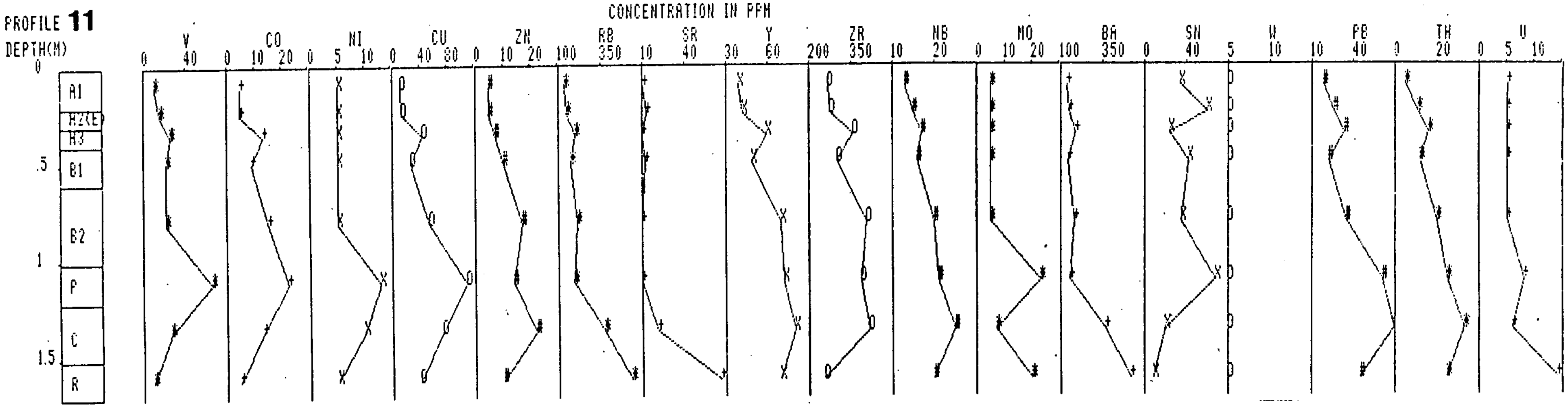


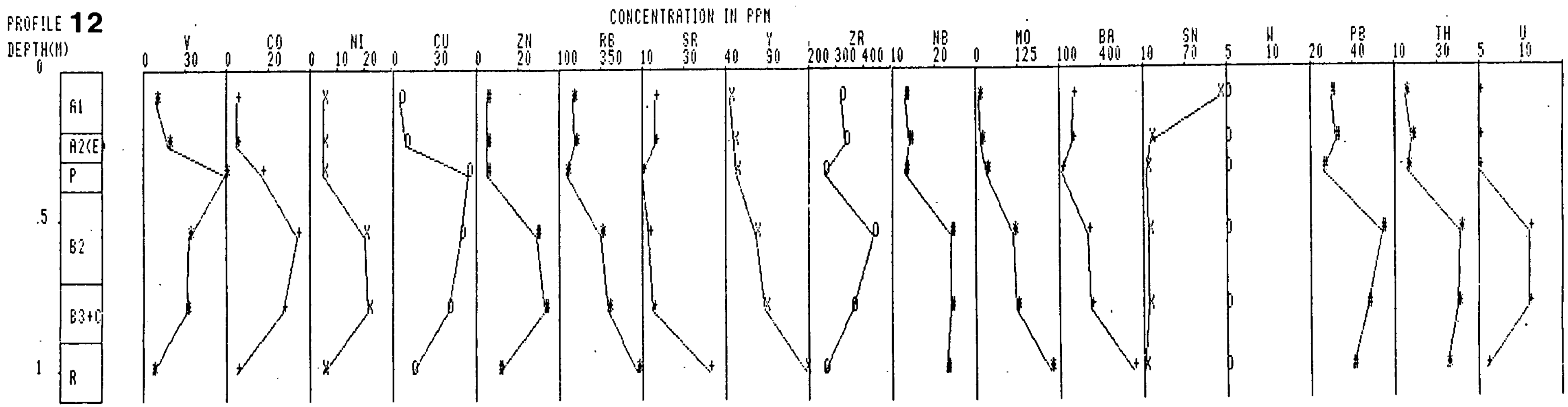
APPENDIX E: (CONTINUED)



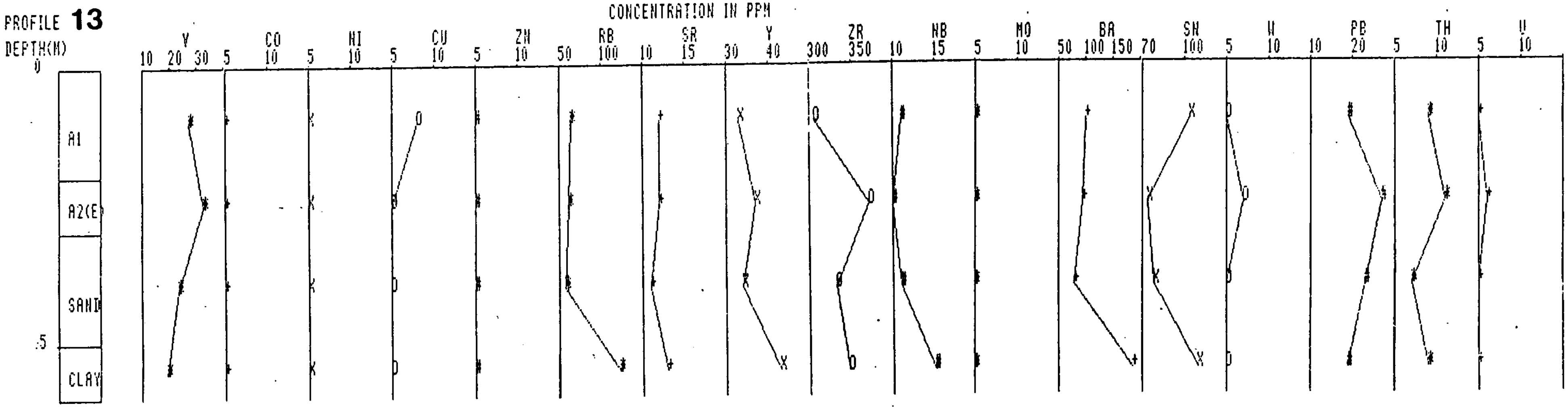


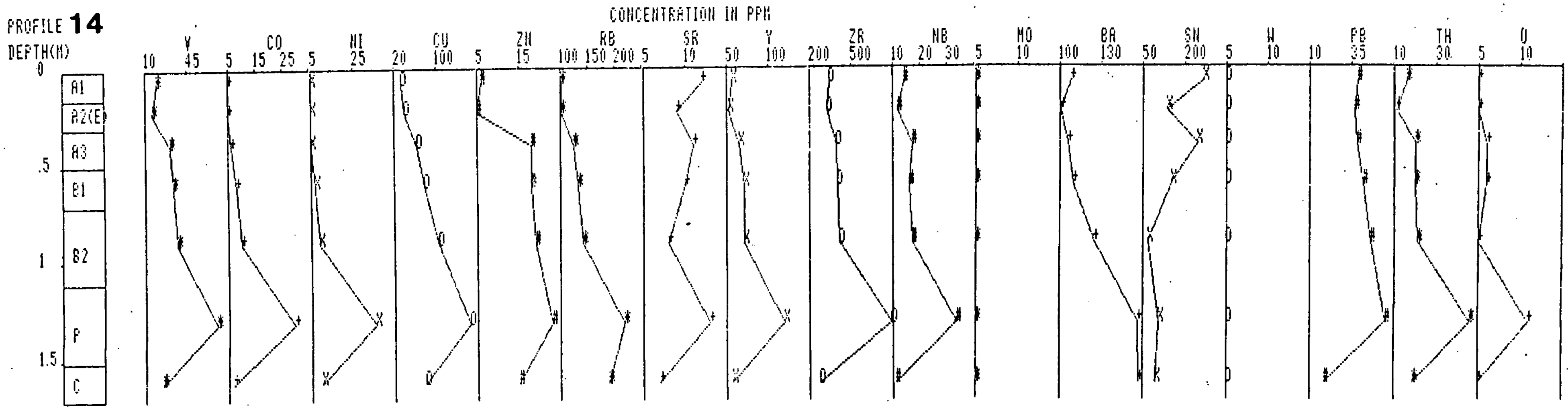
APPENDIX E: (CONTINUED)





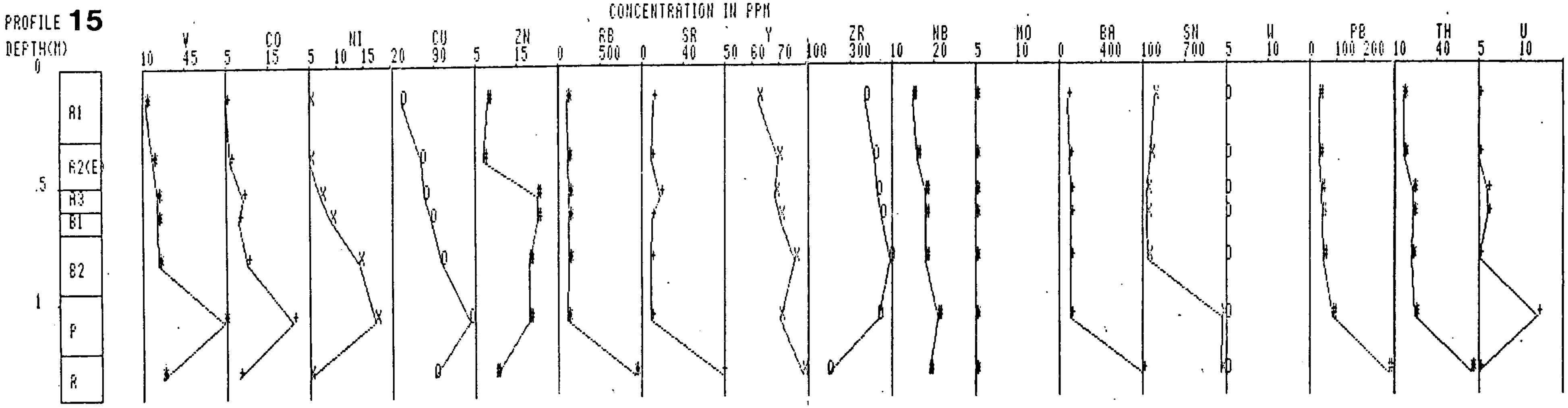
APPENDIX E: (CONTINUED)



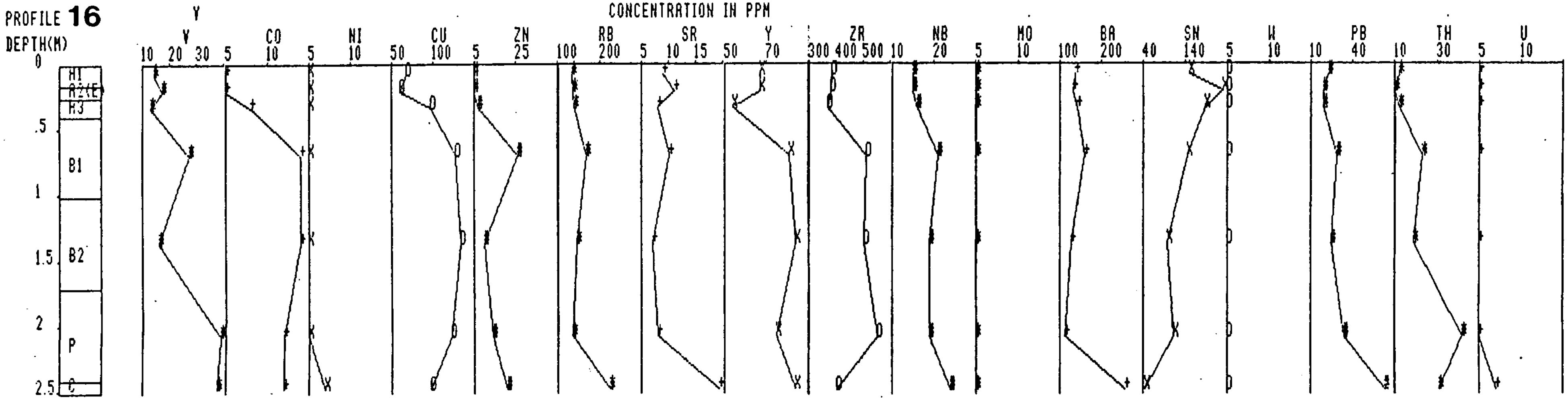


APPENDIX E: (CONTINUED)

PROFILE 15

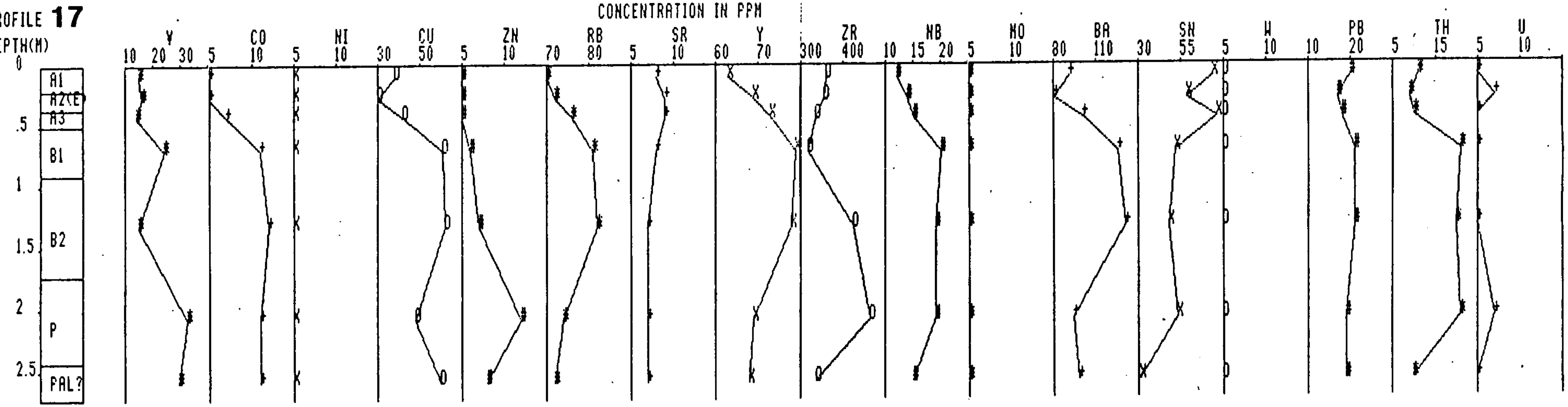


PROFILE 16

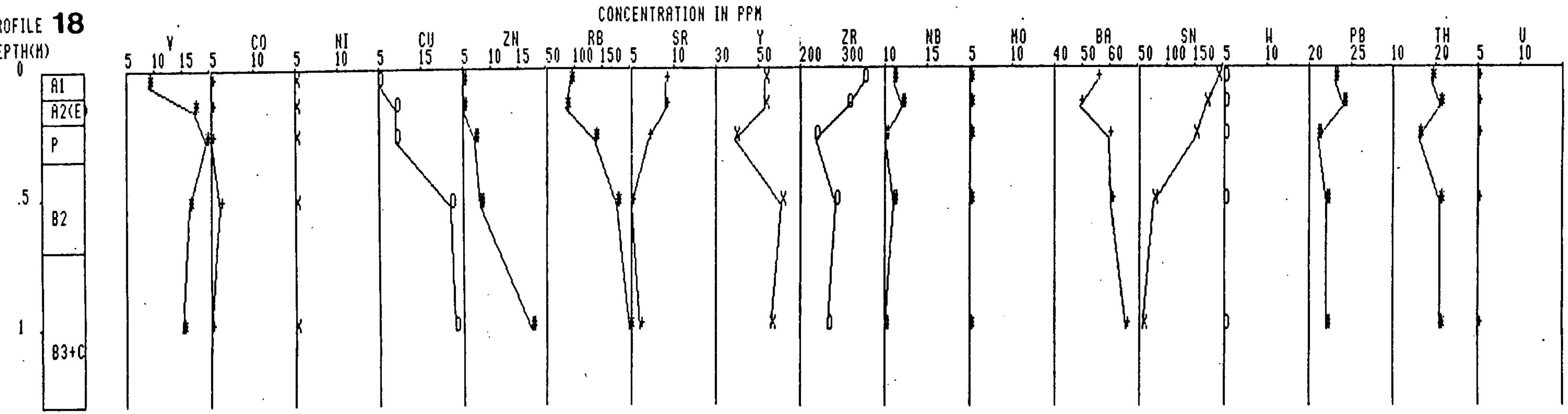


APPENDIX E: (CONTINUED)

