" A GEOBOTANICAL STUDY AROUND THE FLUORITE MINERALIZATION IN KERIO VALLEY, KENYA. "

by

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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This thesis has been submitted for examination with our approval as University Supervisors.

Dr. S. J. Gaciri

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March, 1988

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ABSTRACT

The study area is geologically situated on the Central Kenya Dome, on the western flank of the Great Rift Valley. It is geographically bounded by latitudes 0° 18'N and 0° 22'N, and longitudes 35° 38'E and 35° 40'E, and falls within the jurisdiction of the Kenya Fluorspar Company Limited.

The geobotanical study includes analysis of panchromatic multidate aerial photographs, sequential Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM) imageries; as well as field studies which incorporated collection and analysis of bio-geochemical samples.
The field studies show the existence of some relationship between vegetation communities and pedological, geomorphological and lithological units. It is evident from the study that, the major vegetation communities conform to the major lithological units, while the plant species Harrisonia abyssinica, Vangueria acutiloba and Balanite aegyptiaca localize the fluorite mining sites: interms of the anomalously high concentration values of the elements copper, strontium, uranium, zirconium, rubidium, and manganese in plant ash. Soil samples assayed indicate high concentrations of copper, rubidium, calcium and uranium as associated with the fluortie mineralization, while the trace elements are seen in soil, as accumulations in the valley bottom.

The parent rock, which is probably hydrothermally metamorphosed limestone, coincides with Geobotanical Unit (GBU) I'. In this unit, the dominant species are Laudetia kagerensis, Acacia

tortilis, Combretum molle (with swollen stem), Commiphora africana Indigofera brevicalyx, Harrisonia abyssinica, Rhynchosia spp., Plectranthus spp., Pellaea adiantoides and P. calomelanos.

GBU I' is distinctly characterised by an acacia - croton - combretum - commifora - Harrisonia vegetation community and a distinct photographic and spectral anaomaly.

A C K N O W L E D G M E N T S

This geobotanical study could not have been possible without the assistance of many persons from different institutions, all of whom I wish to thank. There is no significance attached to the order in which these persons are mentioned below.

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CHAPTER 1

INTRODUCTION

1.1 Location of the Study Area.

The study area is situated geologically on the Central Kenya Dome, on the western flank of the Great Rift Valley. It is bounded geographically by latitudes 0^o 18' N and 0^o 22' N, and by longitudes 35^o 40' E and 35^o 38' E. (Fig. 1.1). The study area covers some 4,200 hectares on the Kipkabus sheet 104/1, Series Y 731 (D.O.S. 423), Edition 5 - D.O.S., of the survey of Kenya 1: 50,000 scale, map sheets. The area falls under the jurisdiction of the Kenya Fluorspar Company Limited.

Since the opening of the fluorspar mine in 1971, all weather-loose surface roads have been constructed to open-up the area, but mainly for the delivery of fluorspar to Eldoret, some 48 km away on the Uasin Gishu Plateau, for forwarding to markets overseas. The geological and geographical situation has however, a strong bearing on road and railway - line construction, and affects power - line construction for rural electrification.

The Elgeyo Escarpment to the west of the area, drops some one and a half kilometres over a horizontal distance of about 6 km (from Nyaru to the fluorspar mill). On the valley bottom, from the mill northwards, a road joins the area to the main road from Kabarnet to Iten, at about 2 km NE of Emsea market, to

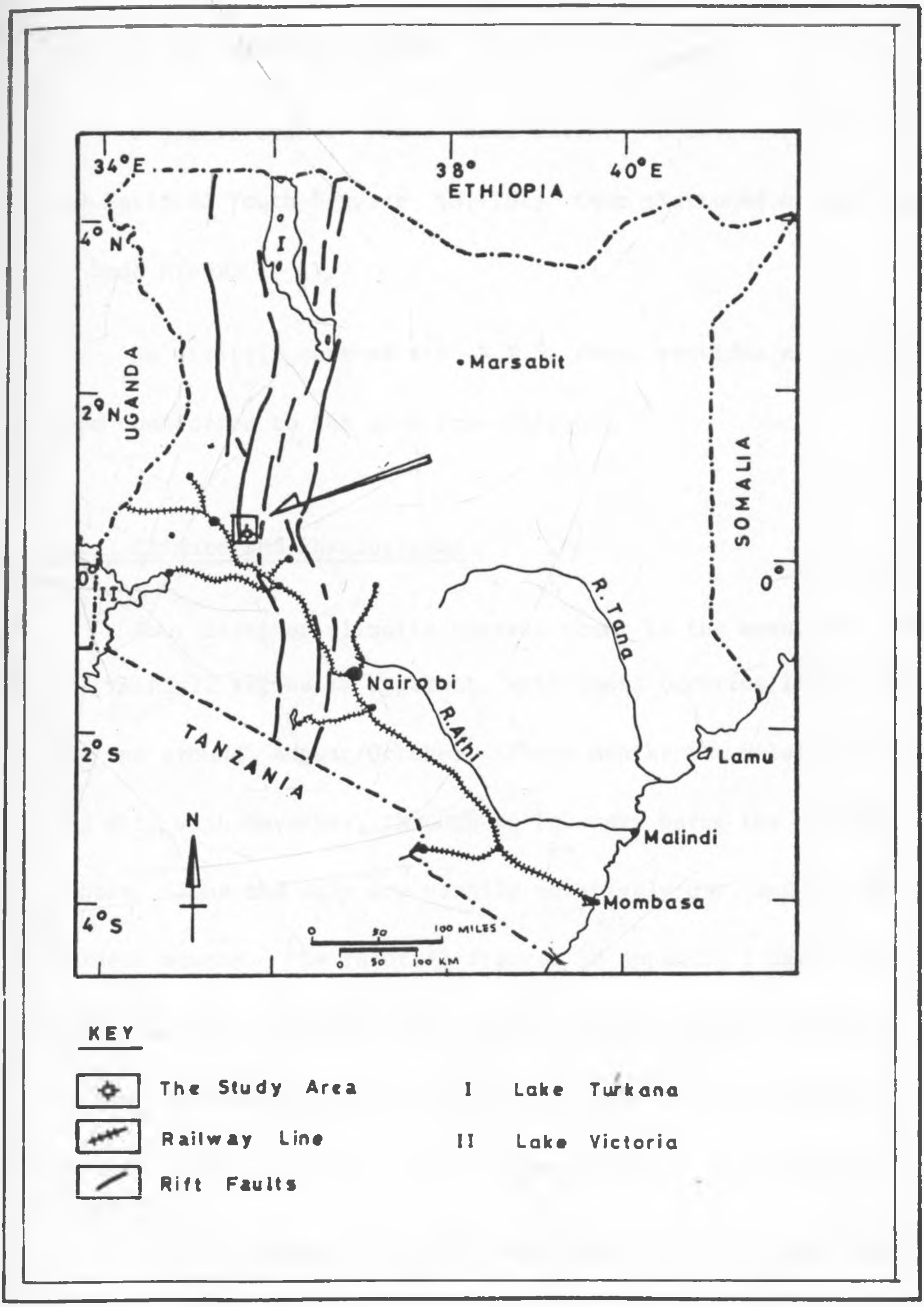


FIG.1 LOCATION OF THE STUDY AREA

the west of Chebloch Bridge.

Other motorable roads have recently been constructed by the National Youth Service (N.Y.S.) team stationed on the banks of Endo River.

An airstrip east of the N.Y.S. camp, provides an alternative connection to the area from Nairobi.

1.2 Climate and Physiography

Four distinct climatic seasons occur in the area. A bimodal rainfall regime is apparent, with peaks occuring in April/ May and around August/October. These months are relatively cold and wet, with November, through to February being the hottest months. June and July are usually relatively dry, and are the coldest months. The rainfall figures in Appendix I have been compiled from raingauge data from the meteorological stations in the surrounding regions. Fig. 1.2 shows the distribution of mean annual rainfall in the region based on these figures.

In this southern part of the Kerio Valley, local rains occur in distinct catchment areas of the tributaries of the main Kerio River, causing flash floods. Heavier down-pours occur

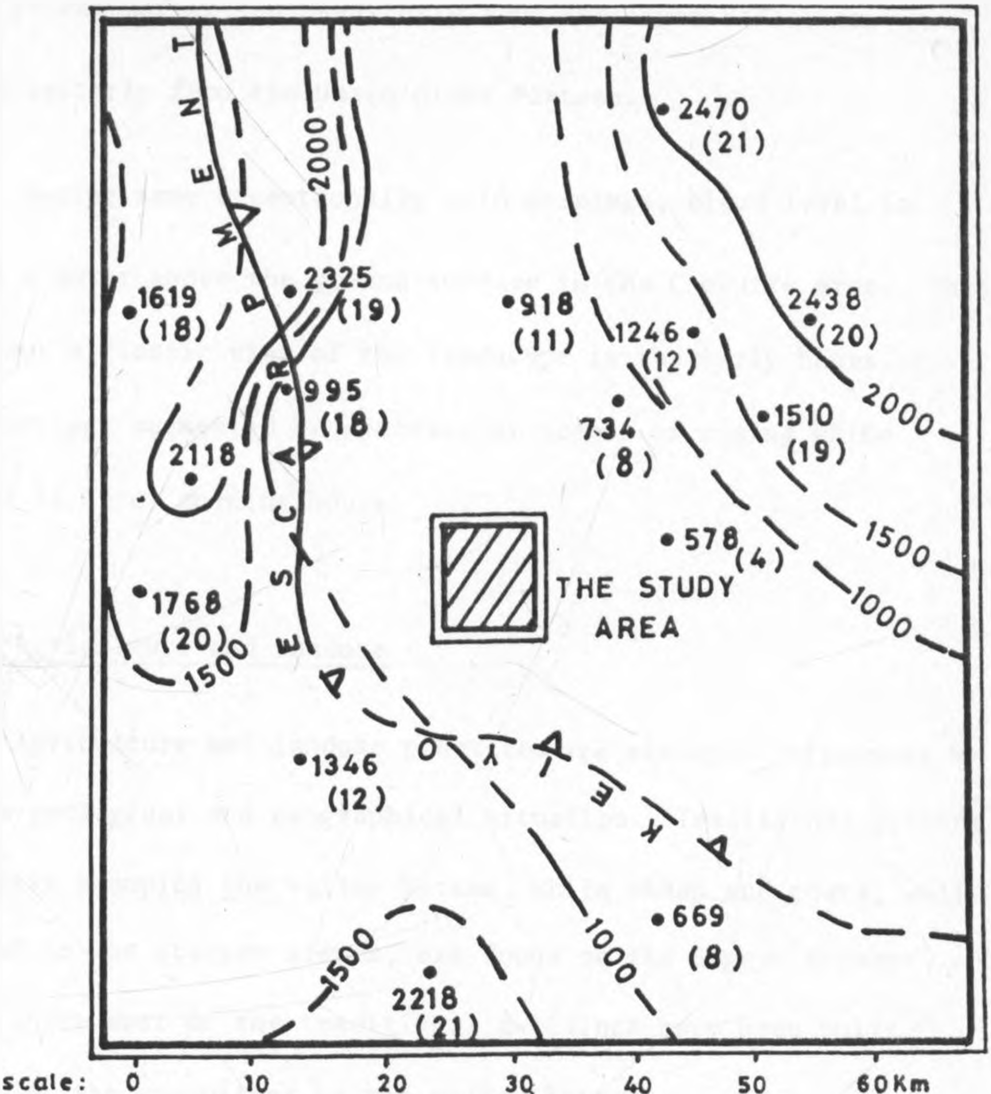


Fig.1.2 Distribution of Mean Annual Rainfall around The Study Area. Isohyets in mm, figures in parenthesis indicate number of years.

from storms moving south-westerly from the Tugen Hills, or north-easterly from the Uasin Gishu Plateau.

During some exceptionally cold mornings, cloud level is about a meter above the ground surface in the Chebutie area. This provides a classic view of the landscape in the early hours of the morning, augmented by spectacular scenes of rising white clouds in later morning hours.

1.3 Agriculture and Landuse

Agriculture and landuse practices are strongly influenced by the geological and geographical situation. Traditional grazing of cattle occupies the valley bottom, while sheep and goats, well adapted to the steeper slopes, are found on the Elgeyo Escarpment, where most of the traditional dwellings have been built to avoid the mosquitoes in the valley bottom.

Cultivation, a recent development in the valley floor, occurs in patches. At Kabokbok, an orchard farm has been started but is not doing well. Higher up the escarpment on soils derived from the basaltic and phonolitic lavas, maize, beans and vegetables are grown on the down-stepped platforms on the valley-sides, particularly around Turesia market. Finger millet is planted on the steeper sandy areas, south of Mong River on soils derived from the Precambrian (Mozambicuan) rocks.

Fluorspar mining is the dominant large-scale landuse practice, and shows how man can be a geological agent when engaged in mining. The fluorite mines can clearly be seen on the 1980 panchromatic aerial photographs, on the successive scenes from the landsat satellite multispectral scanner (MSS) and the Thematic Mapper (TM). These mining sites show clearly due to high reflectance caused by the exposure of the bare ground during mining operations.
Holding ponds for dumping the mill tailings are built as a form of waste treatment. This practice enhances the rate of depletion of the top soil, by wind in the form of dust-storms during the dry months, and as suspended load in the streams, in the wetter months.

1.4 The Purpose and Scope of Study.

The use of plant species for exploration and localization of economic mineral deposits is based on the premise that, plants through their root system, absorb geochemically available elements from the soil environment. Thus, the absence or presence of a certain essential or non-essential mineral element in plants may be ascertained by an analysis and comparison of plants growing in a given zone of mineralization. Often minerals can be detected merely by a Trace Element analyses of plants; since, deep seated mineralization haloes are presumably intercepted by roots of vegetation penetrating into the soil and the underlying rocks (Malyuga, 1964); and thereby provide a geochemical sample of the entire subsurface reached by the root system (Siegel, 1974).

This use of plant communities or indicator plant species in the search for water and mineral deposits, constitutes the science of geobotany, complimented by biogeochemistry which deals with the quantitative analyses of the elements present in the geobotanical samples.

Thus, this study in geobotany, first attempts to locate the fluorspar deposit purely by an XRF Analysis of biogeochemical samples around the mineralization. Only the trace elements Mn, Cu, Zn, Rb, Sr, U and Zr - which are associated with the mineralization are analyzed in detail. Ca, Fe and P are commonly occurring and essential elements for plant nutrition and are not useful for biogeochemical prospecting techniques (Brooks, 1978 and Timperly et al, 1970 - both in Brooks, 1979). Secondly, an attempt is made to try and locate the anomaly in geobotanical unit 1', using remote sensing data.

1.5 A Review of Previous Related Work.

The use of plant communities in the search for subsurface resources has been known since ancient times. Brooks (1972, p. 11) notes that, in Rome during the reign of Augustus Caesar (63 BC to 14 AD), the famed architect Vitruvius wrote;

> "The slender bulrush, the wild willow, the angus, cactus, the alder, reeds, ivy and the like .... usually grow in marshy places .... but water is to be sought in those regions and soils, other than marshes, in which such trees are found naturally and not artificially planted."

Agricola, 1556 (Cannon, 1979) observed physiological effects of metal on vegetation, while Thailus, 1588 (Cannon, 1979) noted the association of Minuartia verna with metalliferous soils. The use of plants in mineral prospecting was also described by Barba, 1640 (Cannon, 1979), in a work completed in Potosi, Bolivia in 1637. Barba states (Cannon, 1979, p. 386) that;

> " Certain trees, marsh plants and herbs are sometimes indicators of veins. Of these are plants of one type, which appear to be planted on a line; they repeat on the surface the course of

> the underlying vein. Plants growing on a metallic vein are smaller and do not show their usual lively colors .... this is due to exhalations of the metals .... they injure the plants, which seem emaciated".

In 1963, Lomonosov (Malyuga, 1964) noted the depauperating effects of mineralized soils on plants. While in 1941, Kapinsky, a Russian Geologist (Brooks, 1972) proposed the observation of entire plant communities as an aid to geological mapping. He recognized that different plant associations exist on varying geological substrates, and that this might be used to characterize the geology of an area. He (Kapinsky) concluded (Brooks, 1972, p. 13) that, "... reliance should be placed on an examination of the whole plant community rather than on one or two characteristic species." This geobotanical aspect of plant accumulation of metallic ions was exemplified by Malyuga (1964, p. 101), who observed that " .... all plants, without exception, experience an increase in the metal content of their ash, regardless of what family or genus they belong, " he also noted that, " .... geobotanical mapping is of limited use, unless it is combined with other geochemical or biogeochemical methods of investigation".

During the early parts of the 19th Century, geobotanists propounded the notion of plant indicators for certain mineral

deposits. In 1887, Raymond (Cannon, 1979) reported Viola intea as an indicator of zinc deposits in Aachen, Germany; while in 1889, Bailey (Cannon, 1979) discovered Polycarpea spirostylis as an indicator of cupriferous soils in Australia. In 1897, Lidgey (Cannon, 1979) reported Eriogonum ovalifolium as an indicator of silver in Montana, USA.
To-date, geobotanists have become more cautious in declaring plants as indicators (Cannon, 1979), and instead prefer the use of more descriptive terms such as super tolerant, accumulators, or merely as specialists. This is apparent from the fact that, there are few (if any) plants which do not occur elsewhere on non-mineralized grounds where conditions are particularly favourable (Vereiskii and Vostokova, 1966). Biogeochemical methods were first used just before World War II when Tkalich, 1938 (Cannon, 1979) found that vegetation could be used to delineate a Siberian iron ore body.

More recent research undertaken in the field of biogeochemistry in the exploration of ore deposits, examines the relationship between metal uptake by plants and various geochemical conditions. These studies include experimental work in various research laboratories, and case studies undertaken in zones of known mineralization.

The process of absorption and uptake of metallic ions by plants is complex, but is influenced by five broad factors (Cannon, 1979). There are:

(i) the available metal rather than the total metal in the soil,

(ii) an increase in availability of major plant nutrients such as phosphate or calcium in mineralized soils of low pH commonly affects the absorption of metals.

(iii) ore-associated elements like Fe, S, As, Cd or Se may be deterrents or stimulants to plant growth or may interact with the more abundant metals to decrease or increase their toxic effects,

(iv) there are physiological differences between plant species, race of species, with respect to metal tolerance and uptake; for example the chelated form in which a metal is transported is unique to each species,

(v) the characteristic pH and total ion concentration of the cell sap may determine whether a plant can live in a given soil environment and the amount of metallic ions it can absorb. For instance, plants adapted to a soil with a high cation content generally have a higher total cytoplasmic ion concentration than do plants that are intolerant of mineralized soils.

Cannon (1979) observed that metal tolerance is closely associated with the location of metals in the cell sap of leaves, which are noted to contain Cu, Zn, Fe, Ni, Mn and traces of Pb, but no Co or Cr. Ernst, 1979 (in Cannon, 1979) noted that, in the root system most metals are tightly bound in the cortex, but are water soluble in the xylem where they are available for transport, but that Cr is tightly bound both in the cortex and in the xylem and therefore remains in the roots while Pb is mostly bound in the cortex, a part being water soluble is available for transport to higher levels. In Australia, Nicolls et al reported (in Cannon, 1979) that normal vegetation was absent, and was replaced by specialized plant communities dominated by Polycarpea glabra and Tephrosia spp. They concluded that geobotany was a useful and inexpensive method that complemented other methods of geochemical exploration. In 1968, Wild (in Cannon, 1979) described Combretum zeyheri with enlarged fruits as true morphological Cu ecotypes in Zimbabwe. However, Cannon did an experimental plot study of mineral uptake by native plants over a period of three years (1956 - 1958), to try and demonstrate that, morphological changes are not necessarily genetic as suggested by Antonovics et al in 1951 (in Malyuga 1964), by Bakker, 1974, and Ochor (Written comm. 1986). She (Cannon) observed that, Euphobia fendleri grew with an upright habit in a gypsum plot, but was completely prostrate, and developed nodules on the stems, at the crowns of the plant, in a lime plot. Thus, she concluded that morphological changes may be due to elemental imbalance.

Reilly (1967) analyzed a wide range of plants, both from mineralized and non-mineralized areas in Zambia for Cu. He found that, several species could tolerate a large concentration of soil Cu, and to accumulate a relatively large concentration of the metal in the leaves; among these are some "indicator" plants like Becium homblei, Vernonia glaberrima, Triumfetta welwitschii, and Cryptosepalum maraniense. He found however that, some species of Graminae (especially Trachypogon spicatus) growing on soils containing as much as 7250 ppm Cu had only 15 ppm of the metal in their leaves. He (Reilly) also observed that many species are cuprifuge and are not found on soils containing more than 20 - 40 ppm Cu (of interest being Becium obovatum and B. angustifolium - which are both closely related to B. homblei). Furthermore, on the old mine dumps in Chongwe, Zambia, soil contains as much as 1% Cu; and even after 20 years of exposure, few plants have managed to establish themselves on the dumps (Reilly, 1967); only B. homblei and the Graminae Chloridion cameronii are found. The former accumulated upto 160 ppm Cu, while the latter contained little more Cu than would be found in plants growing in non-mineralized soils.

Wild, of the Department of Biological Sciences, at the University of Zimbabwe, has done interesting geobotanical studies using indigenous plants on the Great Dyke. He (Wild, 1974) reports that, on chrome rich soils, Rhodesian (Zimbabwean) serpentine species including some serpentine endemics have upto 48000 ppm Cr in the ashes of their leaves (e.g. Sutera fodina) as well as large amounts of Ni. The highest value of Ni recorded in Zimbabwean plants in 153000 ppm (15.3%) Ni in the leaves of Pearsonia metaliifera.

Cole of the University of London, has carried out extensive research in the field of geobotany (Odenyo, V.A.O. - pers. comm. 1985), with vast experience in southern Africa, South America, New Zealand and in Britain. Lefevre (1979) observed that the success of geobotanical and biogeochemical anomaly detection is affected by the vegetation phenology since the appearance and disappearance of an anomaly can be correlated with the growth cycle of plants growing on mineralized ground.

Geobotanical and biogeochemical research in eastern Africa is still in its infancy. Only Chamberlain and Searle (1963) carried out a study on the occurrence of trace elements in East African soils and plants, and Vearncombe, (Tole, pers. comm. 1985), of the University of Witwatersrand, observed a geobotanical anomaly over the chromite deposits near Marich Pass, north of Kapenguria, in Kenya. Promising sources of biogeochemical data lie in the environmental fields of geology and chemistry - where the occurrence and effects of trace elements in the geochemical environment are treated. This is presently being done in the Department of Chemistry, and at the Centre for Nuclear Science and Techniques (CNST) both at the University of Nairobi. Agronomic studies by various agricultural and forestry research institutions such as the Kenya Agricultural Research Institute (KARI), Kenya Soil Survey (KSS), the International Centre for Research in Agroforestry (ICRAF), the

Kenya Rangelands Ecological Monitoring Unit (KREMU), the Global Environmental Monitoring System (GEMS), and Ecosystems Limited, International Project for Arid Lands (IPAL) and UNESCO, could also be other usefull sources of biogeochemical data.

A survey of the available literature shows that a large part of the biogeochemical prospecting research is in the Soviet Union (Cannon, 1979), centred at the Vernadsky Institute (Moscow), the Institute of Geology and Geophysics (Tashkent, USSR), and at the Buriat Interscience Research Institute (Ulan Ude, USSR) - where the methods have been developed into a fine art (Malyuga, 1964).

The introduction of remote sensing techniques to earth resource projects, has enabled the possibility of detecting biogeochemical anomalies from orbital altitudes, since green plants, with active chlorophyll tissue, can be perceived by remote sensing systems in terms of their spectral reflectance in the Near Infra Red (NIR) and the Infra Red (IR) parts of the electromagnetic spectrum (EMS). The sensors on board the earth resource satellites (such as the multispectral scanner, and the thematic mapper) record the reflectance of the vegetation in the NIR and the IR parts of the EMS. In some cases element concentration in leaves has been related to leaf reflectance (particularly lead and copper, Labovitz et al , 1983, p. 759). Lefevre (1980) concluded that, geochemical anomalies can be detected on satellite imagery of particular seasons, if the size of the anomaly is greater than the resolution picture element (PIXEL) of the sensor. The studies published in Economic Geology Vol. 78, 1983, give recent remote sensing case studies. The developments have grown from and complement the use of satellite imagery and aerial photography for locating lineaments and faults, with which ore is often associated (Darch and Barker, 1983, and Chang and Collings, 1983). Birnie and Francica (1981) observed a geobotanical anomaly over porphyry copper mineralization using remote sensing methods, while Kondratyev and Fedchenko (1983) used reflection spectra in recognition of crops, suggesting a technique that excludes the contribution of the spectral brightness coefficient by soil and weeds. Ilyin et al (1983) carried out a case study on the history of the application of space imagery to geology and mineral exploration in the USSR, with a special emphasis on circular features observed on small scale and low-resolution pictures within the Precambrian terrain, and noted the metallogenic significance of circular features in space imagery.

CHAPTER 2

THE GEOLOGY OF THE STUDY AREA.

2.1 Lithology and Stratigraphy.

The geology of the area is composed of Precambrian paragneisses, Upper Miocene volcanics, Lower Miocene sediments, Pliocene sediments, and Quaternary to Recent deposits.

Stratigraphically, the Precambrian rocks are unconformably overlain by the Upper Miocene volcanics (composed mainly of basaltic and phonolitic lavas). In places however, Lower Miocene sediments are sandwiched between the Precambrian rocks and the Upper Miocene volcanics.

Table 2.1 gives a summary of the stratigraphy and geological events in the study area. The details of the geology have been treated in Gaciri (1975), Nyambok (1973), Walsh (1969), and Aljabri (Unpublished reports), thus, in the present study, the geology is treated only with respect to the Geobotanical Units (GBU) which are associated with distinct geological units.

2.1.1 The Precambrian Rocks

The geology of the Precambrian is characterized mainly by paragneisses, varying in composition from hornblende gneisses through biotite gneisses to quartzo - feldspathic gneisses. Intercalations of quartzites, breccia, crystalline limestone or marble also occur. These rocks are exposed at the base of the

TABLE [2.1] LITHOLOGY AND STRATIGRAPHY.