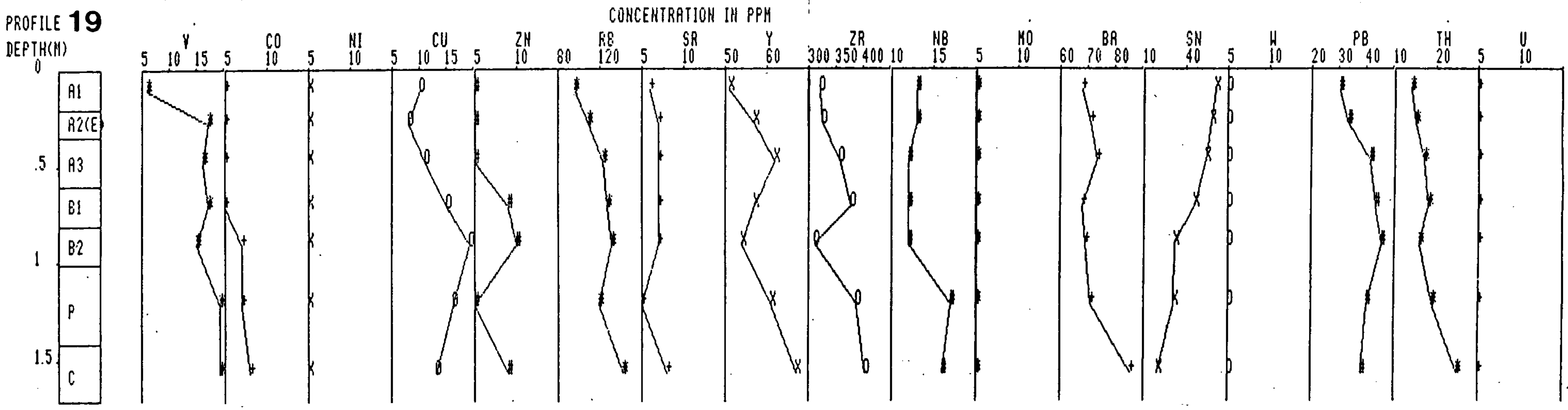
PROFILE **17**

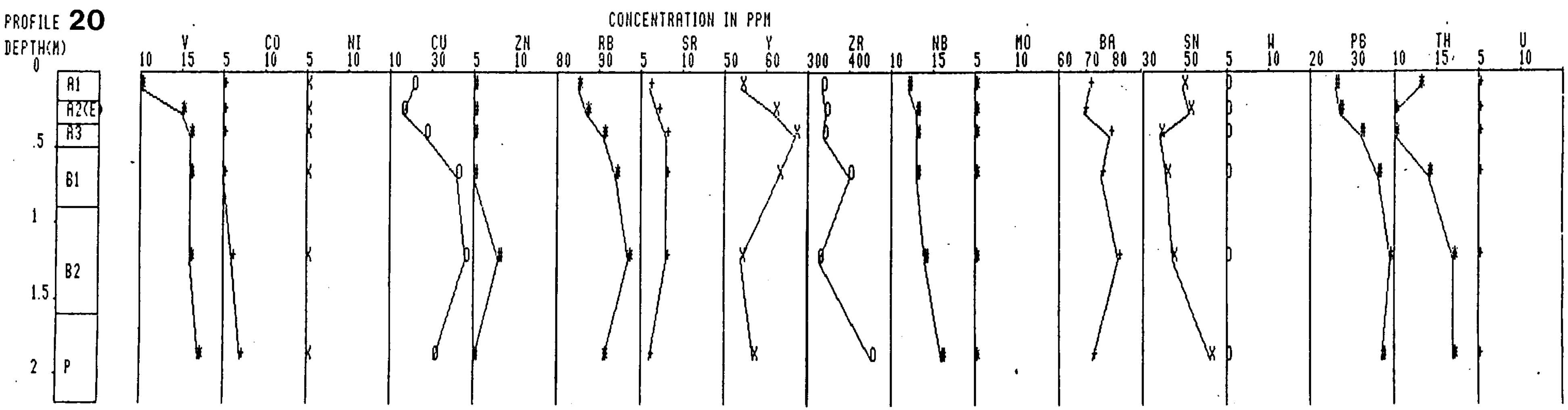


PROFILE **18**

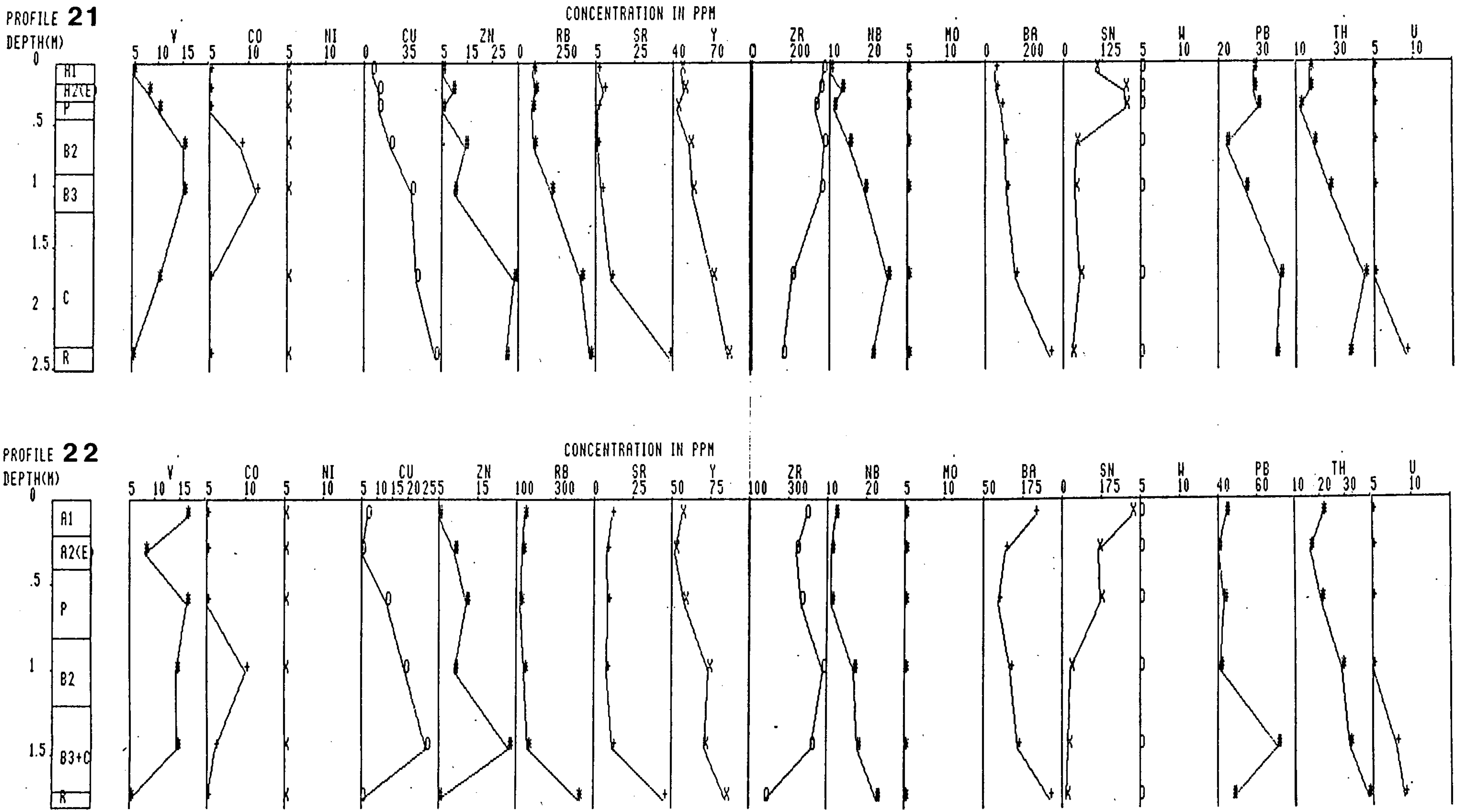


APPENDIX E: (CONTINUED)



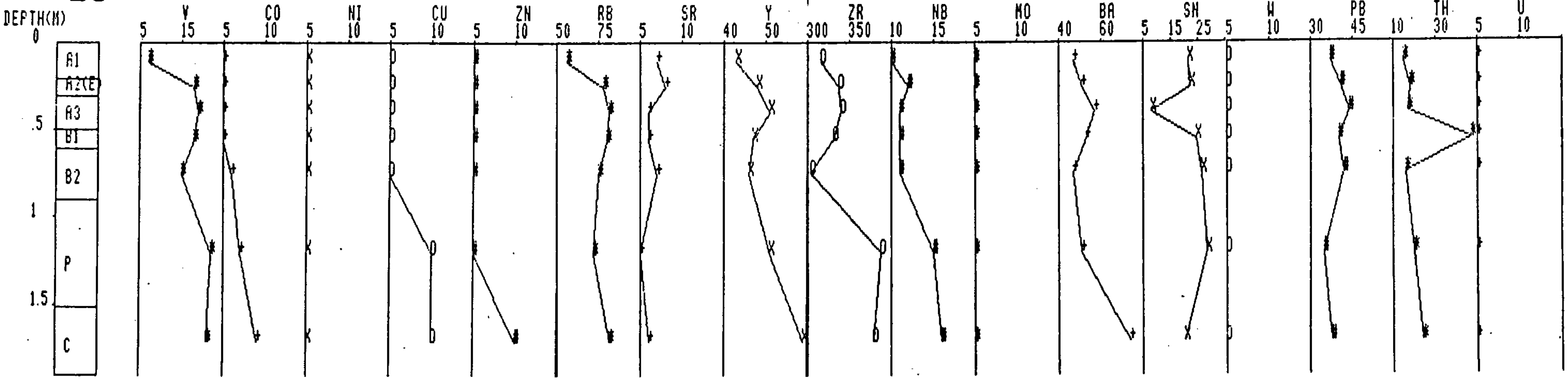


APPENDIX E: (CONTINUED)

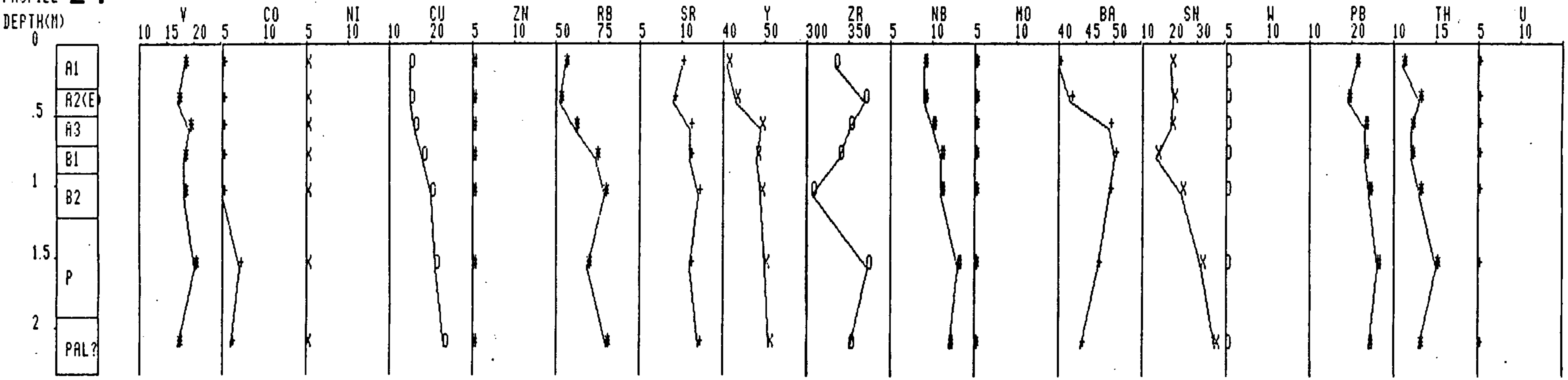


APPENDIX E: (CONTINUED)

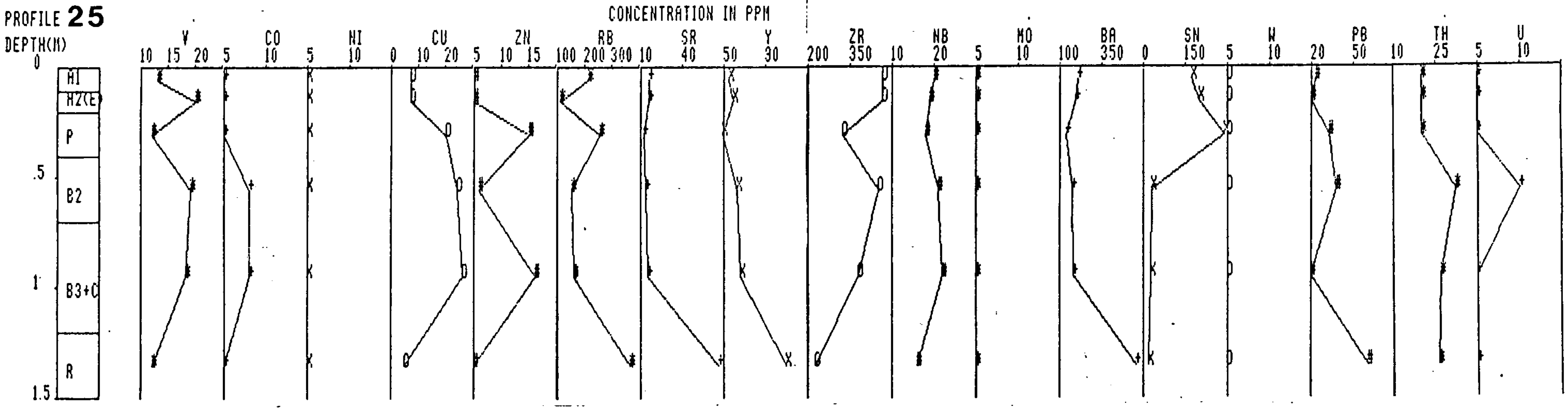
PROFILE 23

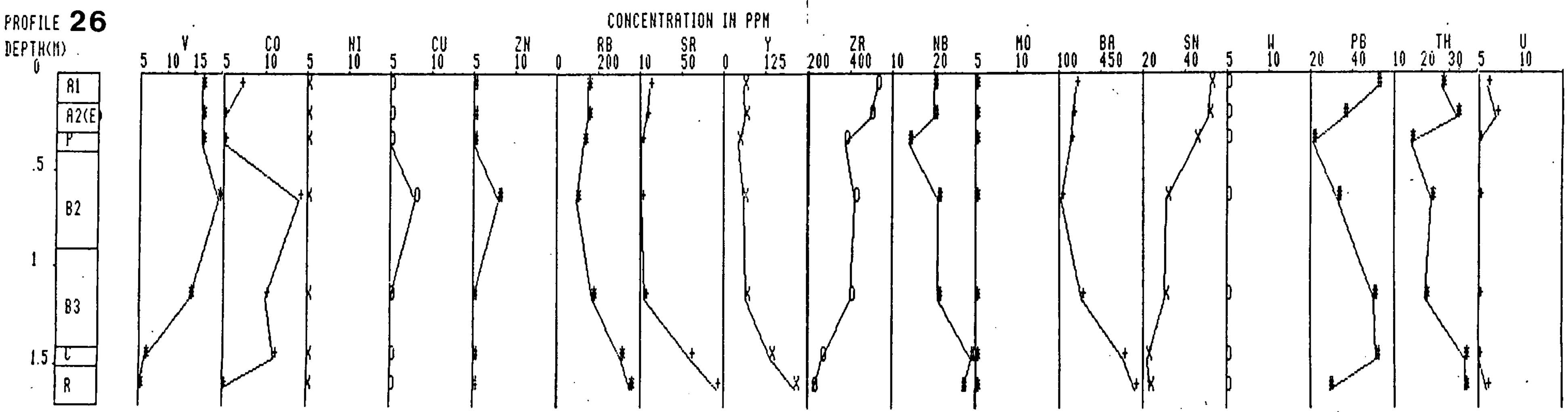


PROFILE 24

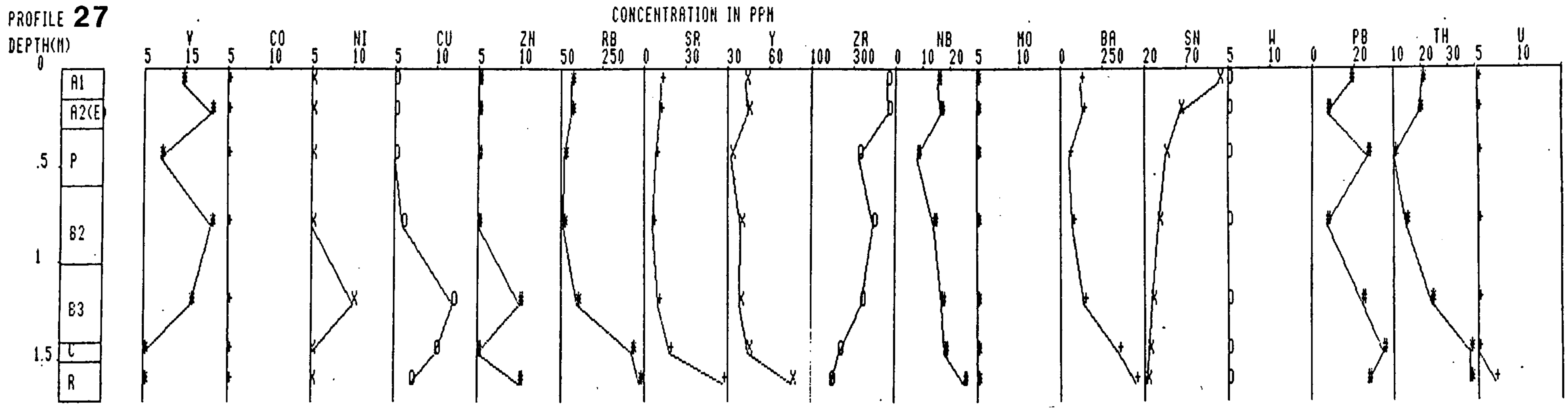


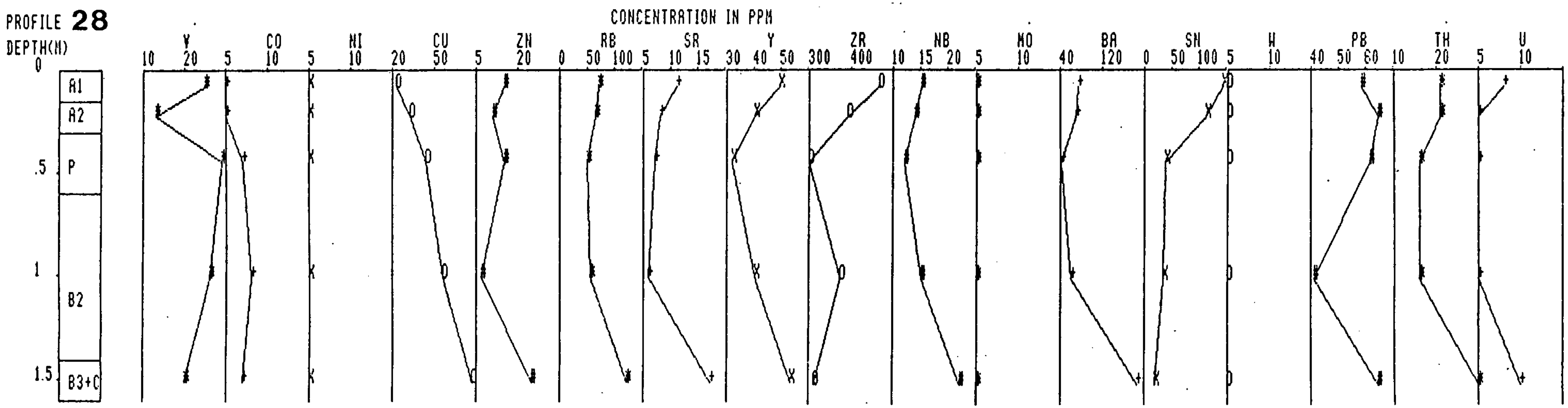
APPENDIX E: (CONTINUED)



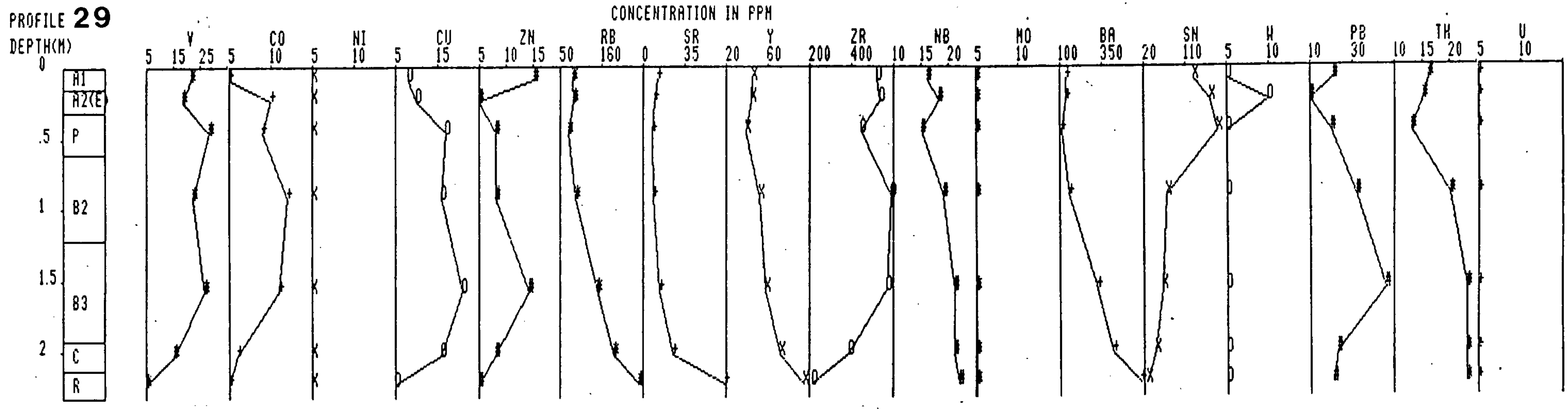


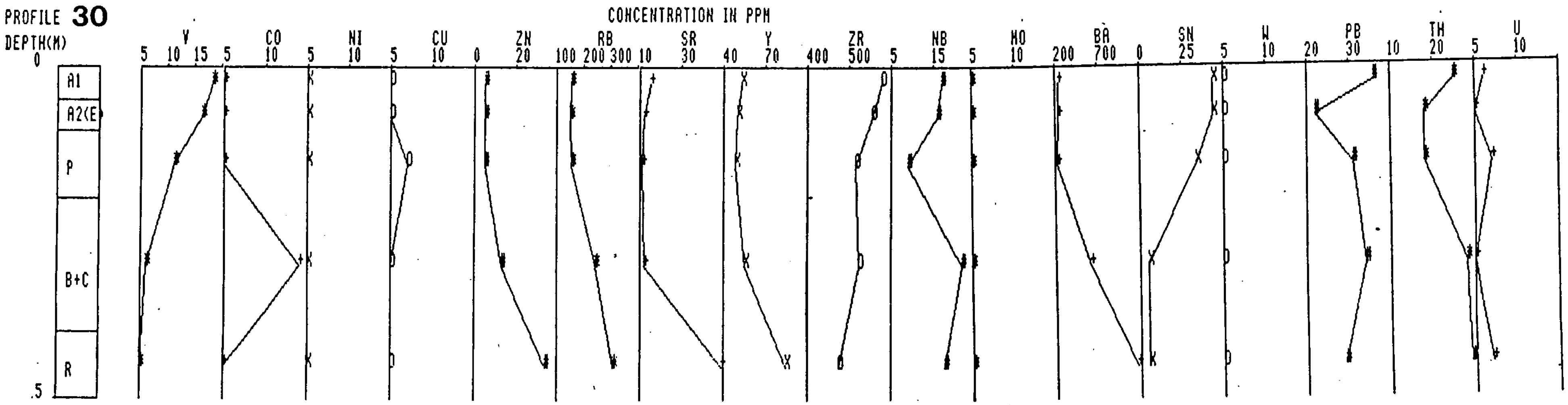
APPENDIX E: (CONTINUED)



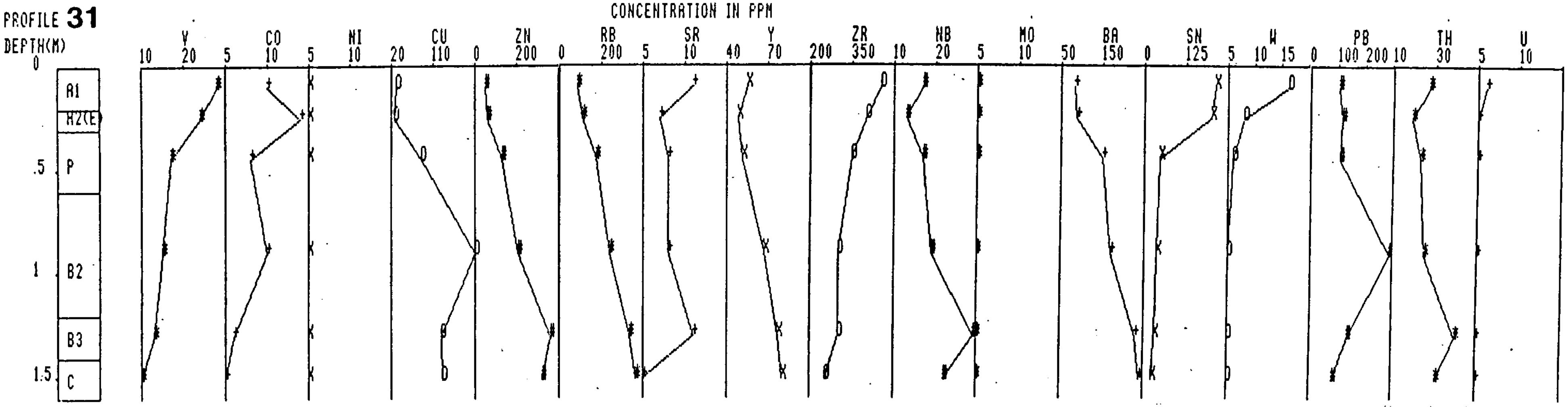


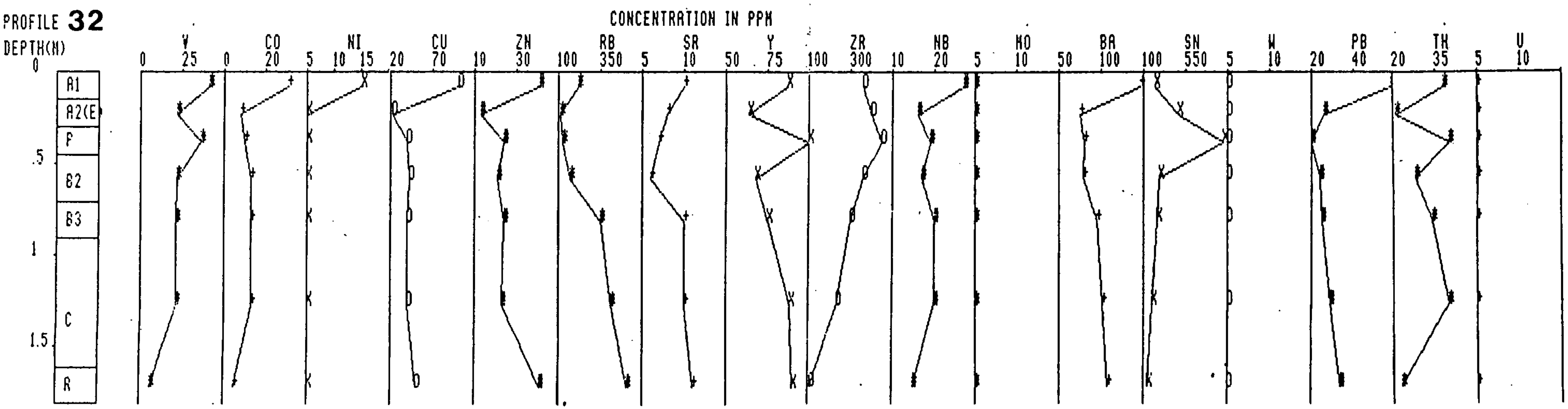
APPENDIX E: (CONTINUED)





APPENDIX E: (CONTINUED)





APPENDIX F: CORRELATION DIAGRAMS INDICATING THE Fe/Cu RELATIONSHIPS IN THE SIZE FRACTIONS OF EACH HORIZON.

NB !! - THE SAMPLES ON THE RIGHT HAND SIDE OF THE BROKEN LINE ARE KNOWN TO BE ANOMALOUS AND THEREFORE NOT TAKEN INTO CONSIDERATION FOR THE CALCULATION OF THE MEAN, STANDARD DEVIATION ETC.

(Fe = TOTAL Fe AS Fe_2O_3)

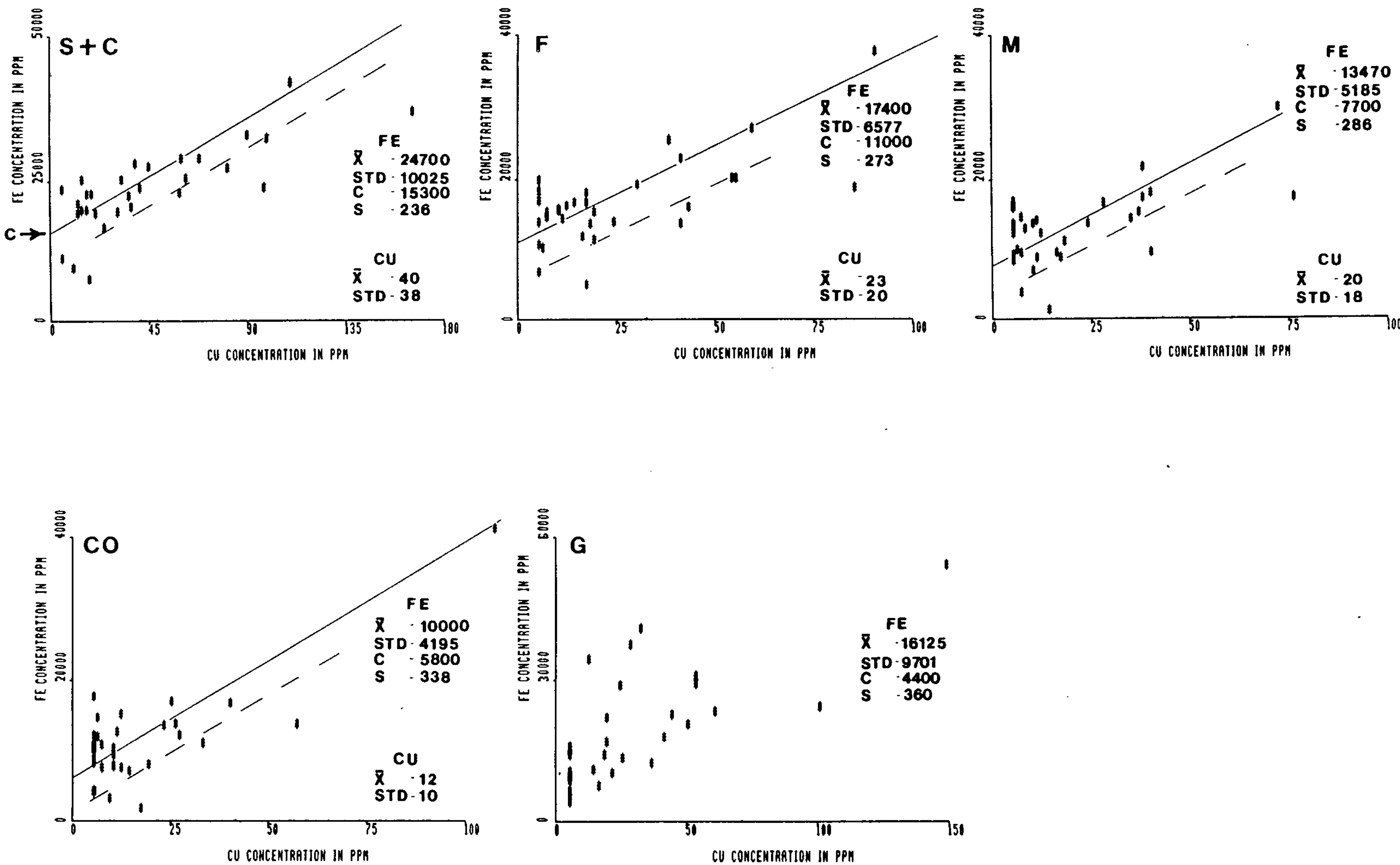
LEGEND

X = MEAN
STD = STANDARD DEVIATION
C = CUT OFF POINT
S = SORPTIVE CAPACITY OF Fe FOR CU
(Fe/Cu RATIO ABOVE THE CUT OFF POINT)