PERIOD	Lithology and Stratigraphy
6. Quaternary to Recent	- Deposition of superficial colluvial and alluvial deposits; basically sandy and clayey loam depending on source material.
5 ? Pliocene	- Sedimentation Phase: Deposition of the friable Soy white sandstone deposits.
	- Mineralization Phase: Fluorite mineralization commenced presumably towards the wanning phase of the Elgeyo volcanicity (post 12.0± 0.3 M.Y)*
4. Upper Miocene	- Tectonics and Volcanicity: Sub-Miocene dormal uplift and axial down-warp of the rift region; accompanied by volcanic flooding and fissure eruptions, and followed by faulting.

This phase is represented by the Elgeyo volcanics - mainly basaltic (the Elgeyo basalts 15.1± 3.2 MY)* and phonolitic (the Uasin Gishu type, 12.0 ± 0.3 MY)* lavas. The Elgeyo Escarpment forming some 15.6 ± 3.2 MY*

3. Pre-Miocene - Sedimentation Phase:

(ii) Deposition of the grey to yellowish green shally limestone deposits; the Kimwarer Sediments.

(i) Deposition and subsequent compaction of the Red sandstone deposits;

- Erosional Phase:

Erosion and planation of the Precambrian surface; culminating in formation of the sub-Miocene peneplane, and the Ancient gravel fan.

2. - - - - - MAJOR UNCONFORMITY - - - - - -

1. Precambrian 600 MY - Diagenesis of pelitic sediments, folding under directed stress, and formation of the Precambrian metamorphic rocks.

Stratigraphical Sequence according to the following works:

* Baker et al (1971) - the radiometric dates (unless indicated), Nyambok & Gaciri (1973), Jennings (1964), Martyn (1969), McCall (1967), Gaciri (1975) and Walsh (1969).

Elgeyo Escarpment. Mylonites are found along the shear zone (Gaciri, 1975), while quartzo-feldspathic, biotite and hornblende gneisses have specks of galena. Biotite schists and amphibolites form the rest of the Precambrian rocks. The crystalline limestone is structurally bound parallel to the foliation direction of the gneissic rocks.

2.1.2 The Lower Miocene Sediments.

These Lower Miocene sedimentary deposits unconformably overlie the Precambrian rocks, in places separating the latter from the overlying Upper Miocene volcanics. These lacustrine deposits consist of two distinct series; the laminated red sandstone deposits, 5 - 10m thick, exposed to the SW of the fluorspar mill, at Sarbap Hill and the grey to yellowish green shaly limestone deposits, exposed along the Elgeyo Escarpment. The latter geological unit, commonly referred to as the Kimwarer sediments (Gaciri, 1975 and Walsh, 1969), is however not encountered in the study area.

2.1.3 The Upper Miocene Volcanics.

These are the oldest volcanic rocks of central and northern Kenya, which rest locally on fossiliferous Lower Miocene sediments or on Precambrian rocks. These volcanics were extruded nearly continuously from early Miocene to Holocene times (Baker et al, 1971).

In the study area, Miocene volcanism is represented by the non-porphyritic Uasin Gishu phonolites (dated as 12.0 ± 0.3 MY)* which conformably overlie the Elgeyo basalts (dated as 15.1 ± 3.2 MY)*. Nephelinitic phonolite (undated) with large euhedral nepheline crystals, is exposed south of Mong River. The Elgeyo basalts outcrop beneath the Miocene phonolites which cap the Elgeyo Escarpment (Shackelton, 1951; Bishop et al , 1969, and Walsh, 1969).

2.1.4. Quaternary and Recent Deposits

These superficial deposits are weathering products derived basically from the Miocene volcanics, and from the Precambrian rocks, and deposited at the valley bottom between the foot of the escarpment and the main Kerio River. Details on the type of these deposits is given in Table 4.2. which describes the Geo-botanical Units (GBU). It is notable however that, the soils derived from the Precambrian paragneisses are basically sandy in texture, while those derived from the volcanics are mainly clayey/ loamy soils.

2.2 Structures

Structural features are restricted mainly to the Precambrian rocks, while the post-Miocene normal rift faulting resulted in a stepped terrain, higher up the escarpment. East-West shear faults

* Bishop et al (1969)

occur in the Precambrian rocks, marked by mylonites and chalcedonic quartz in the Kamnaon and Choff areas (Gaciri, 1975). These shear faults are visualized stereoscopically as linear structural features in Plate 1 and Plate II. It was also observed that the east-west fault controlling the flow direction of the Kimwarer River is a reverse fault, characterized by a steep fault scarp marked by distinct slicken sides. This Kimwarer fault offsets the main western N-S fault and forms the southern end of the Kerio Valley, thus being the youngest of the major faults.

The major Plio-Pleistocene rift forming faults are partly pivotal (Gaciri, 1975) with a total down throw to the east of approximately 1600 m. This attitude was also noted by Walsh (1969) and McCall (1967).

Foliation structures in the paragneisses when plotted on a stereographic projection portray a fold-axis plunging SSW at approximately 20 - 25^{o} (Gaciri, 1975). Foliation planes have steep to moderate dips with strikes conformable to the general trend of the rocks; namely NE to SW. In detail however, the strike of the rocks in the area is dominantly south easterly. Further north of Kabokbok the strike swings to the NW. According to Gaciri (1975), these planar structures suggest the outcrop of the rocks in this area to constitute part of a limb of a major folded structure.

2.3 Morphodynamics of the Geological Environment.

Visualization of the dynamic structural geomorphological evolution of the area, during and after the Miocene Period, is realized by a detailed study of the alluvial-colluvial fans which developed under humid climatic conditions, when vast amounts of water was available to transport the gravel and boulder material of the alluvial fan.

South of the fluorspar mine (Plate 1), alluvial fans typify subsidence following the movement of the major western, northerly trending fault, south of Sarbap Hill, SW of the mill area. This is a major fault off-setting the younger Upper Miocene volcanics SW of the area, covered by the alluvial fan material. Sarbap Hill, a typical cuesta landform, is composed of the Lower Miocene Red sandstone series - originally horizontally deposited and consolidated, but has subsequently been uplifted along the northerly trending fault, and down thrown along the Kimwarer fault; giving an impression of rotational gliding of the enclosed geomorphic unit on which Sarbap Hill lies, gently sloping WWS (Plates 1 and 2).

The two distinct faults, illustrate the dominant orientation of the faults encountered in the area, namely NNE to NE, with few trending north westerly especially on the structural nephelinitic phonolite hill to the south of Mong River, where typical thrust faulting is evident.

2.4 The Fluorite Mineralization.

Fluorite, or fluorspar, the dominant economic mineral deposit, has a cubic crystal habit with a chemical composition CaF_2. It is found as a hydrothermal vein deposit in metamorphosed rocks, and also as a late-stage fissure filling deposit in some alkaline and acid igneous rocks, forming from the reaction-

$$2HF + CaCO_3 \longrightarrow CaF_2 + H_2O + CO_2$$

It was suggested by Uklonskij, 1928 (in Nyambok, 1978) that silicification may also accompany the replacement of limestone according to the following chemical process;

$$3CaCO_3 + H_2SiF_6 \longrightarrow 3CaF_2 + SiO_2 + 3CO_2 + H_2O.$$

Fluorite has also been found in geodal infillings and in veins and veinlets of dolomitic limestones and dolomitic rock of the Carboniferous limestone of Avon Gorge, Bristol (Loupekine, 1951).

In the study area, fluorite bodies occur approximately parallel to the foliation of the metamorphic rocks (which trend N10^{o} W at Kimwarer, and N45^{o} W at Kamnaon), in contact with the breccia. The paragenesis of the fluorite mineralization has been ascribed to hydrothermal emanations, largely replacing calcite ($CaCO_3$), in limestone (Nyambok, 1973). This mode of fluorite mineralization is further elucidated by the association of adularia ($KAlSi_3O_8$) - a feldspar altered at great depths, with fluorite deposits (Barnes, 1967). The general lack of high temperature minerals along the zone of alteration however, suggest emanation of hydrothermal fluids at low temperatures (Nyambok, 1973).

To the north of Kerio Valley, fissure vein fluorite deposits have been reported (Aljabri - person. comm., 1985) as restricted fissures. Around Musgut - Kimwarer area, fissure vein deposits are indicated by banding of fluorite (Nyambok, 1973). The fluorite mineralization occurs mainly in shear zones as replacements and as stratiform deposits with foliation planes serving as channel ways of the mineralizing hydrothermal fluids (Gaciri, 1975); and also as fissure deposits with mineralization being partly by replacement and mainly by fissure fillings. Fissures also occur in the Elgeyo basalts, infilled by calcite, south of the fluorspar mill area.

Geochemical analyses for the trace elements associated with fluorite mineralization has been carried out by Dean and Powell (1968), and by Nyambok (1978). Dean and Powell, analyzed for P, Sr, Ba, Y, La, Ce and Nb, in carbonatite with replacive fluorite and quartz, in Ambar Dongar fluorite deposits in Gujarat, India; while Nyambok undertook an analyses for Cu, Co, Cd, Ni, Cr, Sr, Mg, Zn, Fe, Mn and Ti in the various varities of the fluorites from Kerio Valley, Kenya. In both studies, only Sr is a common element, with a mean concentration of 3300 ppm in the Ambar Dongar fluorite, and a maximum value of 3078 ppm in the Kerio fluorite deposit.

The results of a reconnoissance radiometric survey by Muruga (1981) of Mines and Geology Department, Ministry of Environment and Natural Resources, are of particular interest. In the survey, (Muruga, 1981) relatively high count rates are reported, but he does not observe the occurrence of any radioactive minerals. However, Nyambok (1973), did observe the presence of apatite in the Kerio Valley fluorite deposits. Apatite is a uranium bearing mineral (Bohse et al, 1974) of chemical composition $3Ca_3(PO_4)_2 \cdot Ca(F,Cl,OH)_2$ found in hydrothermally metamorphosed limestone. Other uranium bearing minerals also found in metamorphic limestone include pyrochlore and eudialyte. The former, having a chemical composition $(CaNa)_2(Nb,Ta)_2O_6(O,OH,F)$ has upto 200 ppm of U; while the latter, having a chemical composition $(NaCa)_6ZrSi_6O_{17}(O,OH,Cl)$ with 0.6% $(Nb,Ta)_2O_5$ has between 50 - 869 ppm of U (Bohse et al, 1974). Pyrochlore and eudialyte have not been detected in the Kerio fluorite deposits in previous mineralogical and paragenetical studies.

These uranium - bearing minerals, all occur in hydrothermally metamorphosed limestone ($CaCO_3$) deposits. The genesis of the uranium has not been clearly elucidated. However, uranium being in a residual phase, may have been partitioned into the melt in magma systems rich in fluorine and chlorine, resulting in the formation of complex halide compounds, such as uranium hexafluoride, (UF_6), rather than increasing oxygen fugacity, which prevents the uranium from being precipitated (Bohse et al, 1974). It is suggested (Tole pers. comm. 1985) that, the uranium detected in the present study may have been "locked" within the crystal lattice of the fluorite or merely associated with the uranium bearing apatite which occurs with the fluorite - ore. Nyambok (1973) observed radial pattern in the purple variety of fluorite which could possibly be due to irradiation effects.

CHAPTER 3

METHODOLOGY

An analysis of the panchromatic multidate aerial photographs covering the area (at scales ± 1: 62000 and 1: 50000, of 1969 and 1980 respectively), coupled with an analysis of the LANDSAT MSS imagery of 1976 and Thematic Mapper imagery of June 1984, plus field visits, shows an apparent relationship of the vegetation communities to the geology, mineralization, geomorphology, and pedological units. Geobotanical and biogeochemical methods are particularly significant techniques of mineral exploration in areas where the mineralized host rock is buried beneath thick overburden, be it soil, glacial sediments, or sandy deserts. Thus, the entire area penetrated by the root system forms the total area sampled by an individual plant which thereby provides a biogeochemical sample of the entire subsurface reached by the root system (Siegel, 1974). This biogeochemical sample, represents a relatively large area on the surface compared to the area represented by standard soil and rock samples. Herein lies the economic benefits of the use of plants for mineral prospecting: particularly in large areas covered by overburden, but vegetated.

3.1 Geobotanical Mapping

The methodology of geobotanical mapping included stereo photographic and satellite imagery analysis of the vegetation cover, in relation to the underlying geology. In the field, vegetation communities were identified in terms of the three to four most frequently occuring plant species (Table 4.2, and Appendix II).

The method is usually aided by (when known) the presence of indicator plants which usually have morphological deformities, and are often emaciated in terms of growth form (Brooks 1979). Other morphological deformities such as chlorosis of leaves, color changes of flowers or even rythmic disturbances in plants have been observed by Buyalov and Shvyryayeva, 1961 (in Brooks, 1979).

In the study, biogeochemical sampling and measurement of spectral signatures, of the most commonly occuring species, was done. Finally, a treatment and an analysis of the biogeochemical samples for a quantitative determination of the pathfinder trace elements for the fluorite mineralization was undertaken.

3.2 Photographic Analysis

The study area is covered by Landsat standard enhanced MSS scenes 181/060 and 182/060 of 15th September 1981, and Thematic Mapper satellite image 169/060 of July, 1984. Panchromatic aerial photographs of 1969 and December, 1980 are also available, at scale ± 1: 62000 and ± 1: 50000 respectively.