S+C = SILT PLUS CLAY FRACTION
F = FINE SAND FRACTION
M = MEDIUM SAND FRACTION
CO = COARSE SAND FRACTION
G = GRAVEL FRACTION

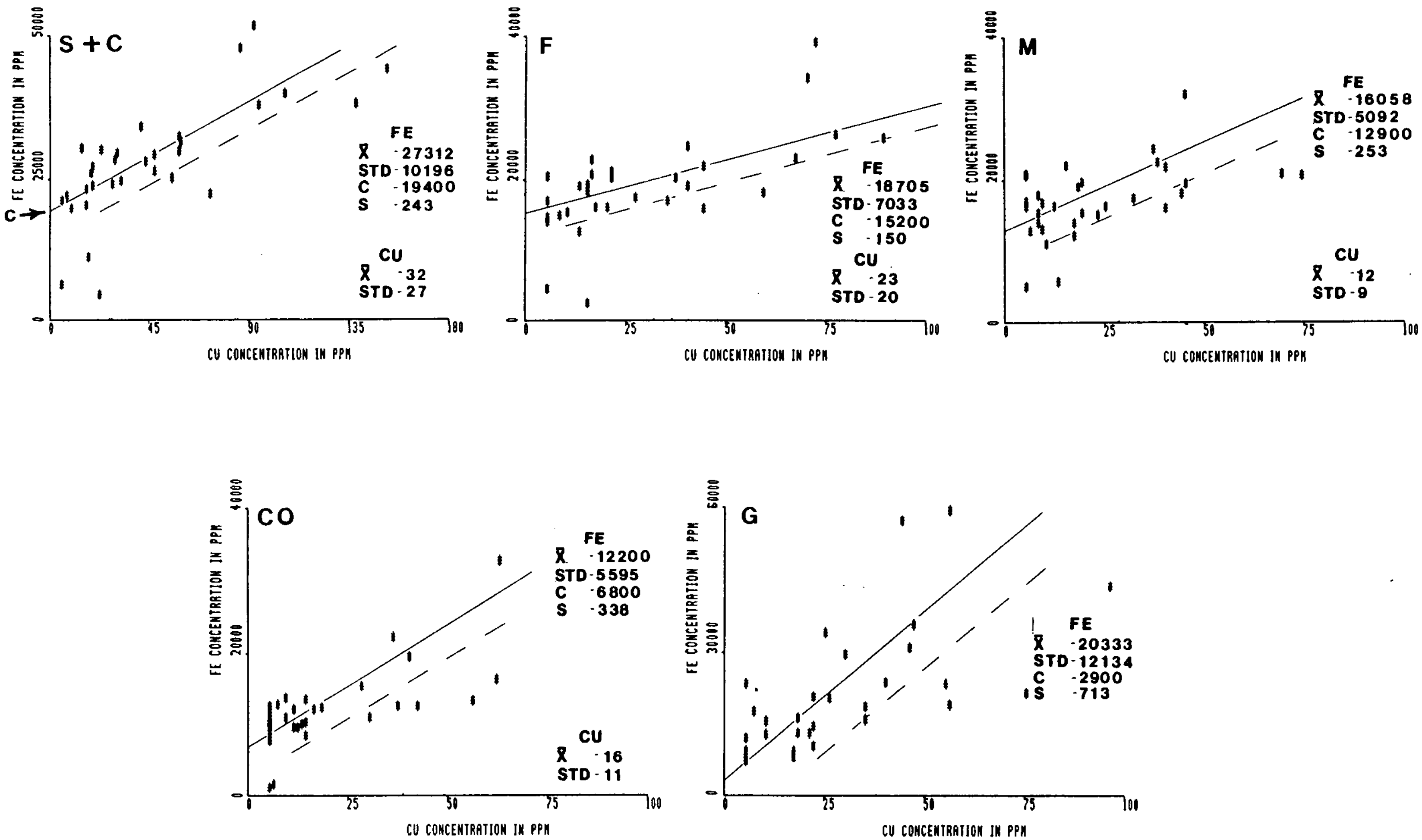
APPENDIX F: (CONTINUED)

A1



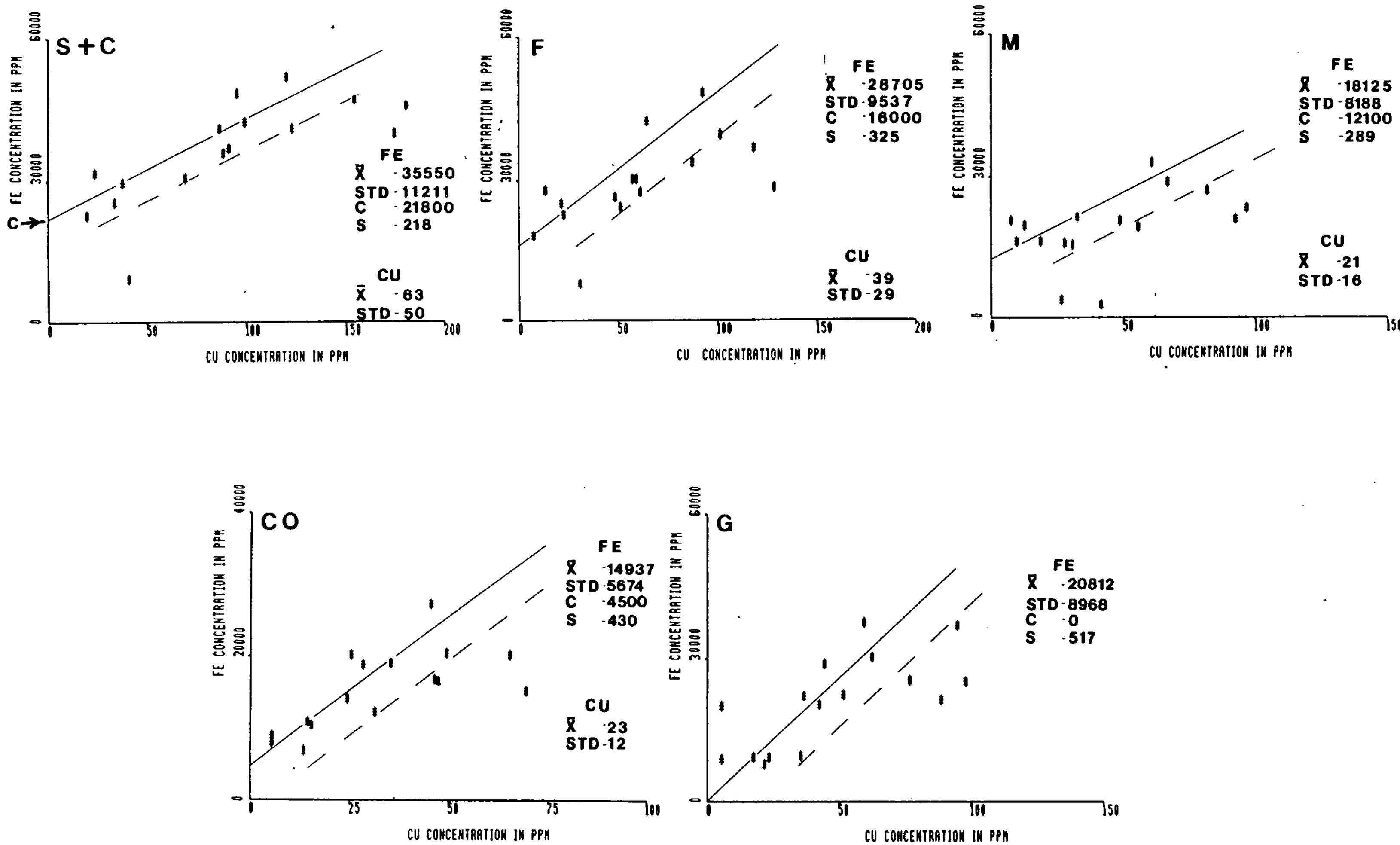
APPENDIX F: (CONTINUED)

A_2



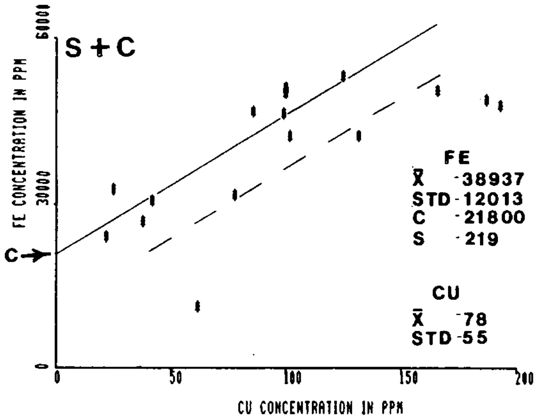
APPENDIX F: (CONTINUED)

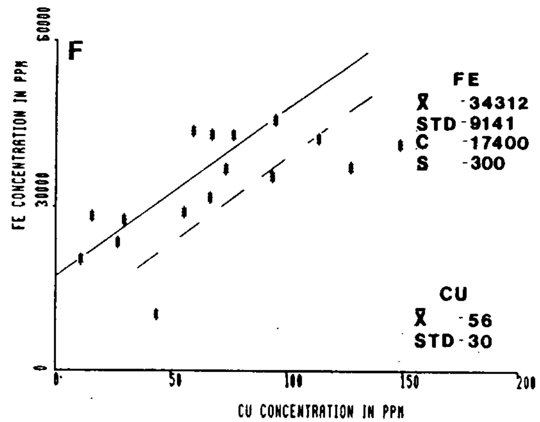
A3

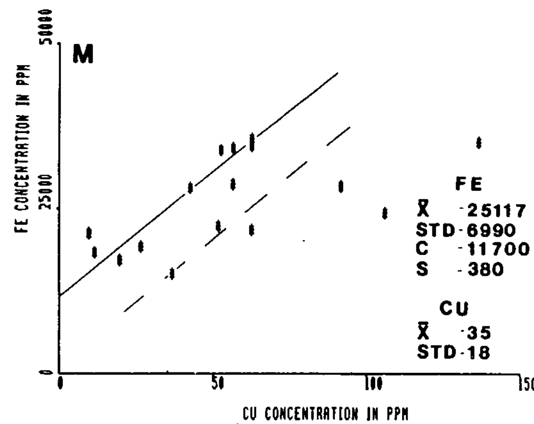


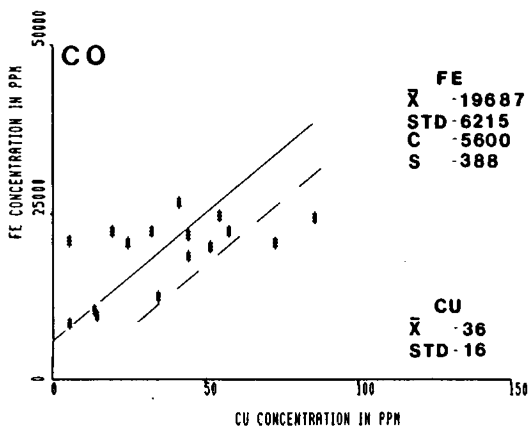
APPENDIX F: (CONTINUED)

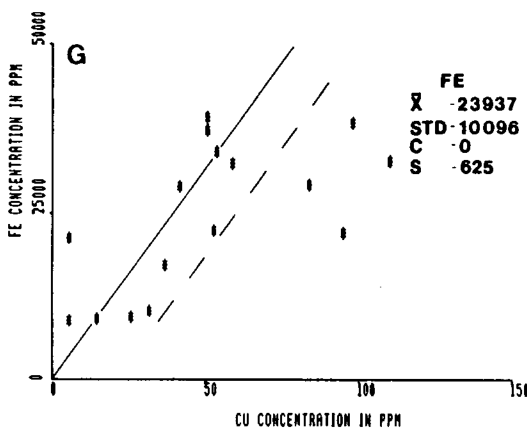
B_1





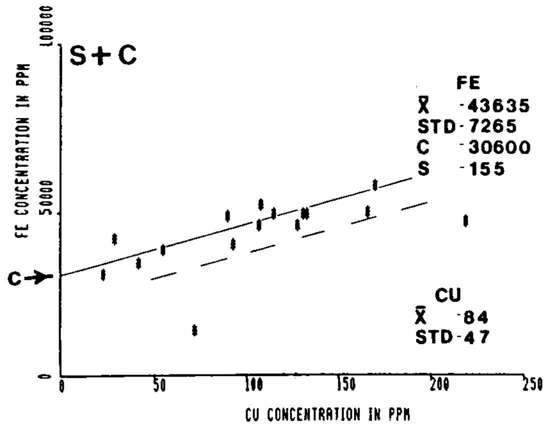


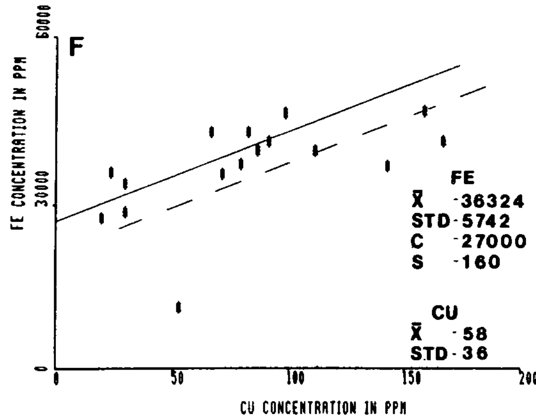


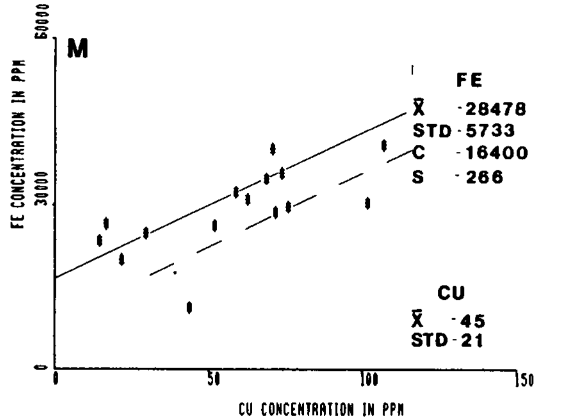


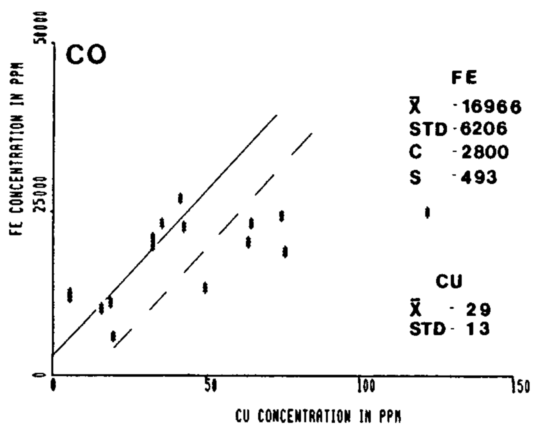
APPENDIX F: (CONTINUED)

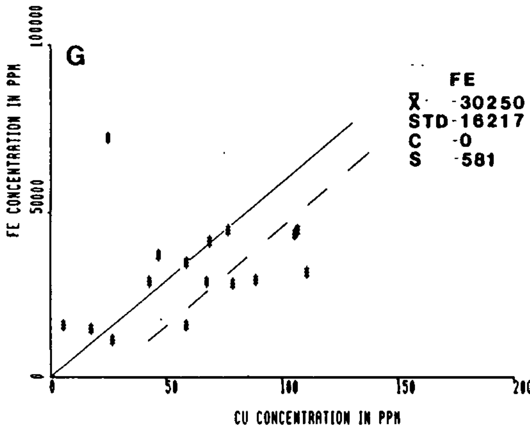
B_2(T)





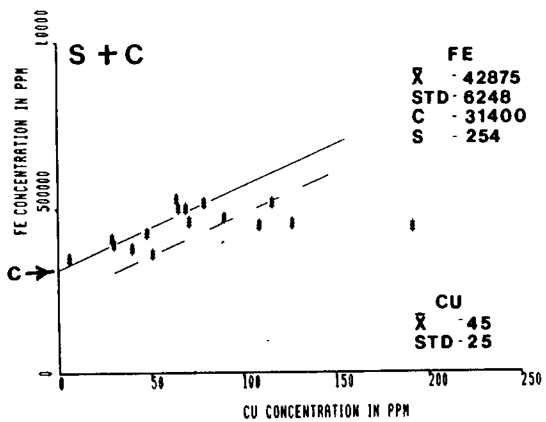


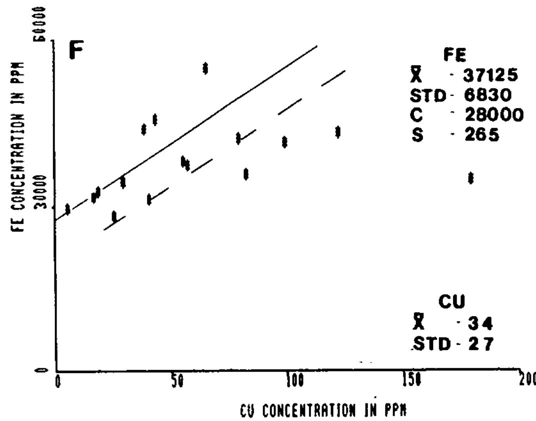


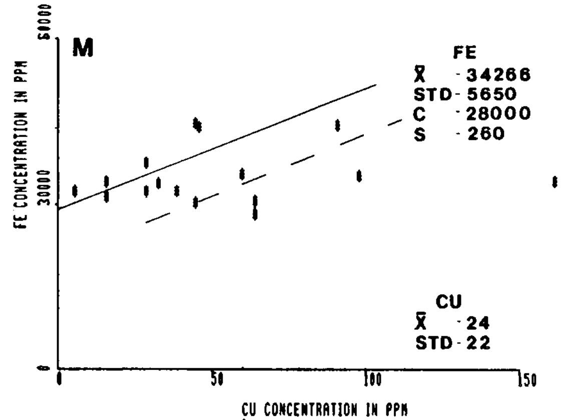


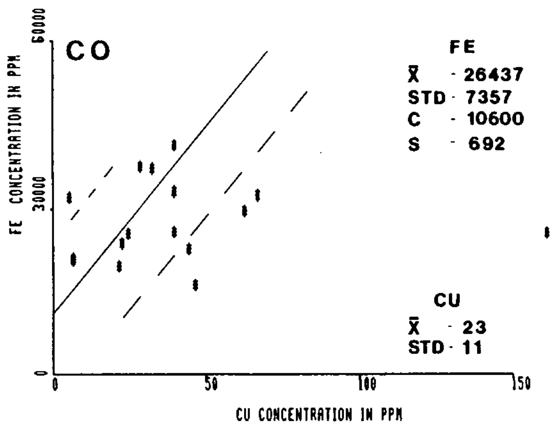
APPENDIX F: (CONTINUED)

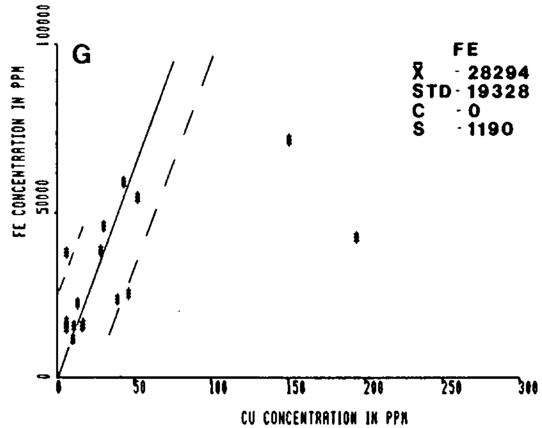
B_2 (R)





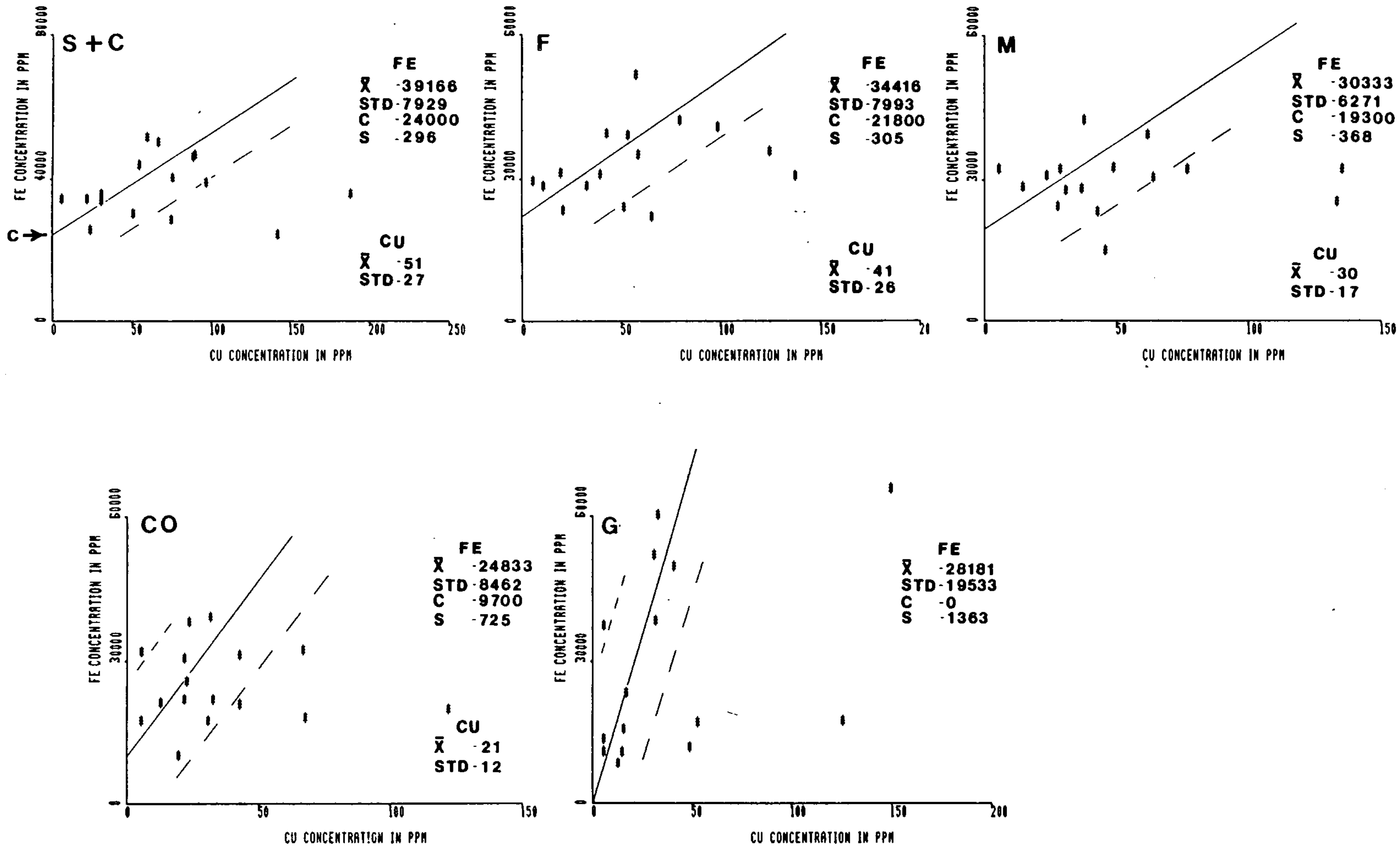






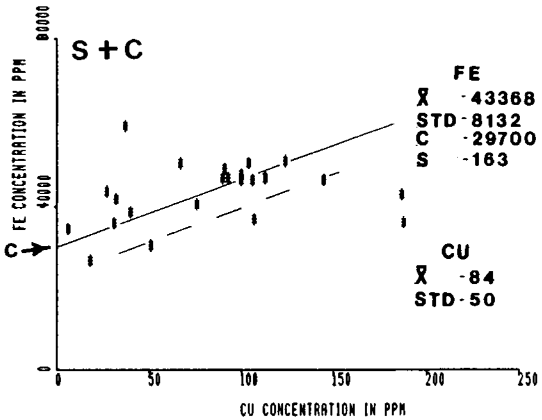
APPENDIX F: (CONTINUED)

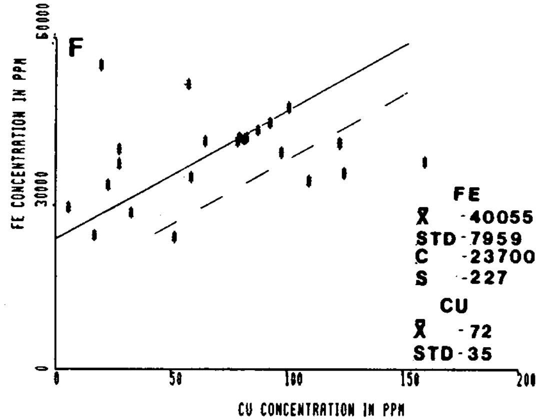
B_3

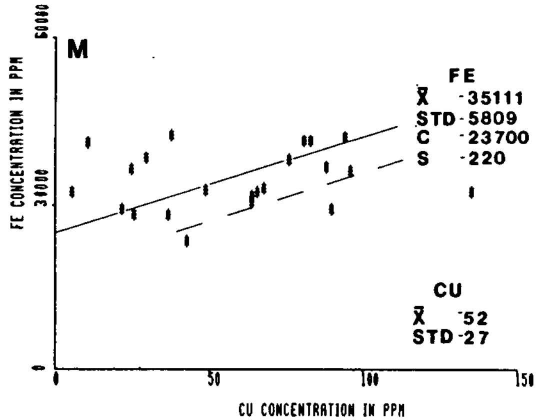


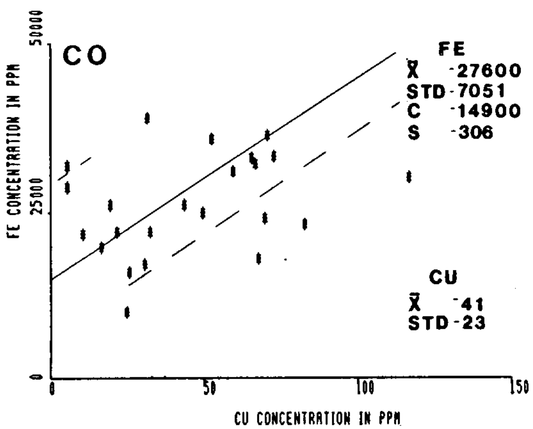
APPENDIX F: (CONTINUED)

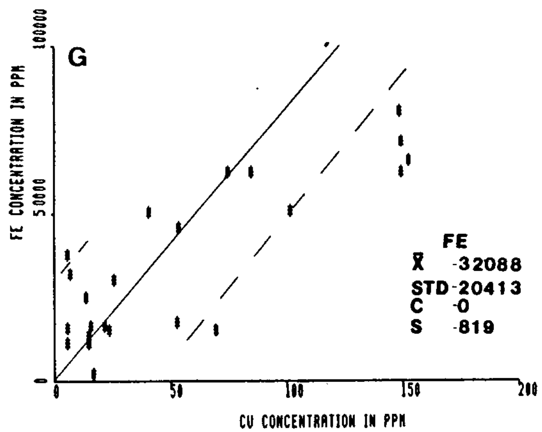
C





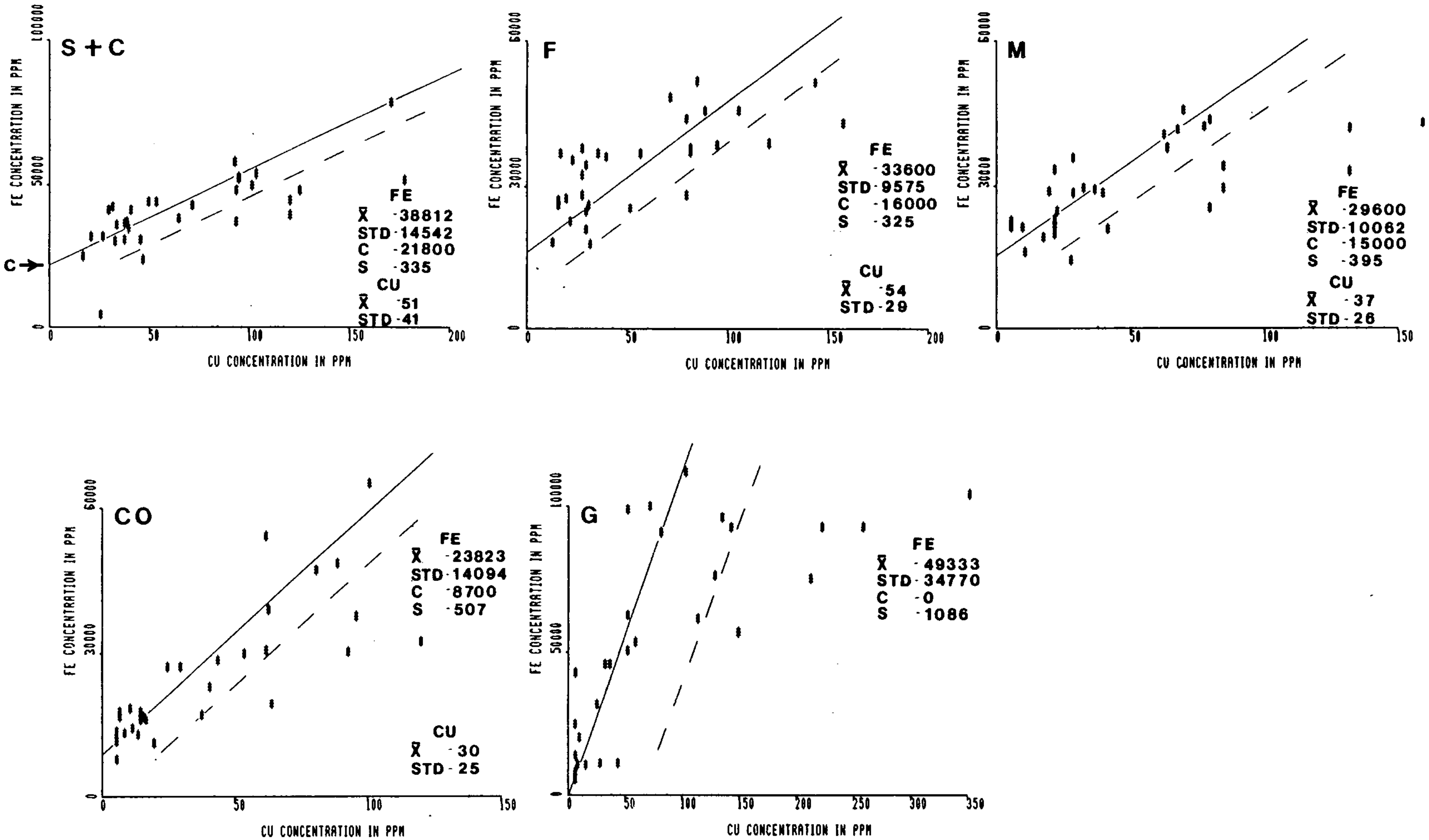






APPENDIX F: (CONTINUED)