The satellite data, obtained from the Landsat satellite, were photographically and digitally enhanced and enlarged to a working scale of 1: 50000. The photographic analysis included

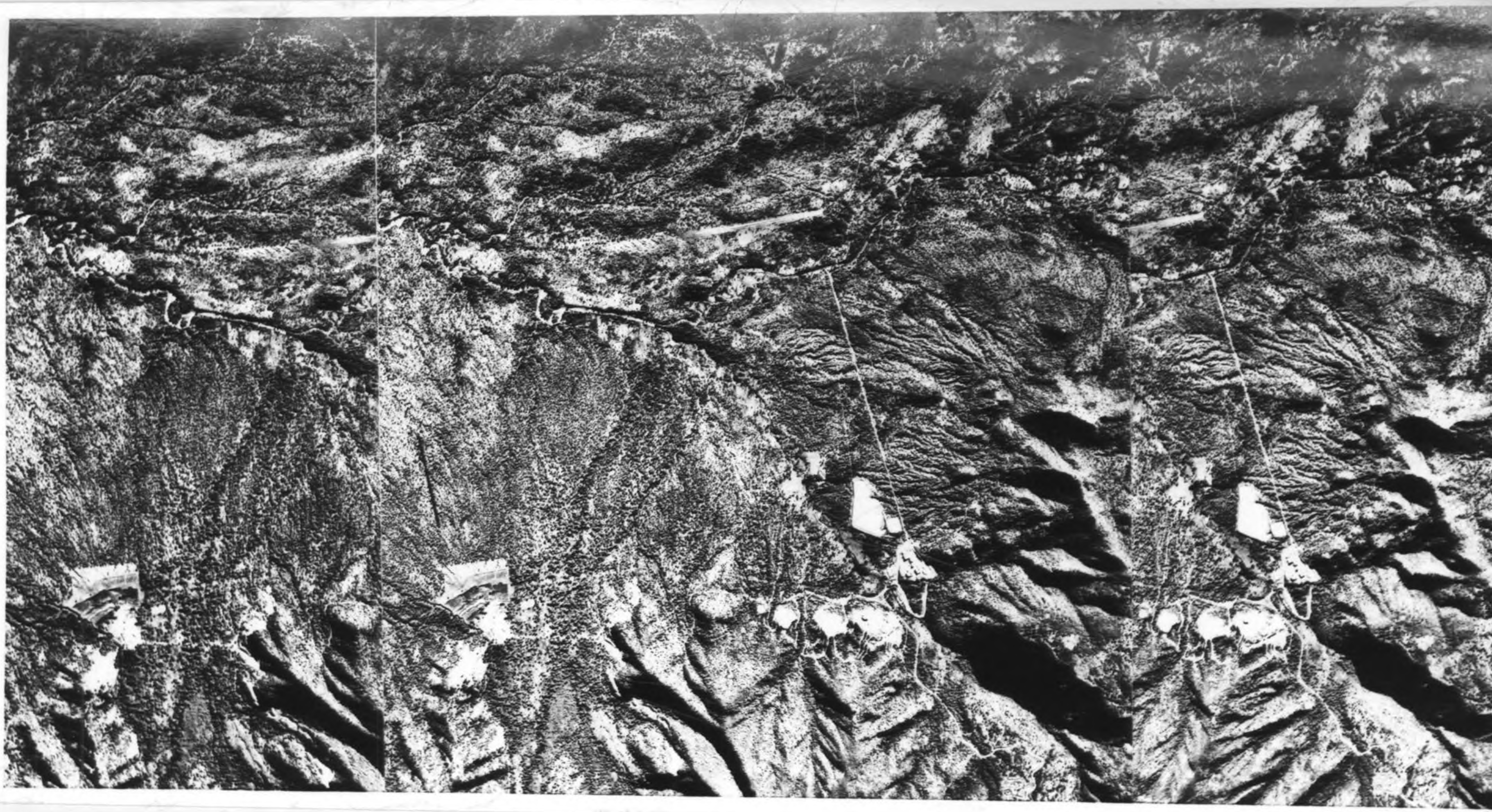


Plate I: A stereotriplet showing the physiography, location of the mine sites, mill tailings, the fluorite mill, landuse and the geobotanical units on the varied geological units. December 1980 photographs at scale 1: 50,000.

70 mm x 70 mm chips for ANALOG color additive viewer multi-band analysis, digital analysis was by the PERICOLOUR 1000, an interactive digital image processing system. The approach aimed at delineating the major vegetation units via a "zooming - in" technique in vegetation and terrain analysis (Verstappen, Th., 1977). A logical analytical treatment of the aerial photographs stereoscopically, for vegetation / habitat, morphological and geological mapping, was as proposed by Guy (1967) to delineate the eleven geobotanical units (GBUs). The units mapped are shown in Plate II and Table 4.1 contains descriptions of each unit.

3.3 Location of Sample points and Sampling.

Biogeochemical methods require quantitative analysis of vegetation samples to determine the concentration of metallic elements present. Biogeochemistry therefore furthers the visual appraisal of vegetation in relation to mineralization in geobotany.

Using a 10 x 10 millimeter grid at scale 1: 50 000, 54 sample points, Fig. 3.1, were selected, from which samples were collected. These sample points were plotted on a transparency and overlaid on a panchromatic vertical aerial photograph at scale 1: 50,000. Stereopairs were used in the field, with a pocket stereoscope for precise location and identification of sample points.

During field work, in December 1984 and April/May 1985,

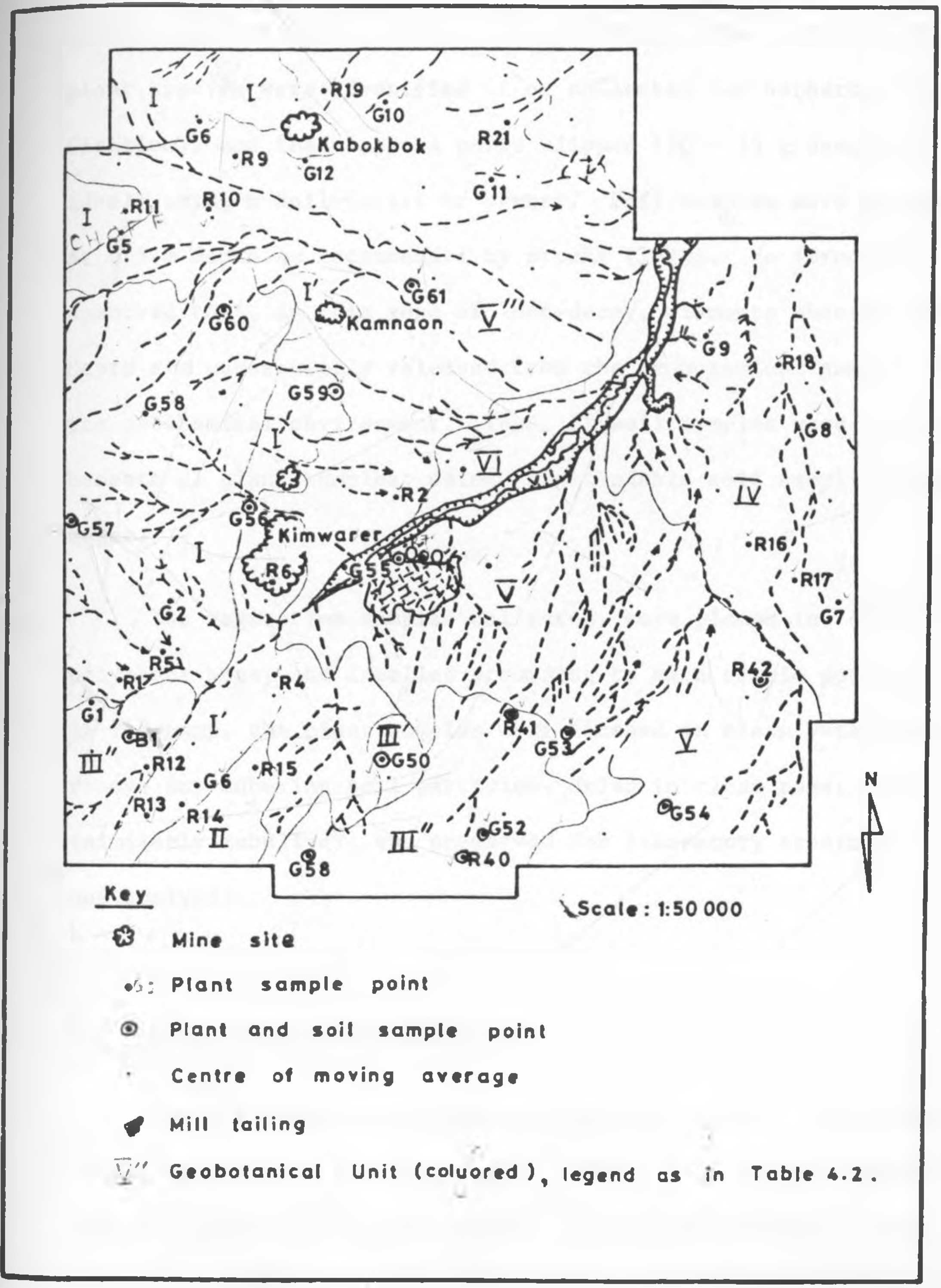


Fig. 3.1: Location of Sample Points in the Area.

geological and geomorphic details of the terrain were recorded (Table 4.1) at each sample site; with respect to rock-type, morphology, structure, aspect, weathering and the land use. Further plant species were identified (or collected for herbarium identification), and their apical parts clipped (10 - 15 g sample are ideal) using a Roll-Cutter or pruner. Soil samples were sampled at 0.5 m depth as recommended by Brooks (1979). He (Brooks) observed that, in this zone of leaf-decay, elements absorbed from depth are subsequently released from the geobotanical samples into the geochemical environment. Thus, 21 soil samples were collected beneath 21 plant samples, using an extendable soil sampling bucket auger.

The vegetation samples collected, were placed in clean polythene bags, and labelled according to each sample point. At the camp, the plant samples were flushed in clean water to remove any adhering soil particles, dried in clean paper bags (similarly labelled), and preserved for laboratory treatment and analysis.

3.4 The Spectral Measurements.

Three fundamental energy interactions occur at the surface of any object when electromagnetic energy, such as solar radiation, is incident upon the object. Various fractions of solar energy are absorbed, reflected and /or transmitted, depending on the particular nature of the object.

In this study, the measurements of spectral reflectance for given plants was done. The energy incident upon a plant, $E_I(\lambda)$ and that reflected from it, $E_R(\lambda)$ was measured using a Portable Field Radiometer (Plate VIII (i) whose, spectral bands correspond to those onboard the Earth Resources Satellite, Landsat, as illustrated in Table 3.4. The Spectral bands being in the visible and near infra-red part of the electromagnetic spectrum. The measurements were taken for each spectral band.

Using $E_I(\lambda)$ and $E_R(\lambda)$, measured above, the percent spectral reflectance (R %) was obtained from the equation of Lillesand and Kiefer (1979):

$$R\,\% = \frac{E_R(\lambda)}{E_I(\lambda)} \times 100,$$

where the symbols are as above. These measurements were done for the most common plant species in a given geobotanical unit.

TABLE 3.4 THE CORRESPONDENCE OF THE RADIOMETER CHANNELS TO THOSE ONBOARD THE LANDSAT SATELLITES.

RADIOMETER	LANDSAT 1,2&3	COLOR	WAVELENGTH	LANDSAT 4&5
Channel 1,	Band 4	Green	0.5-0.6 mm	MSS 1
Channel 2,	Band 5	Red	0.6-0.7 mm	MSS 2
Channel 3,	Band 6	Near IR,	0.7-0.8 mm,	MSS 3
Channel 4,	Band 7	Infra-red,	0.8.1 mm,	MSS 4

Secondly, radiometric values were read along two transects (Plate 2, Fig. 4.3 and Appendix VII) eastwards, from the Kimwarer mine, through the mill tailings, across the study area. These values were obtained from a LANDSAT image of 15 th September, 1981, processed by a Supervised Classification Method (Le Durand, 1983), using sequence X_1-(Appendix IX) on the PERICOLOR 1000. Use was made of a Diskett Classification PROGRAM PC SPOT, inserted in disk drive DØ, and a color composite in disk drive D1. Only channel 3 values were used, since this spectral band enhances best the geological features.

3.5 Treatment and Analysis of the Biogeochemical Samples.

The plant samples were washed with distilled water, dryed in an oven, on a hardened ashless Whatmann filter paper, at 120°C for about six hours. The oven-dried plant material was then pulverized in a micro-hammer mill, and placed in a 25 ml squat PYREX beaker, and ashed in a muffle furnace (Carbolite, Model ESF 2) at 450°C ± 5°, for 8 - 12 hours. The ashing technique reduces the size of the plant material sampled for analysis, and concentrates the trace elements in the samples for XRF analysis (Hamilton, 1980). Soil samples were fused at the same temperature prior to XRF analysis.

Dry ashing of plant material was carried out in the presence of a small amount of air; care being taken not to admit too much air which increases the danger of volitilization of some constituents (Brook, 1972). As such, just enough air supply is essential to avoid black charred material - which is apt to absorb metal and thereby vitiate the assay. This is ensured by opening the furnance at half an hour intervals for a few minutes (Harry, 1980).

The ashed plant material, and the fused finely pulverized soil samples, were then diluted by ANAL cellulose, or starch, by a dilution factor of about five. Using the visor, the pellet making dies, and the pressure jacket, thin pellets were pressed out at 3000 kg/cm^2, for subsequent irradiation by the XRF Analytical system.