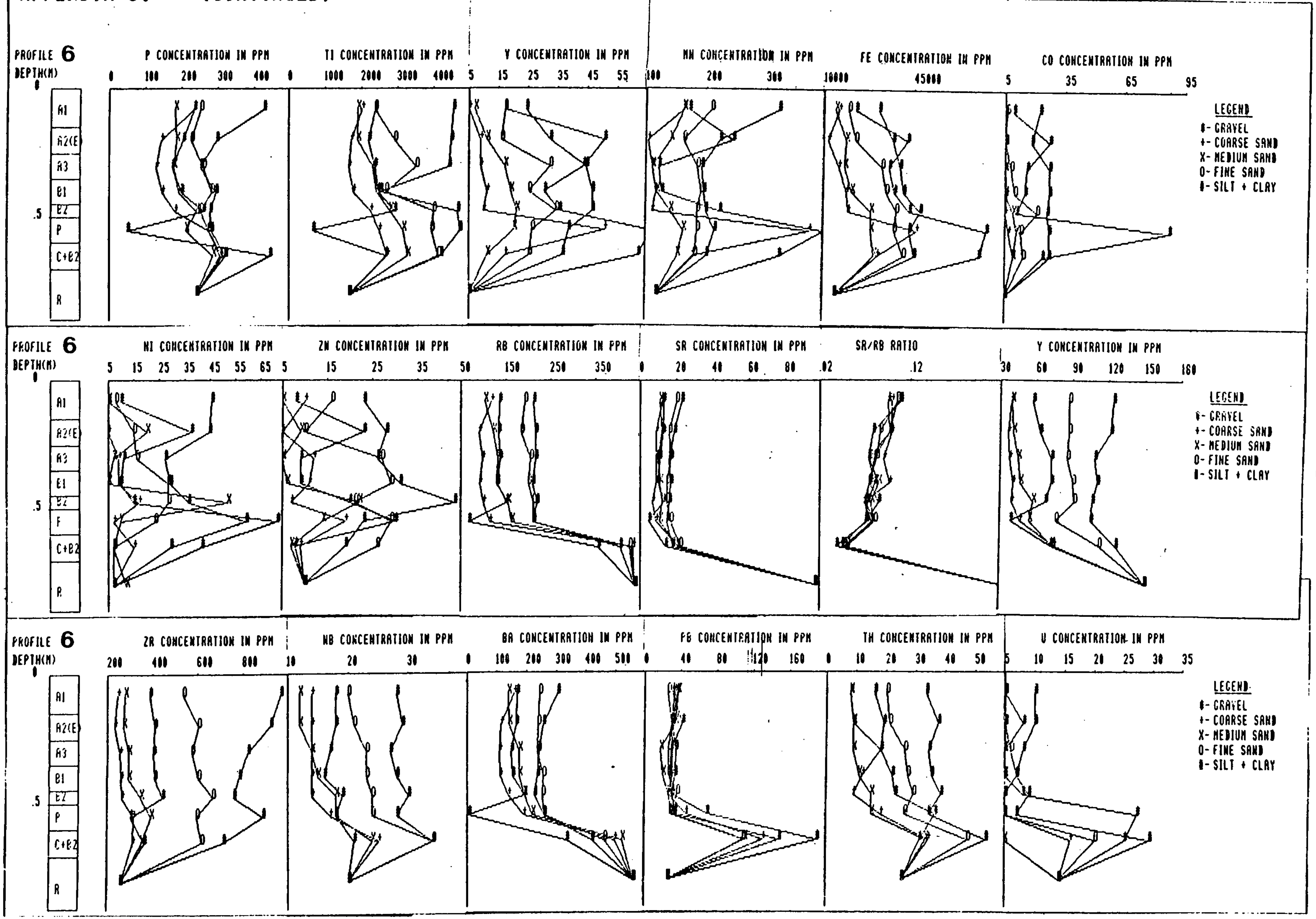
P



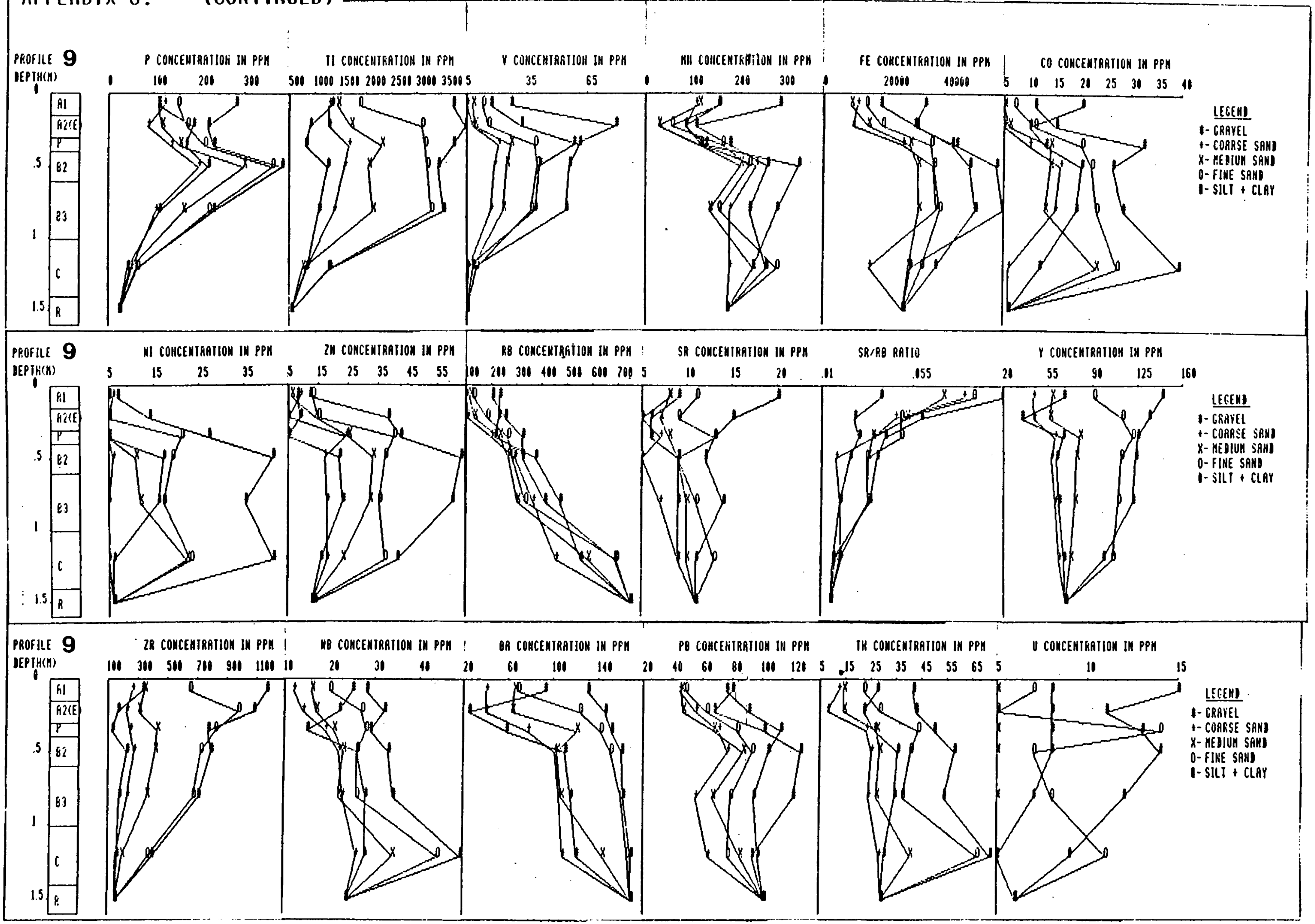
APPENDIX G: THE TRACE ELEMENT DISPERSION PATTERNS IN SIZE FRACTIONS IN 7 SOIL PROFILES.

(Fe = TOTAL Fe AS Fe_2O_3)

APPENDIX G: (CONTINUED)



APPENDIX G: (CONTINUED)



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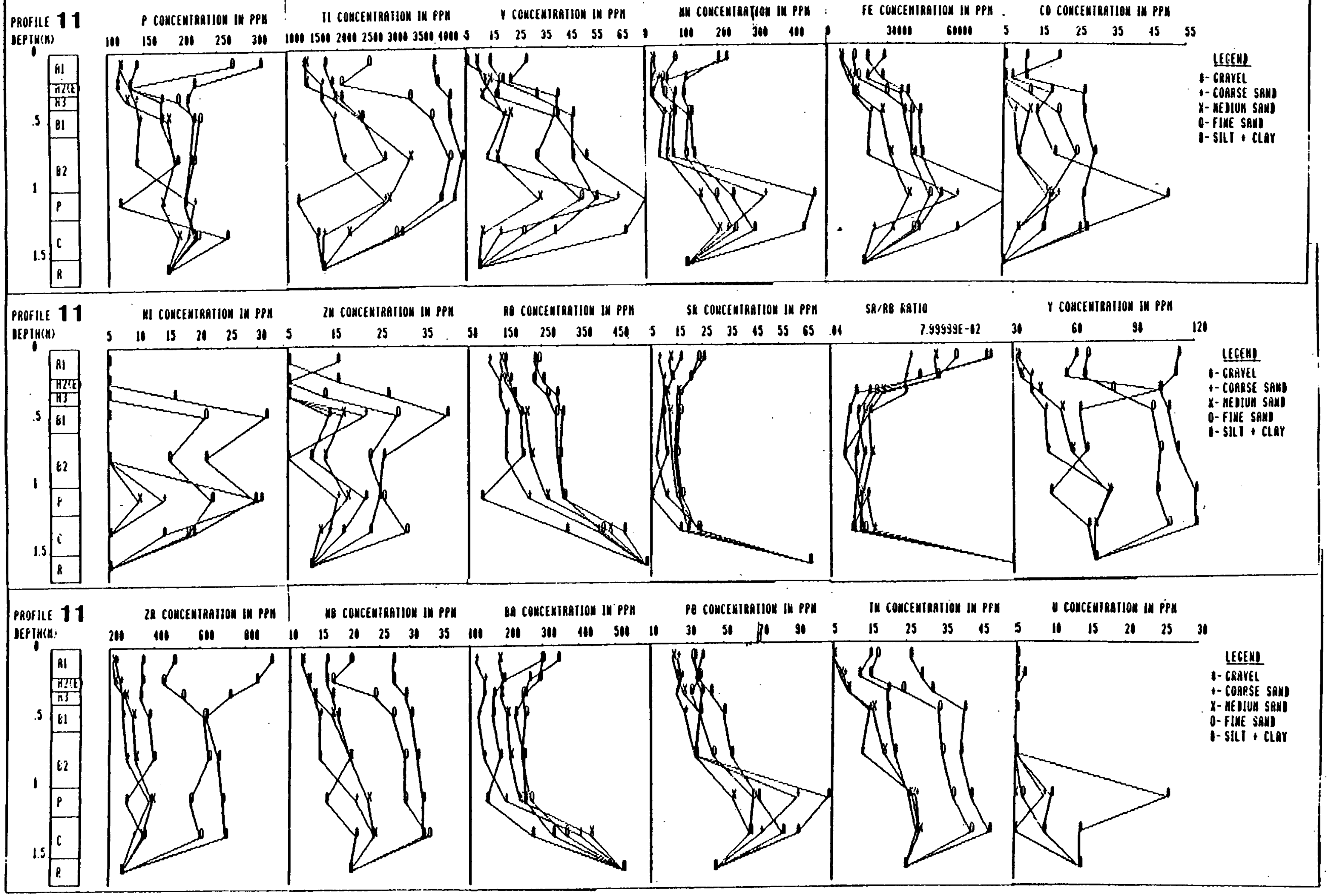
APPENDIX G: (CONTINUED)



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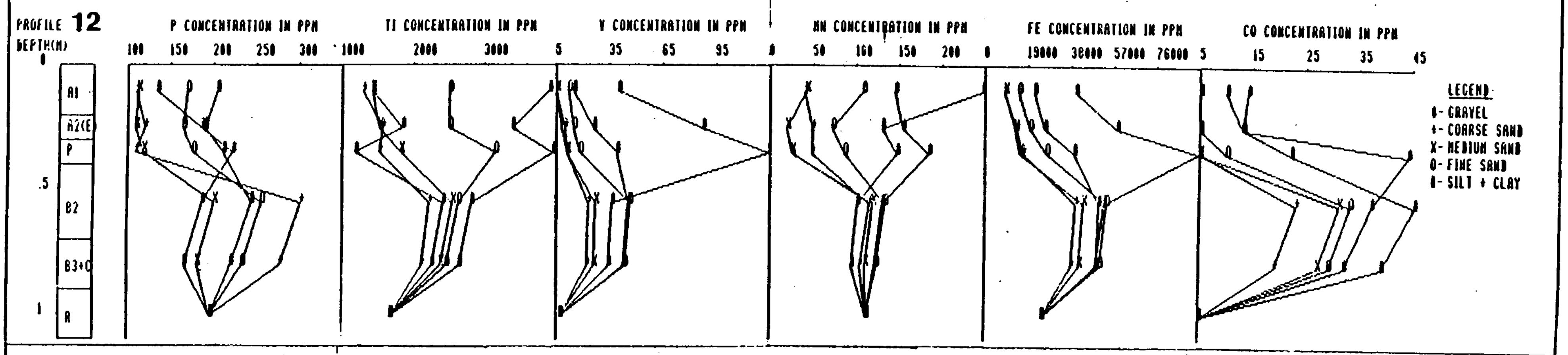
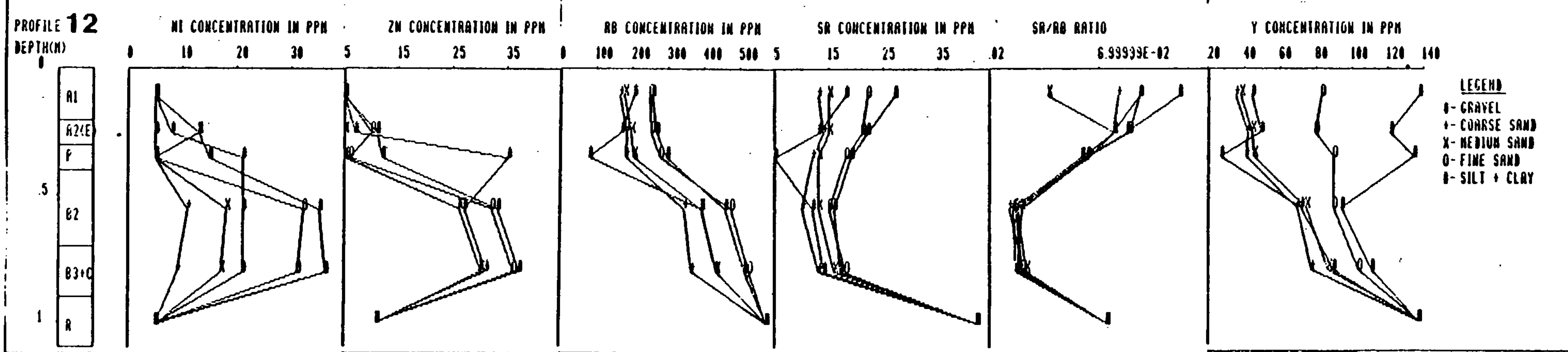
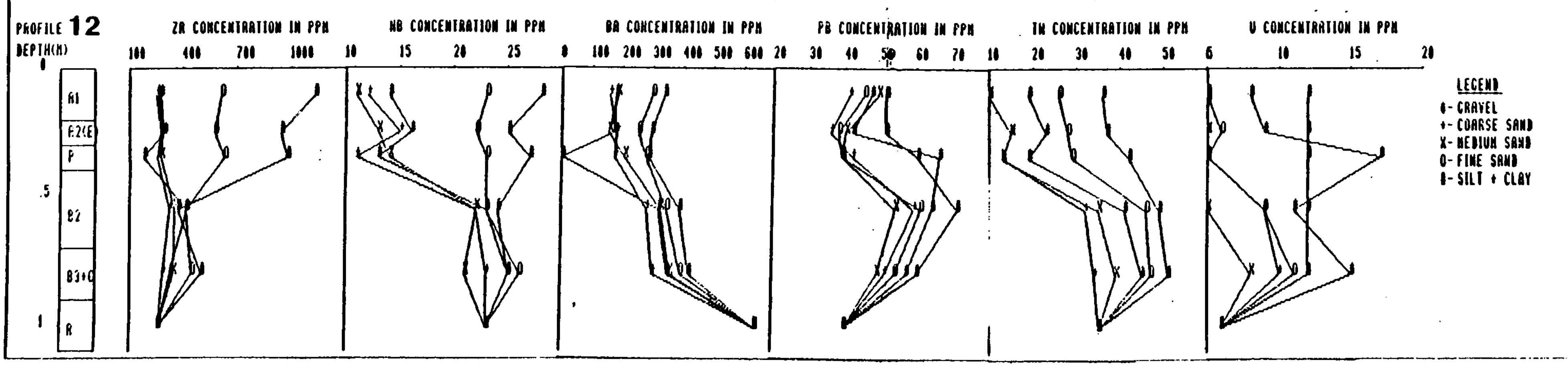
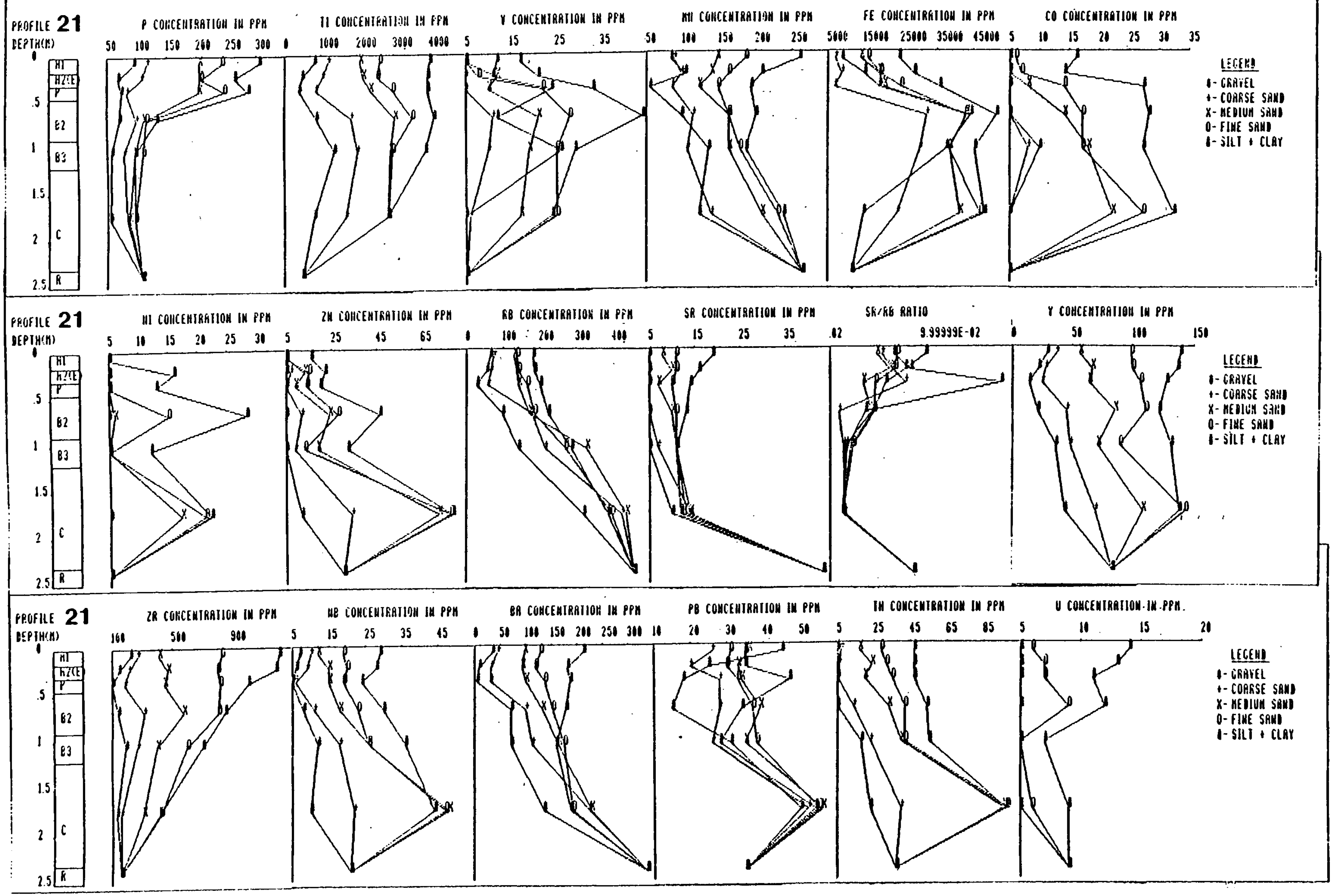
APPENDIX G: (CONTINUED)