3.5.1 XRF Analysis.

Photoelectric interaction is the basic principle in X-Ray Fluoresence Analysis (XRFA). Here, a photon with a certain amount of energy encounters a given atom, where it is absorbed by an electron (in a given energy level - or shell) which is in turn ejected with an energy equal to the photon energy less the shell electron-binding energy. The photoelectron (electron ejected) from an inner shell creates a vacancy which is filled by an eletron of the intermediate outer shell. The difference in binding energies is given off as the characteristic X-Ray photon, or as the Auger - electron Jenkins et al,(1981).

The analytical aspects of XRFA, its calibration, and applications in multielement analysis of geological and non-geological samples has been treated by Kinyua,(1982),Jenkins et al, (1981) and Lavi, (1984). Briefly however, the analysis of the spectrum of X-rays from the specimen, for a given element, is accomplished by the Si(Li) detector and its associated electronics in the Multichannel Analyzer (MCA). The Si(Li) detector plus the elements of the preamplifier, is mounted in a light tight vacuum cryostat, and operated at liquid nitrogen boiling temperature of 77 K (Jenkins et al, 1981). At the amplifier output, the MCA (also a pulse height analyzer) represents the pulse amplitude by a number. This is an analog-to-digital conversion. The frequency of a given pulse (the intensity) of each element is recorded in the memory of the MCA, to form the spectrum of the pulse height (Plate IX Appendix VI) for a given element. The spectrum represents the true number of photons arriving at the detector during the period of data collection (sample irradiation). The MCA can display the spectrum on a cathode Ray Tube on a TV monitor or on an X-Y Plotter.

A recent addition to the XRFA system at the Nuclear Centre for Science and Techniques, University of Nairobi, is a small Digital Professional 350 Computer linked to the MCA. The computer analyzes the spectrum, and computes the raw-element intensities, corrects for inter-element effects, and can also compute the concentration of an element or elements.

The overall accuracy of the XRFA system has been estimated to be 5 - 10%, while its sensitivity ranges from 0.2% for

^{27}Al to 38 ppm for ^{238}U, in solid samples (Lavi, 1984, and Kinyua, 1982).

3.5.2. Atomic Absorption Spectrophotometer Analysis.

Additional analysis for Mn, Co, Cu, Pb, Cr, and Ca was done using the Atomic Absorption Spectrophotometer (AAS, Model VARIAN TECHTRON AA6); available at the Mines and Geology Department, in the Ministry of Environment and Natural Resources. This was done only for nine samples, merely to compare with the values obtained by XRFA for the same samples (Appendix IV). For this purpose, standard stock solutions of 1000 ppm for the desired elements were prepared. The elements were then extracted from the samples (already prepared as described in section 3.2) using the method described by Burgener (1977) as follows:

(i) 0.667g of sample is weighed and placed in a clean test tube, and

(ii) Add 5 mls of 1:1 HCL; heat at $\pm 150^{0}$ for 30 minutes,

(iii) Let to cool to room temperature, and add 15 mls of distilled water. Dilution factor = x 20.

(iv) Centrifuge for 10 minutes, if need be.

The sample solutions were then "scanned" with the AAS to roughly gauge their absorbance range; then 5 to 6 standards of known concentrations were prepared for each element, according to linear working range of the AAS. The objective being to plot an almost linear graph of known concentration versus absorbance, from which the concentration of the desired element is read.

CHAPTER 4

RESULTS

4.1 The Geobotanical Units.

In the study area around the fluorite mineralization, south of Kerio Valley, eleven geobotanical units (GBUs) are recognized in terms of their geology, geomorphology, pedology, vegetation composition, and in terms of their photographic characteristic - observed on standard panchromatic aerial photographic at scale ± 1: 50 000 (Plate I and II, Table 4.1 and Fig. 4.3). GBU I is mainly on the Keiyo Escarpment zone; a zone of rugged terrain with sharp crests on the Precambrian metarmorphic paragneisses; while GBU I' is a sub-rounded terrain with a smooth texture, situated at the lower part of the Keiyo Escarpment. The latter geobotanical unit is composed mainly of the paragneisses, but with hydrothermally metamorphosed limestone. The former unit is characterized by an Acacia-Croton-Euphobia-Ipomoea vegetation community, while an acacia-Croton-Cambretum-Commiphora-Harrissonia community distinguishes GBU I'. Geobotanical unit II is a cuesta landform unit, characterized by a Euclea - Dodonea - Combretum - Gardenia community, on laminated red sandstone deposits of Lower Miocene Period. GBU III' and GBU III" are both on float material of the Tertiary volcanics, unconformably overlying the Precambrian rocks. GBU III' has an undulating terrain with gentle to steep slopes and moderate relief amplitude, while the latter is a terrain of high relief with residual volcanic hills. These units are successively characterized

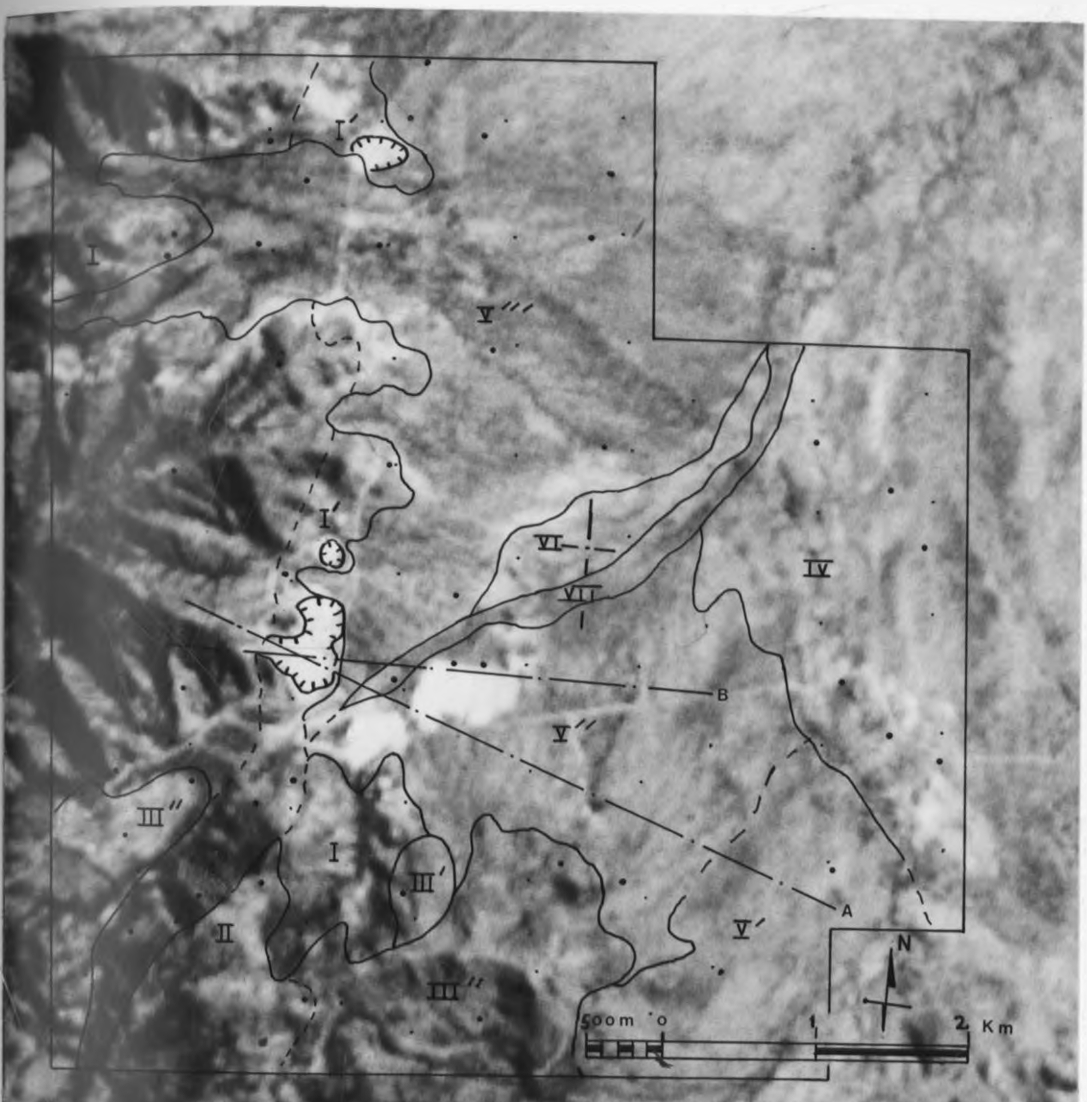


Plate 2: The Geobotanical Units Superimposed Onto a Thematic Mapper Imagery of July, 1984.

= The mining sites ; A & B = The Radiometric transects

• = The Sample Points

(For details see Table 4.2)

by Acokanthera - Acalypha - Acacia, and a Combretum - Croton - Euclea - Acacia vegetation communities. GBU IV is a dissected erosional glacis developed on tuffaceous, easily weathered volcanics, which overly the friable partly consolidated Soy Sandstone deposits (Plates 1, and 2). The unit is composed of Croton - Balanite - Acacia - Tamarindus vegetation community. The geobotanical units V', V" and V''' are all on Quaternary to Recent superficial alluvial deposits. However, GBU V' has soils developed from tuffaceous Tertiary volcanics while GBU V'' has soils developed from trachytic and basaltic lavas. GBU V''' is composed of soils derived from ferromagnesium rich gneisses. GBU VI is a cultivated unit (the Kimwarer Terrace level 1) composed of partly cemented fanglomerates. GBU VII is the flood plain of the Kimwarer River, with soils derived from mixed alluvial deposits, characterized by a ficus-Cleoradendron-Acacia vegetation community.

It is therefore evident that a geobotanical unit defines appromixately the underlying geological formation.

The distribution of the plant species in the geobotanical units (Table 4.3) shows that <u>Croton dichogamus</u> is the most widely distributed plant species, followed by <u>Combretum molle</u> and by <u>Ipomoea spathulata</u> and by <u>Acacia tortilis</u> which forms the overstory canopy while the most widely distributed species forms the understory. <u>Ficus natalensis</u> and <u>Cleorodendron</u> spp. are geobotanical indicator species for GBU VII, while <u>Commifora</u> spp., <u>Combretum</u>

TABLE 4.1 DESCRIPTION OF THE GEOBOTANICAL UNITS

GBU	Description
I	The geology is composed mainly of the Precambrian rocks which include gneisses, paragneisses and marble. A ragged terrain with sharp crests oriented westerly, on the escarpment zone. Soils well drained, very shallow, dark to reddish brown, sandy loam to sandy clay loam, derived from the ferromagnesium - rich Precambrian rocks. A unit with a rough texture and fine lineations trending northwesterly and characterized by an Acacia-Croton-Euphobia - Ipomoea community.
I'	The geology same as for GBU I, but has hydrothermally metamorphosed limestone, forming the fluorite mineralization. A smooth and rounded terrain trending north easterly, at the foot of the Keiyo Escarpment zone. Pedology as for GBU I. Has a greyish tone with a cornical form on 1969 panchromatic aerial photographs, and is characterized by an Acacia-Croton-Combretum-Commifora-Harrisonia community.
II	A cuesta landform unit composed of the Red Kimwarer Red Sandstone Formation. Has brown loamy soils of moderate depth, and a light gray tone with patches of cultivated plots. The unit is characterized by a Euclea-Dodonea-Combretum-Gardenia community.

TABLE 4.1 Cont.

GBU	Description
III'	An undulating terrain with gentle to steep slopes, composed mainly of float material of volcanic origin, which unconformably overlie the Precambrian rocks. Soils are dark and clayey, of moderate depth, and derived from the Miocene volcanics. No peculiar tonal characteristics. Composed of Acokanthera-Acalypha-Acacia community.
III"	Geology same as for GBU III', a terrain of high relief with residual volcanic hills. Soils as for the preceeding geobotanical unit, but characterized by a Combretum-Croton-Euclea-Acacia community.
IV	A dissected erosional glacis, composed of the friable partly consolidated Soy Sandstone deposits - overlying the Plio-Pleistocene volcanics. Soils are mainly fine calcareous and loamy, moderately deep, but shallow in places. A unit with a distinct whitish to greyish tone, with patches of pure white on bare ground, and characterized by a Croton-Balanite-Acacia-Tamarindus community.
V'	Composed mainly of colluvial material derived from tuffaceous Tertiary volcanics. An undulating terrain with moderate gully erosion. Soils developed from olivine basalts, well drained, very shallow dark (reddish) brown to musky red

TABLE 4.1 Cont.

GBU	Description
	clay loam, and composed of an Acacia-Croton-Euclea community, with a uniform and smooth texture on the black and white photographs.
V"	A unit composed of colluvial material derived from trachytic and basaltic lavas. A gently sloping terrain, a "colluvial-fan" with severe gully erosion - accelerated by the construction of the mine-dump reservoirs. Soils similar to those of GBU V', and is characterized by an Acacia-Combretum-Ipomoea community.
V'''	An alluvial/colluvial unconsolidated fan deposit derived from the Precambrian gneisses. Soils are reddish-brown sandy clay loam, developed on colluvium of ferromagnesium rich gneisses, well drained and moderately deep. A geobotanical unit characterized by an Acacia-Croton-Balanite-Cissus vegetation community.
VI	A unit composed mainly of partially cemented fanglomerates. It forms the Kimwarer River Terrace Level 1, a straight and horizontal geomorphological unit. Soils are moderately deep, reddish brown clay loam. A cultivated and inhabited unit easily distinguished on black/white photographs, Plate I.

TABLE 4.1 Cont.

GBU	Description
VII	Composed mainly of river alluvium. A flood plain unit seasonally flooded, with soils derived from mixed alluvial deposits of the flood plain. A unit characterized by a Ficus-Cleorodendron-Acacia vegetation community.

Note: The plant associations forming the vegetation communities are arranged in decreasing order, for example Acaci > Croton > Combretum > Commifora > Harrisonia community of GBU I', with Harrisonia being a geobotanical indicator for GBU I'.

TABLE 4.2 DISTRIBUTION OF PLANT SPECIES IN THE GEOBOTANICAL UNITS (GBUs)

DOMINANT PLANT SPECIES	FAMILY	OCCURENCE IN THE G.B.Us											
		I	I'	II	III'	III''	IV	V'	V''	V'''	VI	VIII	% FREQUENCY IN G.B.U.s
ACACIA AMARA	MIMOSACEAE						x						9.10
A. DREPANOLOBIUM	"									x			9.10
A. KIRKII	"												
A. MELLIFERA	"	x				x	x			x			36.40
A. SENEGAL	"	x							x	x			36.40
A. SEYAL	"	x			x			x		x			36.40
A. TORTILIS	"	x	x		x		x	x		x			54.50
ACALPYPHA FRUTICOSA	EUPHORBIACEAE	x	x		x			x			x		45.50
ACOKANTHERA FRIESCORIUM	APOCYNACEAE	x				x	x	x		x			45.50
ALBIZIA AMARA	CAESALPINIACEAE						x						9.10
ANNONA SENEGALENSIS	ANNONACEAE				x								9.10
ALOE Spp.	LILIACEAE	x		x			x			x			36.40

TABLE 4.2 Cont.

DOMINANT PLANT SPECIES	FAMILY	OCCURRENCE IN THE G.B.Us											% FREQUENCY IN* G.B.Us.
		I	I'	II	III'	III''	IV	V'	V''	V'''	VI	VII	
BALANITES AEGYPTIACA	BALANITACEAE	x			x		x	x		x			45.50
CAPPARIS TOMENTOSA	CAPPARACEAE									x			9.10
CASSIA OCCIDENTALIS	CAESALPINIACEAE							x			x		18.20
CISSUS ROTUNDIFOLIA	VITACEAE	x								x			18.20
CISSUS QUADRANGULARIS	VITACEAE	x					x						18.20
CLERODENDRUM Spp.	VERBENACEAE											x	9.10
COMBRETUM MOLLE	COMBRETACEAE		+	+	x	x	x	x	x	x			63.20
COMMIPHORA AFRICANA	BURSERACEAE		+										9.10
COMMIPHORA CORIACEA	BURSERACEAE						x						9.10
CROTON DICHOGAMUS	EUPHORBIACEAE	x	x		x	x	x	x	x	x	x		81.80
DODONAEA VISCOSA	SAPINDACEAE	x	x	+		x							36.40
EUCLEA DAVINORUM	EBENACEAE					x		x	x				27.30
EUCLEA NATALENSIS	EBENACEAE	x	x	x	x								36.40

* Chances of finding any species in a Geobotanical unit.

\+ Spp. with swollen stem.

TABLE 4.2 Cont.

DOMINANT PLANT SPECIES	FAMILY	I	I'
EUPHORBIA GOSSIPINA	EUPHORBIACEAE		
EUPHORBIA NYIKAE	EUPHORBIACEAE	x	
FICUS NATALENSIS	MORACEAE		
GARDENIA Spp.	RUBIACEAE		
GNIDIA SUBCORDATA	THYMELAEACEAE		
HARRISONIA ABYSSINICA	SIMAROUBACEAE		x
IPOMOEA SPATHULATA	CONVOLVULACEAE	x	x
INDIGOFERA BREVICALYX	PAPILIONACEAE		x
JUSTICIA FLAVA	ACANTHACEAE		+
LANNEA TRIPHYLLA	ANACARDIACEAE	x	
LIPPIA JAVANICA	LABIATAE	x	
LOUDETIA KAGERENSIS	GRAMINEAE		x
PELLAEA ADIANTOIDES	ADIANTACEAE		x

OCCURENCE IN THE G.B.Us

II	III'	III''	IV	V'	V''	V'''	VI	VII	% FREQUENCY IN G.B.Us.
			x						9.10
									9.10
						x		x	18.20
x									9.10
	x								9.10
				x					18.20
	x		x	x		x			54.50
									9.10
			x			x			27.30
	x		x	x					36.40
						x			18.20
									9.10
									9.10

TABLE 4. 2 Cont.

DOMINANT PLANT SPECIES	FAMILY	I	I'
PELLAEA CALOMELANOS	ADIANTACEAE		x
PLECTRANTHUS Spp.	LABIATAE		x
PSIADIA PUNCTULATA	COMPOSITAE	x	x
PTERIDIUM Spp.*	DENNSTAEDIACEAE		
RHYNCHOSIA Spp.	PAPILIONACEAE		x
RHUS NATALENSIS	ANACARDIACEAE		x
SOLANUM INCANUM	SOLANACEAE		
SPHAERANTHUS UKAMBENSIS	COMPOSITAE		
TAMARINDUS INDICA	CAESALPINIACEAE		
TECLEA NOBILIS	RUTACEAE		
TERMINALIA ORBICULARIS	COMBRETACEAE		
TERMINALIA PRUNIOIDES	COMBRETACEAE	x	x

OCCURRENCE IN G.B.Us

II	III'	III''	IV	V'	V''	V'''	VI	VIII	%FREQUENCY IN G.B.Us
									9.10
									9.10
									18.20
			x						9.10
									9.10
		x	x						27.30
						x			9.10
						x			9.10
			x						9.10
	x				x				18.20
				x					9.10
	x		x			x			45.50

TABLE 4.2

DOMINANT PLANT SPECIES	FAMILY	OCCURRENCE IN G.B.U.s											
		I	I'	II	III'	III"	IV	V'	V"	V'''	VI	VII	% FREQUENCY IN G.B.Us
UVARIA LUCIDA	ANNONACEAE	x	x		x			x		x			45.50
VANGUERIA ACUTILOBA	RUBIACEAE	x			x			x		x			36.40
WOODFORDIA UNIFLORA	LYTHRACEAE	ONLY FOUND ON NEPHELINITIC PHONOLITE											
ZIZIPHUS MAURITIANA	RHAMNACEAE						x						9.10

No. of Species sampled = 54

Total No. of Families = 30

	I	I'	II	III'	III"	IV	V'	V"	V'''	VI	VII
No. of Species identified in a G.B. Unit =	22	19	5	15	7	20	16	4	21	3	2

<u>Other Plant Species (LN)</u>

Cheprirpeiyet

<u>ECONOMIC SPECIES</u>:

BALANITES AEGYPIACA – Evergreen, Used as fodder in drought periods

CAPPARIS TOMENTOSA – Magic-medicinal plant in Africa (in Kuchar, 1981).

TABLE 4.2 Cont.

<u>Other Plant Species (LN)</u>

Kiborwet

Lomoyuet

Markeiyuet

Muyengwo

Singorwet

<u>ECONOMIC SPECIES:</u>

CROTON DICHOGAMUS	-	Good for goat feeding.
INDIGOFERA BREVYCALYX	-	Edible seeds. Milky sap used as arrow poison.
PSIADIA PUNCTULATA	-	Roots boiled and eaten for stomach constipation in children.
WOODFORDIA UNIFLORA	-	Similar variety W. FRUTICOSA (Exotic) an important source of red dye. Leaves have 12-20% tannin (Kuchar, 1981). Also medicinal uses.

NOTE:

* Family = POLYPODIACEAE (Vereiskii & Vostokova Eds.).
Plant family sequence follow Hutchinson sequence used at E.A. Herbarium, KREMU Herbarium and U.O.N Herbarium, and Agnew (1974)

LN = Local Names in Kalenjin.

molle (with a swollen stem, plate V) and Harrisonia abyssinica are geobotanical indicator species for the mineralised GBU I'.

In the eleven geobotanical units 54 different plant species were identified, out of which 53.7% were assayed (selected randomly as no information about their preference for particular elements was available). The most dominant plant species assayed comprise 20.4% of the total number of species sampled. The rest of the plants assayed once (Table 4.4a) constitute 33.3% of the plant samples; this percentage comprise the lesser occurring plant species in the geobotanical unit. Emphasis for trace elements analysis has therefore beeén mainly on the lesser plant species - which localize the fluorite mineralization; while it is evident (Table 4.1) that the dominant species which constitute the major vegetal component of the study area, define approximately the underlying geological formations.

Some of the plants found in the study area are of economical value, particularly in the chemical industry, and in medicine. Others suppliment for animal fodder during dry spells (Table 4.2, foot notes).

Distinct morphological deformity in the form of abnormal growth-form is developed on the stem of Combretum molle (Plate V), only in species growing in geobotanical units I' and III. In other geobotanical units, this species has distinctly straight stems.

4.2 Element Concentrations.

The plant and soil samples collected around the fluorite mineralization were quantitatively analyzed using X-Ray Fluorescence (XRF) analysis for the elements calcium (Ca), phosphorous (P), copper (Cu), Zinc (Zn), Manganese (Mn), Rubidium (Rb), Uranium (U), Strontium (Sr) and Zirconium (Zr). The concentration of these so-called path finder elements for the fluorite mineralization, had initially been determined in samples of fluorite-ore, collected at the Kimwarer mine site, which contained concentrations as illustrated in Table 4.3, below.

Table 4.3 Element Concentration in a Fluorite-Ore.

Element	Ca%	Cu	Zn	Mn	Rb	Sr	Zr	U	p
Mean Conc. (6 assays)	27.7%	45	18.83	681	61.3	1211.2	4412.3	197.5	3.68%
Sd	1.07	2.61	2.48	6.67	3.83	27.43	25.05	8.17	0.23

(Values in ppm unless indicated)

Other elements determined quantitatively in the plant and soil samples, but not analyzed in the study are appended in Appendix III (a) and III(b). The assay data in Table 4.4(a) and (b) suffice in giving

TABLE 4.4 (a) ELEMENT

G.B.U.	SITE	PLANT SPECIES	SAMPLE NO.
I	R1	ACACIA MELLIFERA	KV/BD-029
	R4	A. TORTILIS	KV/BD-056
	G2	CISSUS QUADRANGULARIS	- -026
	G5	VANGUERIA ACUTILOBA	- -031
	R1	EUPHOBIA NYIKAE	- -021
	G60	A. TORTILIS	016B
	G57	CROTON DICHOGAMUS	012B
	G57	C. DICHOGAMUS	012C
I'	R6	HARRISONIA ABYSSINICA	- -099
	G6	INDIGOFERA BREVICALYX	- -109
	G4	CROTON DICHOGAMUS	- -093

CONCENTRATION IN PLANT SAMPLES

ELEMENT CONCENTRATION

%		PPM							
P	Ca	Mn	Fe	Cu	Zn	Rb	U	Sr	Zr
6.89	5.97	286	1444	229	223	510	ND	1802	ND
-	-	80	2212	22	123	38	ND	588	85
9.29	10.96	404	1544	529	282	ND	ND	4212	ND
-	-	563	5204	335	706	3720	ND	ND	ND
-	-	586	382	25	22	36	ND	282	46
13.60	10.70	182	2869	147	149	110	16	3775	148
28.90	27.60	1187	3298	195	108	292	45	4037	127
12.60	15.70	1036	4378	314	364	115	1	1859	ND
10.00	15.20	22100	29600	2369	5148	605	101	29600	2152
5.00	10.70	1915	6422	99	250	114	ND	ND	ND
26.70	24.40	1655	3019	146	295	113	18	2451	205

TABLE 4.4 (a) Cont.

G.B.U	SITE	PLANT SPECIES	SAMPLE NO.	% P
I'	G56	CROTON DICHOGAMUS	011B	16.80
	G59	C. DICHOGAMUS	015A	15.00
	G6	DODONAEA VISCOSA	KV/BD-112	-
	R13	EUCLEA NATALENSIS	- - 120	-
	$G6_1$	JUSTICIA FLAVA	- -131A	7.30
II	R15	DODONAEA VISCOSA	- - 104	5.40
III	R41	COMBRETUM MOLLE	006C	13.40
	R40	CROTON DICHOGAMUS	004B	8.70
	G51	DODONAEA VISCOSA	003A	9.60

ELEMENT CONCENTRATION

				PPM				
Ca	Mn	Fe	Cu	Zn	Rb	U	Sr	Zr
16.70	587	5426	229	180	107	ND	2385	204
20.70	433	2383	180	318	81	11	375	285
-	3318	5899	251	471	109	ND	2000	ND
-	1550	4514	217	239	126	ND	8959	ND
11.00	1054	4428	97	280	61	ND	2447	97
7.60	739	5789	100	173	84	ND	1409	208
21.90	472	1496	110	173	64	ND	1978	213
13.90	1944	3684	265	312	62	14	2369	153
10.30	3653	10000	268	471	170	1	791	164

TABLE 4.4 (a) Cont.