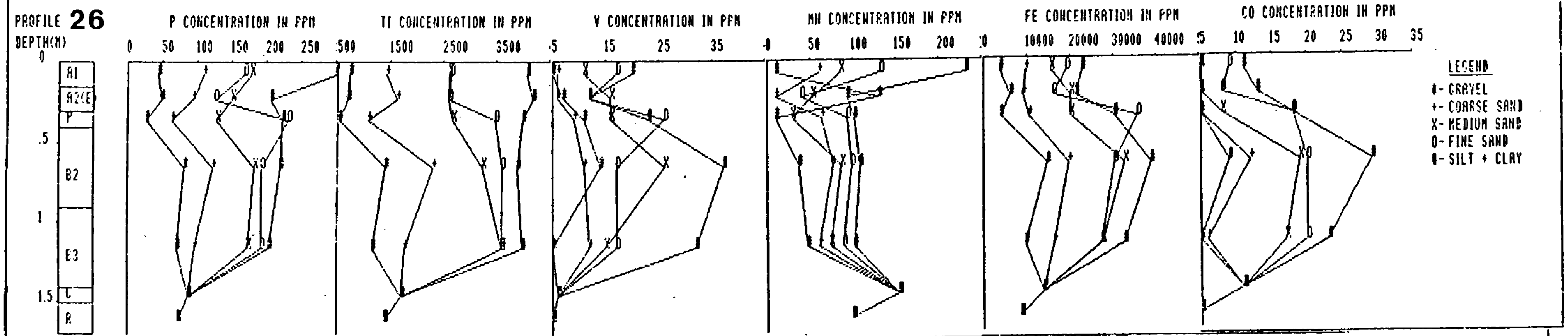


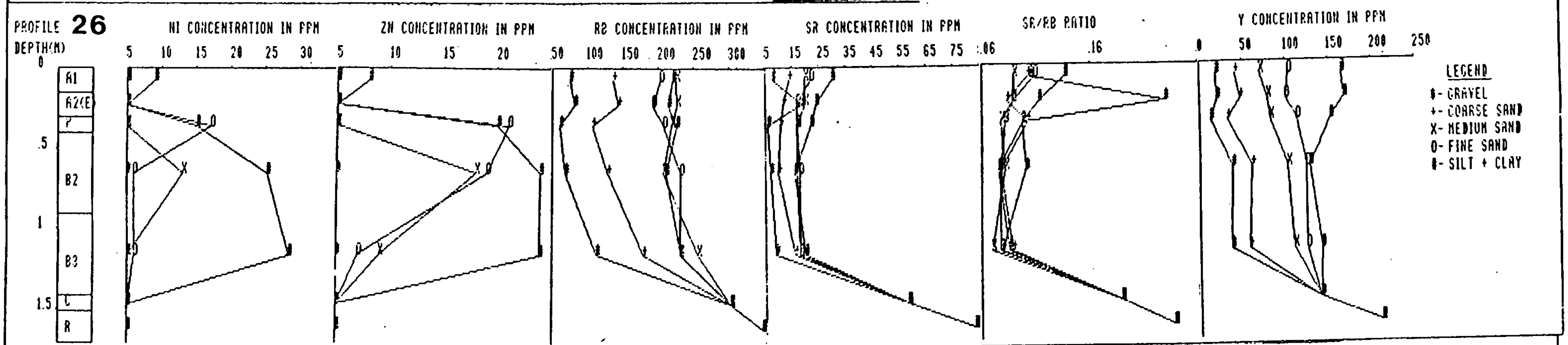


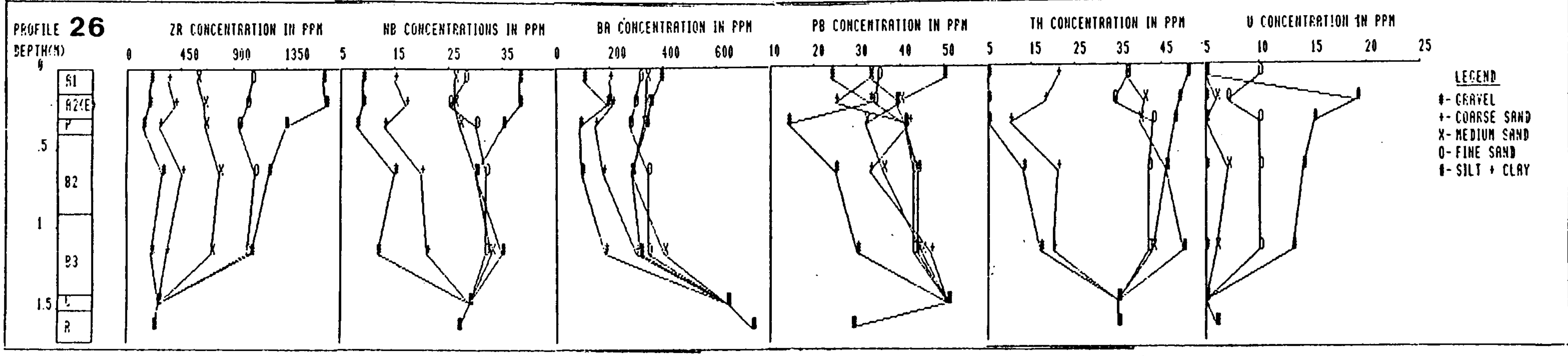
APPENDIX G: (CONTINUED)



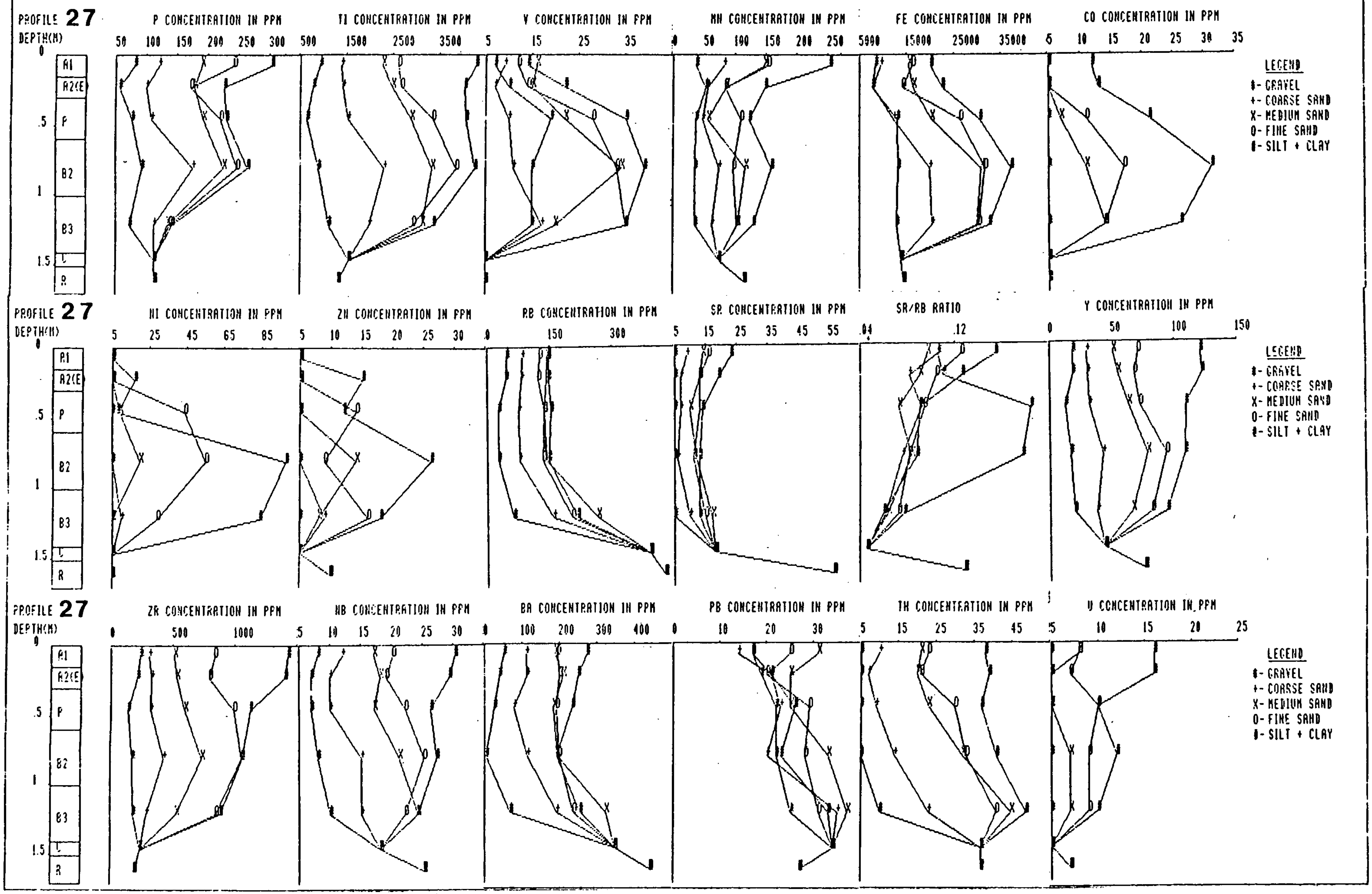
APPENDIX G: (CONTINUED)



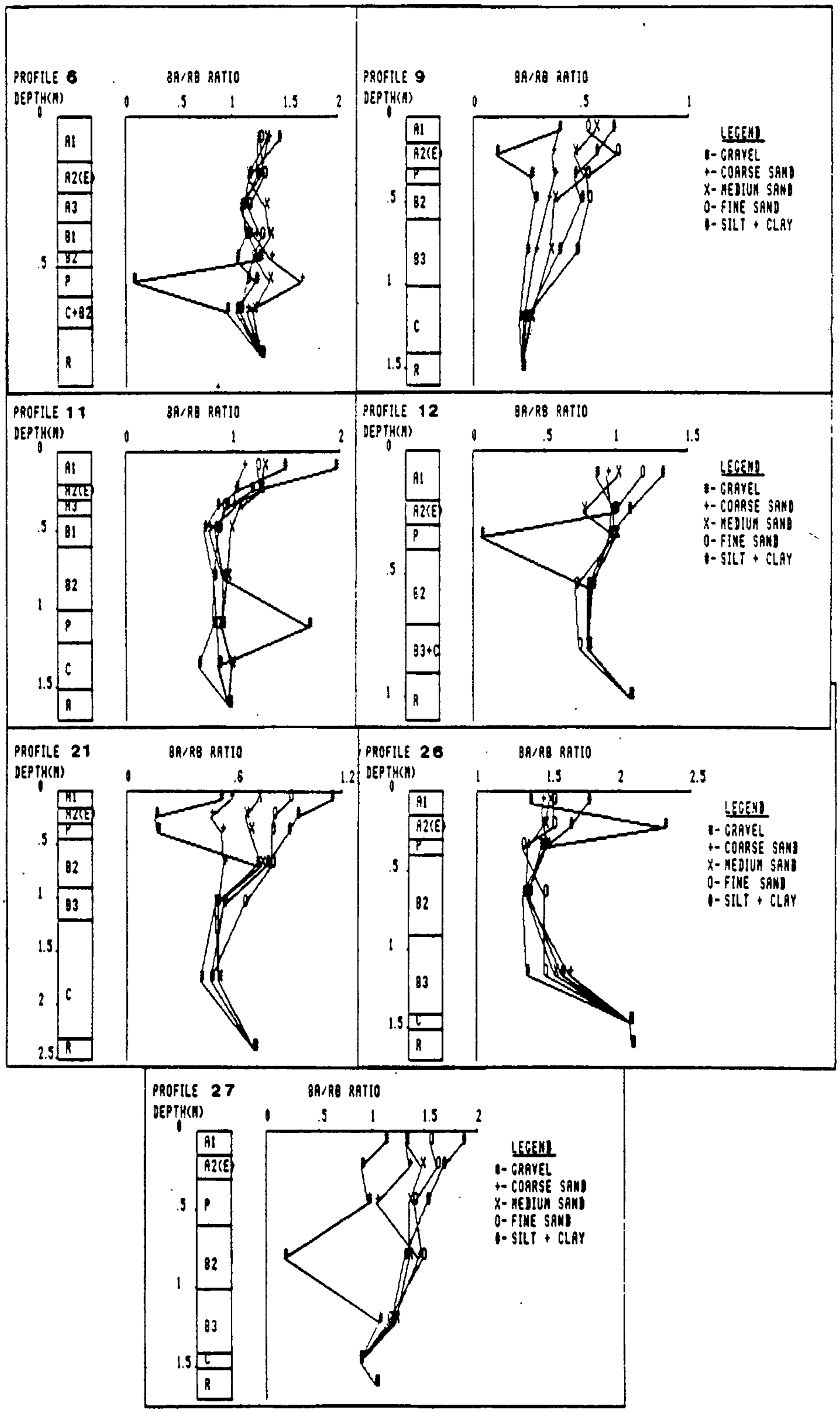




APPENDIX G: (CONTINUED)



APPENDIX G: (CONTINUED)



APPENDIX H: THE CONCENTRATIONS FOR Sn, Cu, Cu CORRECTED FOR Fe_2O_3, Mo, Fe_2O_3, Rb AND SR AND THE Rb/Sr RATIO ALONG TRAVERSE LINES B, C, D, E AND F (FROM NW-SE) AND A (FROM SW-NE).