G.B.U.	SITE	PLANT SPECIES	SAMPLE NO.	% P
III"	G52	RHUS NATALENSIS	005C	20.20
III'	G1	ACALYPHA FRUITCOSA	KV/BD-005	32.30
	B1	BALANITES AEGYPTIACA	P-001	9.80
	G50	CROTON DICHOGAMUS	002A	12.95
	G1	IMPOMOEA SPATHULATA	KV/BD-004	2.70
	G1	I. SPATHULATA	- -020	-
	G50	VANGUERIA ACUTILOBA	002C	2.90
	G1	UVARIA LUCIDA	KV/BD-003	-

ELEMENT CONCENTRATION

PPM

Ca	Mn	Fe	Cu	Zn	Rb	U	Sr	Zr
20.30	351	3162	134	498	91	12	3360	158
7.58	744	11	139	850	36	ND	1702	175
10.60	168	3876	121	494	151	9	1901	82
16.30	999	2674	261	348	40	ND	2465	93
3.30	1825	4672	501	1014	156	ND	3190	ND
-	1338	11964	643	346	187	ND	1224	ND
1.50	662	4776	160	620	17	24	2209	ND
-	1149	8515	439	508	60	ND	1390	ND

TABLE 4.4 (a) Cont.

G.B.U	SITE	PLANT SPECIES	SAMPLE NO.	% P
IV	G7	ACACIA AMARA	- - 143	-
	G8	A. MELLIFERA	- - 139	-
	R16	COMMIPHORA CORIACEA	- - 156	ND
	G8	CISSUS QUADRANGULARIS	- - 136	0.56
	R17	CROTON DICHOGAMUS	- - 148	12.80
	R16	C. DICHOGAMUS	- - 160	17.30
	G9	C. DICHOGAMUS	- - 074	16.70
	R18	C. DICHOGAMUS	- - 132	-
	G7	EUPHOBIA GOSSYPINA	- - 142	-
	G7	IPOMOEA SPATHULATA	- - 145	-
	R18	LANNEA TRIPHYLLA	- - 134	-

ELEMENT CONCENTRATION

PPM

Ca	Mn	Fe	Cu	Zn	Rb	U	Sr	Zr
-	1106	13146	94	682	113	ND	2432	ND
-	90	1738	99	237	192	ND	4392	ND
8.14	142	902	9	34	12	ND	670	ND
0.74	14	522	28	16	43	ND	631	98
22.70	1013	3850	140	277	93	15	2675	83
18.60	1508	5260	155	289	118	19	3119	102
25.20	1346	4397	97	258	275	50	3733	290
-	5953	2443	134	320	355	14	2602	118
-	ND	790	100	107	ND	ND	1977	321
-	686	1996	162	127	134	ND	ND	173
-	6640	5460	69	230	110	22	1499	ND

TABLE 4.4 (a) Cont.

G.B.U	SITE	PLANT SPECIES	SAMPLE NO.
IV	R17	TERMINALIA PRUNIOIDES	. - - 151
V"	R7	ACACIA SEYAL	- - 063
	G53	A. TORTILIS	007A
	R7	ACALYPHA RUITCOSA	KV/BD-062
	G53	COMBRETUM MOLLE	007B
	O''	IPOMOEA SPATHULATA	019p
	O'	PTERRIDIUM Spp.	013
	R7	IPOMOEA SPATHULATA	KV/BD-067
V''	G54	CROTON DICHOGAMUS	008B
	G54	EUCLEA DAVINORUM	008A

ELEMENT CONCENTRATION

%		ppm							
P	Ca	Mn	Fe	Cu	Zn	Rb	U	Sr	Zr
ND	ND	430	1855	299	299	71	ND	2585	331
-	-	313	3225	172	288	146	ND	2763	ND
29.40	29.30	323	4346	74	218	54	2	3562	ND
-	-	297	4863	159	445	50	ND	1707	ND
22.90	28.40	2336	2421	222	208	8	10	2435	160
14.60	14.40	1190	12000	332	271	103	8	1461	331
8.00	4.57	927	5483	214	378	77	1	713	76
16.33	30.97	433	2897	1740	424	141	ND	1847	19
18.50	21.10	1463	3321	255	249	96	ND	1846	118
42.30	37.70	2511	2502	143	163	78	4	1999	ND

TABLE 4.4 (a) Cont.

G.B.U		SITE	PLANT SPECIES	SAMPLE NO.	% P
V''		G54	TECLEA NOBILIS	008C	11.40
V'''	* (	G61	BALANITES AEGYPTIACA	017B(i)	16.70
	(		-- " --	017B(ii)	19.10
		G12	-- " --	KV/BD-161	ND
		R21	-- " --	-"-172	-
		R19	COMBRETUM MOLLE	-"-185	-
		G11	CISSUS ROTUNDIFOLIA	-"-167	-
		R2	CROTON DICHOGAMUS	-"-011	15.70
		R10	-- " --	-"-041	-
		R9	UVARIA LUCIDA	-"-045	-
		R9	VANGUERIA ACUTILOBA	-"-043	-

* Duplicate Analysis

ELEMENT CONCENTRATION

ppm

Ca	Mn	Fe	Cu	Zn	Rb	U	Sr	Zr
15.50	1115	3367	244	549	36	7	1507	106
13.40	168	2300	79	122	189	4	1729	ND
15.90	202	2687	87	132	194	4	1771	ND
12.99	452	2753	101	238	ND	ND	16300	ND
-	414	1356	47	287	ND	ND	ND	207
-	1923	3634	196	447	45	ND	2008	ND
-	254	1523	368	116	ND	ND	1179	ND
18.80	807	4319	197	223	130	23	3243	199
-	4728	1993	204	325	ND	ND	4483	607
-	ND	ND	774	657	24	ND	808	ND
-	530	2427	150	176	63	ND	1390	202

TABLE 4.4 (a) Cont.

G.B.U		SITE	PLANT SPECIES	SAMPLE NO.	P	Ca	Mn	Fe	Cu	Zn	Rb	U	Sr	Zr
					%		ppm							
							ELEMENT CONCENTRATION							
VI		G55	CLEORODENDRUM Spp.	010C	25.30	16.90	6575	7837	828	602	125	17	1956	267
		-"-	ANON	---	-	-	644	1566	141	289	144	ND	1471	ND
	*(	G64	COMBRETUM MOLLE	020(i)	21.00	20.00	1133	2780	234	436	86	6	3053	ND
	(	-"-	-- " --	020(ii)	13.00	16.90	1015	2621	196	422	85	6	3017	ND
		G65	CROTON DICHOGAMUS	018B	15.50	21.30	2097	2470	191	295	263	39	2355	262
				MEAN =	15.18	16.11	1595.61	5876	262.35	394.15	184.65	17.34	2942	232.57
				STDEV. =	8.54	8.10	2956.07	13651	358.25	619.51	472.30	20.04	4058	337.19

* Duplicate Analysis. The two asseys are closely related, therefore one analysis is adequate, in as far as obtaining a general picture of element concentrations in the samples.

TABLE 4.4 (b)

ELEMENT CONCENTRATION IN SOIL SAMPLES

G.B.U.	SITE	SAMPLE NO.	pH	MV	Ca%	Fe%	Mn (ppm)	Cu (ppm)	Zn (ppm)	Rb (ppm)	U (ppm)	Zr (ppm)	Sr (ppm)
III'	B1	S-001	9.10	-20	0.19	8.20	725	170	141	82	15	694	179
	G50	S-002	9.85	-50	0.16	11.60	2304	212	197	17	12	432	975
II	G51	S-003	6.95	125	0.34	13.70	2157	456	387	40	6	542	337
III''	R40	S-004	9.45	45	1.20	11.20	3342	473	177	90	4	440	335
III'	G52	S-005	9.25	0.00	2.30	13.00	2252	322	142	126	ND	537	878
	R41	S-006	10.50	-65	0.95	11.50	3422	308	157	224	ND	329	404
V'	G53	S-007	10.10	-65	3.30	13.50	4130	282	223	68	6	429	842

TABLE 4.4 (b) Cont.

G.B.U	SITE	SAMPLE NO.	pH	MV	Ca%	Fe%
V''	G54	S-008	8.30	55	0.22	11.00
	R42	S-009	10.60	-90	0.83	9.30
		S-010	8.20	-15	0.91	7.90
I	G56	S-011	9.70	-20.50	0.80	10.70
	G57	S-012	10.60	-70	2.40	11.00
	G62	S-013	8.95	0.00	0.04	10.60
		S-014	9.05	-10	2.00	13.90
I'	G59	S-015	10.60	-90	1.60	9.60
I	G60	S-016	9.20	0.00	0.70	10.00

ppm

Mn	Cu	Zn	Rb	U	Zr	Sr
457	494	258	159	22	709	223
2956	133	214	176	1	846	318
1920	313	167	143	ND	421	379
1923	239	160	126	15	275	236
1560	208	223	53	16	265	560
2722	2924	271	121	21	665	489
4010	685	256	89	6	832	453
1372	328	165	1630	6	261	453
1512	190	249	95	ND	247	219

TABLE 4.4 (b) Cont.

G.B.U	SITE	SAMPLE NO.	pH	MV	Ca%	Fe%	Mn (ppm)	Cu (ppm)	Zn (ppm)	Rb (ppm)	U (ppm)	Zr (ppm)	Sr (ppm)
V'''	G61	S-017	8.30	30	0.82	8.97	2482	156	246	134	85	616	535
		S-018	10.30	-55	0.35	4.70	712	200	277	72	9	656	565
Tail	O'	01S01	8.80	25	9.71	3.00	705	204	99	48	7	ND	301
V''		S-020	9.95	-85	0.57	4.29	1771	161	247	159	3	797	305
			MEAN		1.50	9.9	2122	426	213	183	15	526	449
		STANDARD DEVIATIONS			±2.07	±2.98	1053	589	63.7	336	19.2	196	220

NOTE: Element concentration in rectangular boxes are higher than the local threshold values, i.e are significant anomalies.

a general picture of element concentrations in the biogeochemical sample, since duplicate analyses (Table 4.4 (a) of different plant samples gave perfect correlations (r-values of + 1). In these tables of element concentrations, the samples having anomalous element concentrations are highlighted in rectangular boxes. These are concentration values higher than the local threshold value. Further, while these anomalous elements have local background concentrations values which are higher than the universal background concentration value, their standard deviations are also higher than their local mean concentration values.

The scatter plots (fig. 4.1), show element concentrations in Kerio Valley plants, around the fluorite mineralization. The UBVs in plants are as given in Cannon, 1960, Vinogradov, 1959, Taylor, 1964, Bear, 1964 and Bowen, 1966 (all in Siegel, 1974). In soils UBV are according to Andrew Jones, 1968 (Brooks, 1972).

In the study, the local background value (LBV) is taken as the mean concentration value ($\bar{X}$) plus one standard deviations (SDV), as in Rose, Hawkes and Webb (1979), while the local threshold value (LTV) is as proposed by Sayala (1979) and Marmo (1953) to be $\bar{X}$ + 2 sd.

The resulting element concentration plots (fig. 4.2) were obtained when a smoothing - moving avarage technique is applied onto the biogeochemical data in Table 4.4 (a) and 4.4(b). These plots, the zones of element concentrations were obtained by drawing

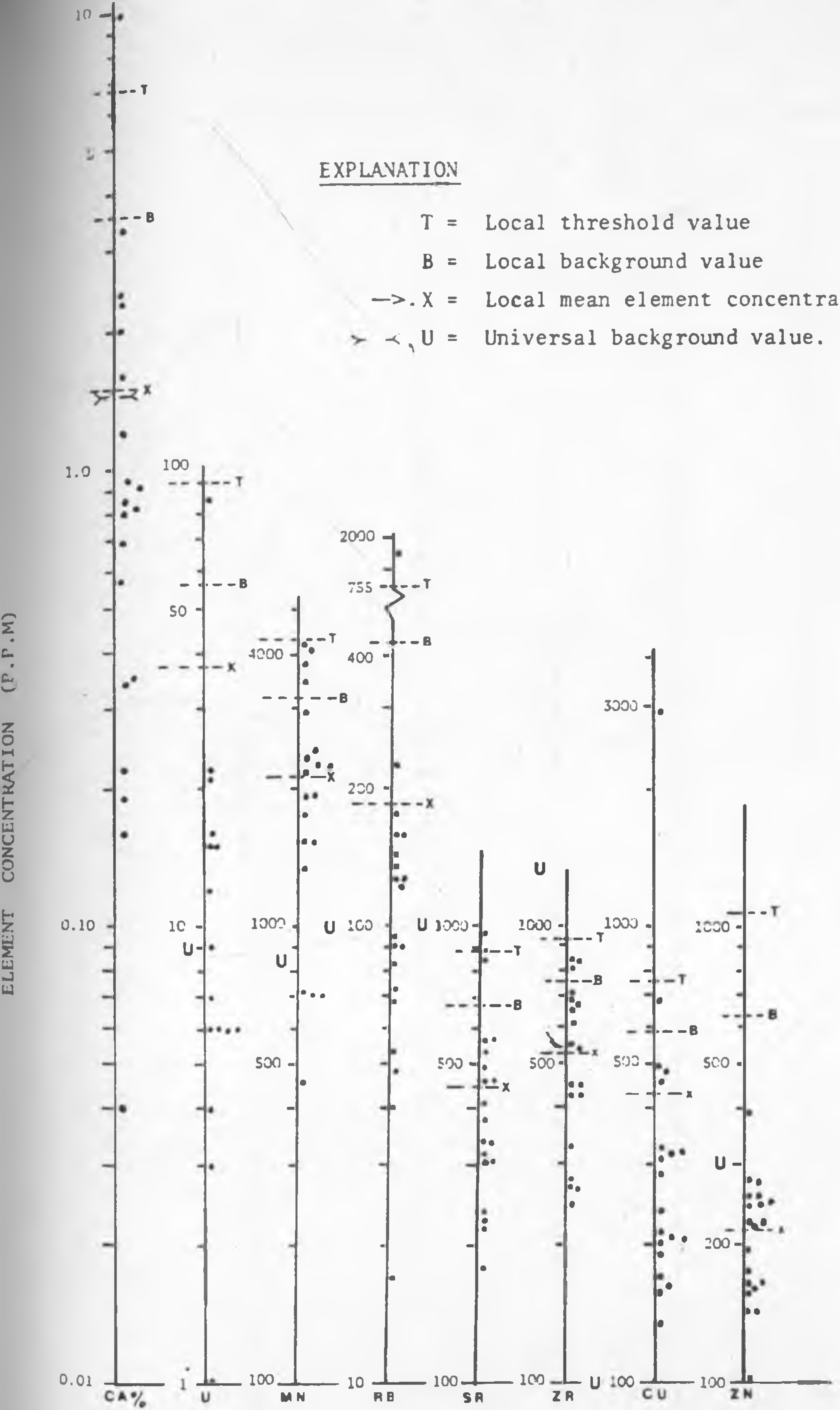


Fig. 4.1 (b). Scatter Plot of Element Concentration in Soil Samples.