(TOTAL Fe AS Fe_2O_3)

APPENDIX H: (CONTINUED)

TRAVERSE A

DISTANCE (m)	Sn	Cu	Cu(C)	Mo	Fe_2O_3	Rb	Sr	Rb/Sr
0	24	33	----	<5	28832	155	15	10.3
90	37	23	----	<5	27010	145	15	9.7
180	41	24	----	<5	24831	146	15	9.7
270	40	22	----	<5	25914	183	14	13.1
360	35	17	14	<5	16139	197	16	12.3
450	41	40	22	<5	19108	120	13	9.2
540	36	67	----	<5	33671	143	14	10.2
630	45	88	----	<5	38614	175	14	12.5
720	45	94	----	<5	38823	186	14	13.3
810	29	89	----	<5	37734	179	14	12.8
900	57	75	----	<5	36003	140	11	12.7
990	44	78	2	<5	33487	129	12	10.8
1080	10	26	----	<5	31179	114	16	7.1
1170	36	66	4	<5	30695	105	11	9.5
1260	27	79	9	11	32808	110	11	10.0
1350	18	78	----	10	36940	112	13	8.6
1440	16	69	7	<5	29872	91	14	6.5
1530	39	54	4	<5	26904	88	13	6.8
1620	16	33	25	<5	17269	86	17	5.1
1710	20	25	25	<5	4581	67	17	3.9
1800	406	93	93	<5	14838	220	16	13.8
1890	162	98	48	<5	27508	131	13	10.1
1980	129	78	36	<5	25690	98	10	9.8
2070	109	77	5	<5	33004	100	10	10.0
2160	153	84	22	<5	30977	175	10	17.5
2250	46	42	----	<5	26914	180	13	13.8
2340	81	37	----	<5	26286	139	11	12.6
2430	68	37	----	<5	28133	143	12	11.9
2520	69	40	----	<5	28753	157	11	14.2
2610	66	28	----	<5	26048	147	13	11.3
2700	43	32	----	<5	29339	127	10	12.7
2790	27	33	----	<5	30891	139	12	11.6
2880	19	27	----	<5	30471	197	11	17.9
2970	21	29	----	<5	33107	177	14	12.6
3060	14	24	----	<5	22959	116	11	10.5
3150	24	37	----	<5	33239	193	13	14.8
3240	24	26	----	<5	24337	127	11	11.5
3330	12	29	----	<5	26922	136	12	11.0
3420	16	24	----	<5	28263	156	13	12.0
3510	25	33	----	<5	25596	155	17	9.1
3600	27	58	37	<5	20965	122	15	8.1
3690	25	37	17	<5	19471	131	19	6.8

TRAVERSE B

DISTANCE (m)	Sn	Cu	Cu(C)	Mo	Fe_2O_3	Rb	Sr	Rb/Sr
0	25	38	----	<5	32449	140	12	11.7
50	15	26	----	<5	28998	142	15	9.5
100	14	30	----	<5	24620	105	14	7.5
150	15	25	----	<5	28381	131	16	8.2
200	13	31	----	<5	25740	113	16	7.1
250	24	48	----	<5	33280	117	13	9.0
300	15	34	----	<5	25084	124	19	6.5
350	10	29	----	<5	29336	127	16	7.9
400	46	30	----	<5	23653	132	13	10.1
450	10	23	----	<5	21498	119	17	7.0
500	11	31	23	<5	17065	105	14	7.5
550	9	24	----	<5	22019	124	19	6.5
600	16	35	7	<5	21902	125	18	6.9
650	12	28	----	<5	24809	119	15	7.9
700	14	39	2	<5	23663	121	15	8.1
750	25	25	11	<5	17347	127	20	6.3
800	130	46	28	<5	19458	107	17	6.3
850	115	27	----	<5	24385	111	14	7.9
900	120	54	----	<5	28864	170	16	10.6
950	111	24	----	<5	23598	106	14	7.6
1000	122	43	----	<5	20953	125	14	8.9
1050	109	40	----	<5	30690	146	15	9.7
1100	79	23	----	<5	26042	109	12	9.1
1150	71	27	----	<5	29271	118	12	9.8
1200	69	43	----	<5	28613	116	12	9.6
1250	51	21	----	<5	28375	114	12	9.5
1300	49	18	----	<5	23178	105	12	8.8
1350	45	30	----	<5	25507	115	12	9.6
1400	26	15	----	<5	24688	125	12	10.4
1450	31	27	----	<5	28479	144	12	12.0
1500	130	45	7	<5	24815	129	12	10.8
1550	49	23	----	<5	26128	131	12	10.9
1600	36	23	----	<5	30836	160	10	16.0
1650	47	28	----	<5	29061	166	12	13.8
1700	57	23	----	<5	26969	173	12	14.4
1750	67	23	----	<5	25832	157	12	13.2
1800	84	23	----	<5	24142	137	12	11.4
1850	99	23	----	<5	25118	146	12	12.2
1900	69	34	----	<5	26202	181	13	13.9
1950	61	18	----	<5	24410	189	13	14.5
2000	60	19	----	<5	26316	227	15	15.1
2050	37	24	----	<5	24310	261	15	17.4
2100	47	26	----	<5	25097	229	15	15.3
2150	69	39	----	<5	28224	228	16	14.3
2200	48	24	----	<5	23452	226	16	14.1
2250	61	37	----	<5	23240	257	16	16.0
2300	67	24	----	<5	21084	261	17	15.3
2350	82	36	18	<5	19243	289	15	19.2
2400	16	21	13	<5	17267	233	20	11.6
2450	37	29	21	<5	17324	191	17	11.2
2500	36	16	----	<5	20905	150	15	10.0
2550	36	26	8	<5	19801	181	15	12.0
2600	45	17	----	<5	22632	200	16	12.5

APPENDIX H: (CONTINUED)

TRAVERSE C

DISTANCE (m)	Sn	Cu	Cu(C)	Mo	Fe_2O_3	Rb	Sr	Rb/Sr
0	27	25	----	<5	23146	160	16	10.0
50	30	27	----	<5	24543	289	24	12.0
100	40	30	----	<5	26084	304	26	11.6
150	40	34	9	<5	21007	150	24	6.2
200	39	30	9	<5	20456	170	22	7.7
250	41	45	3	<5	24687	180	21	8.5
300	47	47	13	<5	23436	160	18	8.9
350	45	51	14	<5	23867	160	17	9.4
400	39	61	27	<5	23415	155	16	9.7
450	34	50	13	<5	24586	143	15	9.5
500	40	50	20	<5	22431	150	14	10.7
550	57	54	17	<5	23919	133	15	8.8
600	62	67	22	<5	25687	140	13	10.7
650	68	71	17	<5	27586	145	16	9.1
700	82	70	8	<5	30439	152	16	9.5
750	109	68	----	<5	33004	190	16	11.8
800	88	58	----	<5	32824	212	19	11.1
850	99	30	----	<5	30467	209	17	12.3
900	78	47	10	<5	24736	219	19	11.5
950	141	40	3	<5	24114	176	14	12.5
1000	78	42	17	<5	21498	175	15	11.6
1050	84	40	----	<5	24172	155	14	11.0
1100	47	40	----	<5	28843	163	15	10.8
1150	228	77	44	<5	23271	141	13	10.8
1200	64	52	7	<5	26189	128	12	10.6
1250	94	37	----	<5	27432	133	13	10.2
1300	91	56	----	<5	28177	118	13	9.1
1350	139	44	----	<5	26729	156	10	15.6
1400	134	79	42	<5	24432	118	9	13.1
1450	131	56	35	<5	20826	113	9	12.5
1500	111	40	22	<5	19471	119	9	13.2
1550	68	54	24	<5	21502	112	11	10.2
1600	67	30	----	<5	22146	110	10	11.0
1650	34	39	18	<5	20153	121	10	12.1
1700	44	30	5	<5	21462	105	11	9.5
1750	40	31	6	<5	20535	100	10	10.0
1800	41	31	10	<5	19624	110	10	11.0

TRAVERSE D

DISTANCE (m)	Sn	Cu	Cu(C)	Mo	Fe_2O_3	Rb	Sr	Rb/Sr
0	21	21	----	<5	25525	161	17	9.5
50	45	30	----	<5	23701	191	19	10.0
100	31	20	----	<5	22663	202	20	10.1
150	39	32	2	<5	22837	239	22	10.8
200	67	30	----	<5	24754	303	24	12.6
250	57	31	10	<5	20022	296	26	11.4
300	21	23	----	<5	21081	300	28	10.7
350	13	20	2	<5	19539	135	25	5.4
400	47	57	32	<5	21746	151	24	6.2
450	78	27	27	<5	12605	130	22	5.9
500	67	18	18	<5	10256	125	15	8.3
550	79	30	30	<5	12297	157	20	7.8
600	41	16	16	<5	11367	153	27	5.7
650	51	26	26	<5	7967	110	21	5.2
700	70	24	24	<5	10953	102	29	3.5
750	103	39	39	<5	9016	107	22	4.8
800	290	56	38	<5	19003	182	25	7.3
850	55	54	48	<5	16690	169	22	7.7
900	57	45	45	<5	11607	236	21	11.2
950	31	34	34	<5	10791	112	19	5.8
1000	147	18	18	<5	12270	211	18	11.7
1050	47	36	36	<5	9910	115	18	6.4
1100	81	41	7	<5	23762	89	11	8.1
1150	71	76	26	<5	27775	142	15	9.4
1200	94	70	----	<5	35683	142	13	10.9
1250	119	82	12	<5	32683	132	15	8.8
1300	78	71	9	<5	30905	126	12	10.5
1350	91	65	----	<5	34267	187	12	15.5
1400	84	46	----	<5	29681	144	13	11.1
1450	79	41	----	<5	26529	144	13	11.1
1500	68	33	----	<5	29686	167	17	9.8
1550	78	43	----	<5	26323	156	16	9.7
1600	85	32	----	<5	26280	162	14	11.5
1650	119	33	----	<5	25211	180	15	12.0
1700	197	34	4	<5	22337	192	15	12.8
1750	260	42	21	<5	20877	218	15	14.5
1800	227	21	----	<5	20693	222	19	11.7
1850	207	42	12	<5	22757	214	16	13.4
1900	199	40	----	<5	30654	227	14	16.2
1950	234	54	17	<5	24205	196	16	12.2
2000	241	30	9	<5	20500	199	15	13.2
2050	240	44	2	<5	25840	203	14	14.5
2100	197	48	23	<5	20904	199	15	13.3
2150	149	37	37	<5	13263	196	16	12.2
2200	119	20	20	<5	12920	163	17	9.6
2250	107	23	23	<5	3790	160	15	10.6
2300	94	15	15	<5	8056	181	18	10.0
2350	93	24	24	<5	10897	180	19	9.5
2400	36	30	30	<5	13191	182	21	6.3
2450	35	40	----	<5	32644	130	11	11.8
2500	29	28	28	<5	9976	114	16	7.1

APPENDIX H: (CONTINUED)

TRAVERSE D (CONTINUED)

DISTANCE (m)	ELEMENT Sn	Cu	Cu(C)	Mo	Fe_2O_3	Rb	Sr	Rb/Sr
2550	27	34	34	<5	10916	138	16	8.6
2600	35	15	7	<5	17904	77	14	5.5
2650	34	23	23	<5	12558	69	13	5.3
2700	26	14	14	<5	9330	71	13	5.5
2750	44	40	19	<5	20115	103	11	9.4
2800	26	31	----	<5	30117	108	13	8.3
2850	34	38	----	<5	28450	93	10	9.3
2900	31	31	----	<5	36259	129	11	11.7
2950	150	28	----	<5	28690	239	16	8.7
3000	29	27	----	<5	32316	124	11	11.3
3050	41	29	----	<5	25301	123	10	12.3
3100	24	21	----	<5	26930	165	12	13.8
3150	27	32	----	<5	23530	145	10	14.5
3200	41	24	----	<5	26500	154	13	11.8

TRAVERSE E

DISTANCE (m)	ELEMENT Sn	Cu	Cu(C)	Mo	Fe_2O_3	Rb	Sr	Rb/Sr
0	38	28	22	<5	16192	200	20	10.0
50	39	34	9	<5	21456	190	19	10.0
100	44	40	----	<5	25167	180	16	11.2
150	46	60	----	<5	30614	180	14	12.8
200	47	61	----	<5	30267	174	15	11.6
250	41	58	----	<5	30432	169	16	10.5
300	34	47	----	<5	26862	154	15	10.2
350	39	46	----	<5	28436	156	14	11.1
400	42	44	----	<5	27457	138	15	9.2
450	34	50	----	<5	29467	132	16	8.2
500	31	52	10	<5	25468	148	14	10.6
550	46	46	----	10	26731	157	13	12.0
600	45	49	----	11	27451	154	14	11.0
650	38	42	----	17	26564	176	15	11.7
700	40	47	----	19	27435	179	17	10.5
750	42	42	----	15	26189	183	16	11.4
800	50	49	7	10	25437	181	14	12.9
850	43	48	3	<5	26561	188	14	13.4
900	75	42	----	<5	27451	185	15	12.3
950	35	50	4	<5	28321	187	16	11.7
1000	65	45	----	<5	27436	211	15	14.0
1050	38	42	----	<5	28517	198	13	15.2
1100	69	37	----	<5	30776	196	15	13.1
1150	54	80	4	<5	34618	193	16	12.0
1200	91	95	11	<5	36243	215	15	14.3
1250	130	100	12	<5	37427	223	16	13.9
1300	210	80	----	<5	38457	183	14	13.1
1350	182	62	----	<5	37159	135	13	10.4
1400	206	98	28	<5	32167	169	8	21.0
1450	6843	850	800	<5	28167	378	5	75.0
1500	750	110	65	<5	26080	177	13	13.6
1550	4126	260	215	<5	26143	143	7	20.0
1600	291	110	60	<5	27621	138	10	13.8
1650	179	115	61	<5	28431	133	12	11.0
1700	215	120	61	<5	29167	151	13	11.6
1750	264	160	90	<5	32258	227	14	16.2
1800	206	98	44	<5	28462	151	14	10.7
1850	170	100	50	<5	26817	151	13	11.6
1900	160	70	50	<5	19456	140	15	9.3
1950	140	30	30	<5	12824	130	20	6.5
2000	104	10	10	<5	8585	121	29	4.7

APPENDIX H: (CONTINUED)

TRAVERSE F								
DISTANCE	ELEMENT							
(m)	Sn	Cu	Cu(C)	Mo	Fe_2O_3	Rb	Sr	Rb/Sr
0	<5	18	----	<5	23315	96	13	7.4
50	15	16	----	<5	24495	122	15	8.1
100	19	21	----	<5	20016	93	11	8.4
150	23	18	----	<5	24146	115	13	8.8
200	16	24	----	<5	25660	149	11	13.5
250	35	19	----	<5	25466	127	15	8.5
300	19	29	----	<5	27902	144	17	8.5
350	59	37	16	<5	20941	184	19	9.7
400	47	64	7	<5	29385	187	18	10.4
450	41	21	----	<5	23215	109	14	7.8
500	24	25	22	<5	15542	118	14	8.4
550	10	23	----	<5	21545	159	21	7.5
600	21	25	25	<5	7622	99	16	6.2
650	36	27	27	<5	13984	78	16	4.8
700	59	47	20	<5	26164	96	15	6.4
750	71	69	4	<5	31451	114	17	6.7
800	57	69	19	<5	27388	105	16	6.5
850	67	59	2	<5	29738	102	18	5.7
900	59	86	41	<5	26365	89	14	6.3
950	51	87	25	10	30650	121	18	6.7
1000	51	127	62	10	31783	151	19	7.9
1050	31	61	24	11	24244	113	17	6.6
1100	41	105	35	15	32023	156	21	7.4
1150	41	71	26	17	26914	152	20	7.6
1200	39	91	46	22	26935	150	18	8.3
1250	47	48	30	19	19134	141	18	7.8
1300	41	48	18	25	22235	129	16	8.1
1350	49	42	----	26	24718	157	17	9.2
1400	58	36	6	26	22381	148	15	10.3
1450	55	41	4	12	24337	165	16	10.3
1500	69	39	14	<5	21106	196	19	10.9
1550	58	43	----	<5	25915	207	19	10.9
1600	31	36	6	<5	21772	144	18	8.0
1650	51	39	9	<5	22042	219	22	10.0
1700	32	37	----	<5	29873	114	20	5.7
1750	55	34	13	<5	20560	220	27	8.1
1800	71	103	38	<5	31842	237	24	9.9
1850	78	34	4	<5	22357	189	22	8.6
1900	131	48	18	<5	21892	185	19	9.7
1950	59	31	26	<5	16211	145	17	8.5
2000	68	45	24	<5	20238	159	18	8.8
2050	53	32	7	<5	21087	116	16	7.2
2100	55	63	33	<5	22226	96	14	6.8
2150	57	54	17	<5	24192	92	15	6.1
2200	67	66	26	<5	22534	96	14	6.8
2250	45	53	19	<5	23291	117	18	6.5
2300	45	61	27	<5	22687	131	18	7.3
2350	34	65	9	<5	27943	152	18	8.4
2400	28	60	----	<5	30277	135	17	7.9
2450	35	37	----	<5	23286	119	18	6.6
2500	24	33	----	<5	13239	97	13	7.4
2550	20	15	15	<5	10485	94	15	6.3
2600	10	10	10	<5	10273	85	13	6.5
2650	21	10	10	<5	8205	81	14	5.8
2700	24	10	10	<5	11935	129	23	5.6
2750	21	13	13	<5	12460	119	15	7.9
2800	27	28	28	<5	14470	125	15	8.3