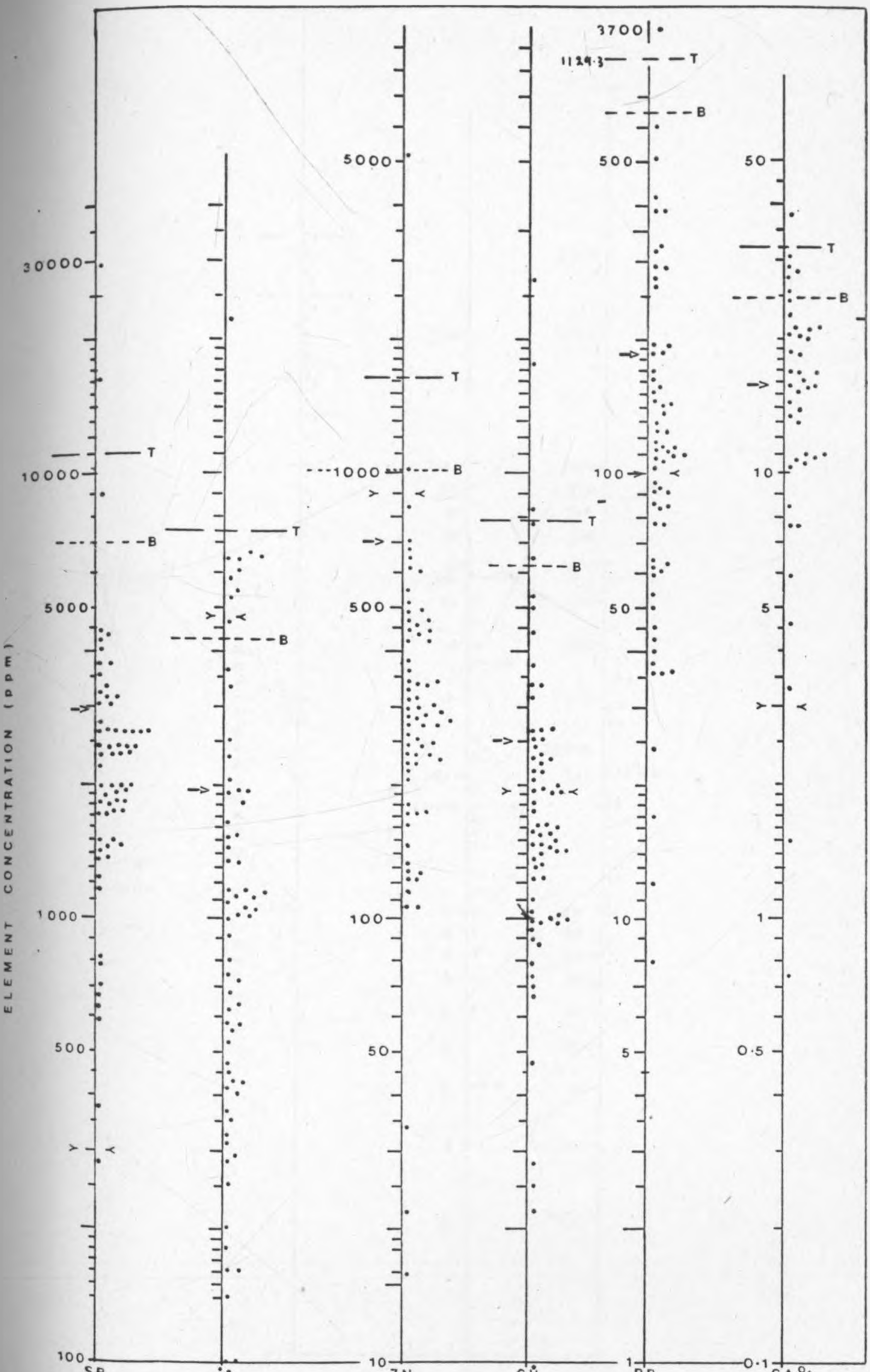


Fig. 4.1 (a) Scatter Plot of Element concentration in Plant Samples.

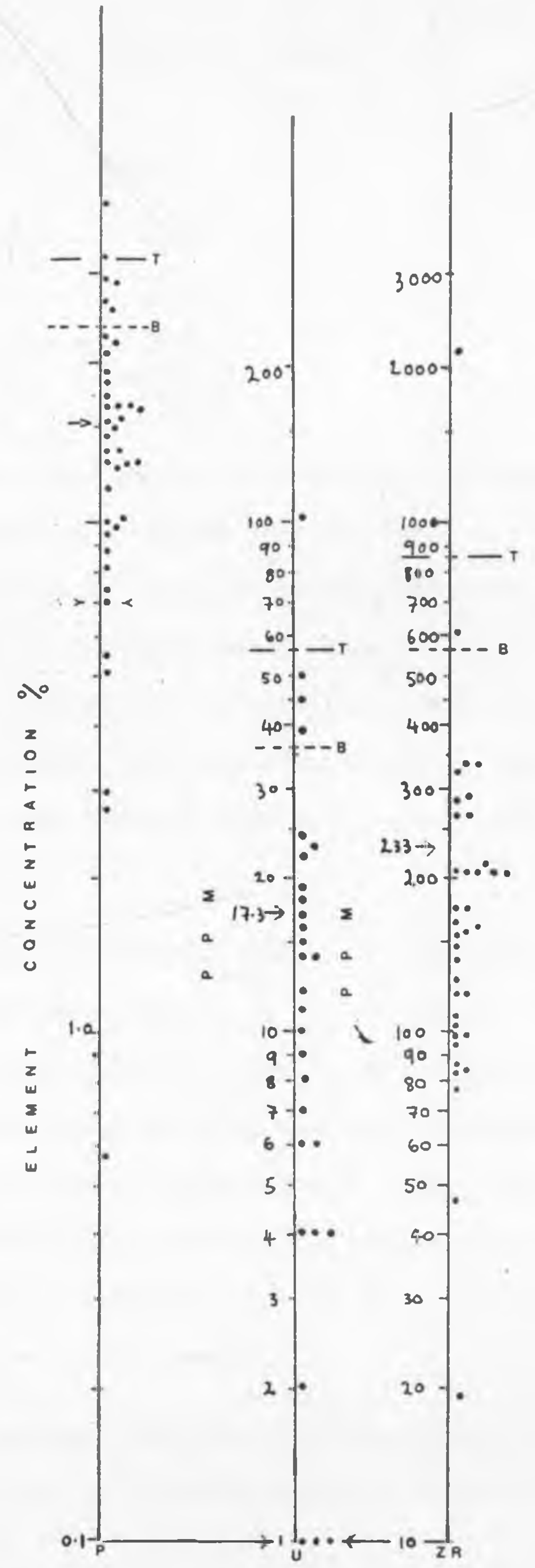


Fig. 4.1 (a) Continued.

isograds between the following themes:

Theme	Shade
$\bar{X}$	
$\bar{X}$ to $\bar{X}$ + sd.	
$\bar{X}$ + sd to $\bar{X}$ + 2 sd.	
$\bar{X}$ + 2 sd.	

where, $\bar{X}$ = total mean element concentration in samples.

sd = standard deviation from the mean

X + sd = the local background value, and

X + 2 sd= as the local threshold value;

Values higher than the local threshold value are usually geochemically anomalous (Siegel, 1974, and Sayala, 1979). These concentration ranges are the most commonly selected in geochemical prospecting (Siegel, 1974).

The degree of variation between the local threshold value and the peaks (individual values), is the geochemical contrast, or the geochemical relief, (Levinson 1974). The geochemical contrast is determined by dividing the local mean concentration by the local background value (Rose, Hawkes and Webb, 1979). Table 4.5 (a) gives the geochemical contrast values of the selected elements in the plant samples, while Table 4.5 (b) gives the contrast values for the elements in soil samples.

It is apparent from table 4.5 (a) that the trace elements, Cu, Sr, Zn, Mn, and Rb, have standard deviations larger than their

(a) Element conc. in Plants (b) Element conc. in Soils.

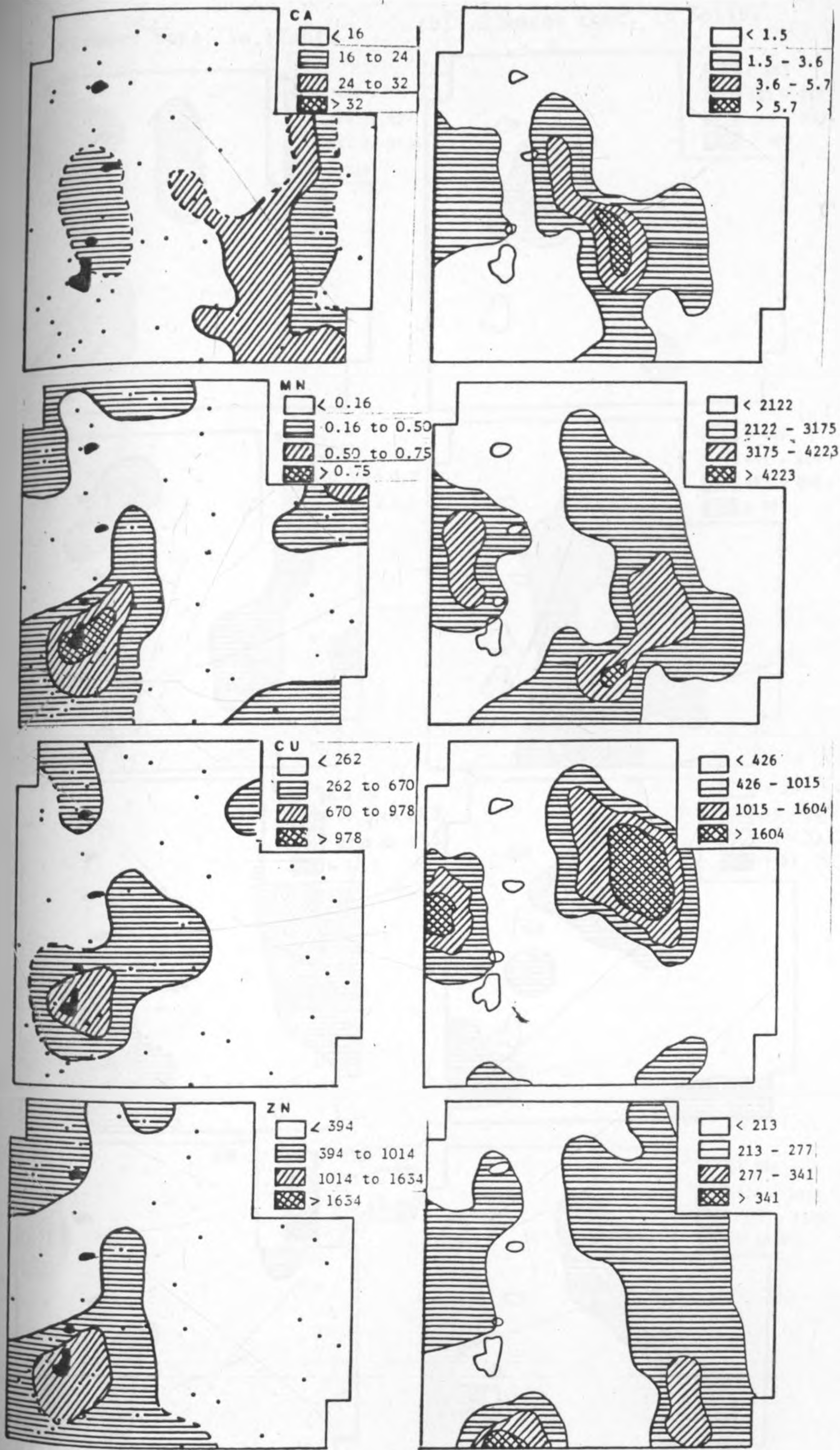


Fig. 4.2 Element concentration Plots for Plant and Soil samples.

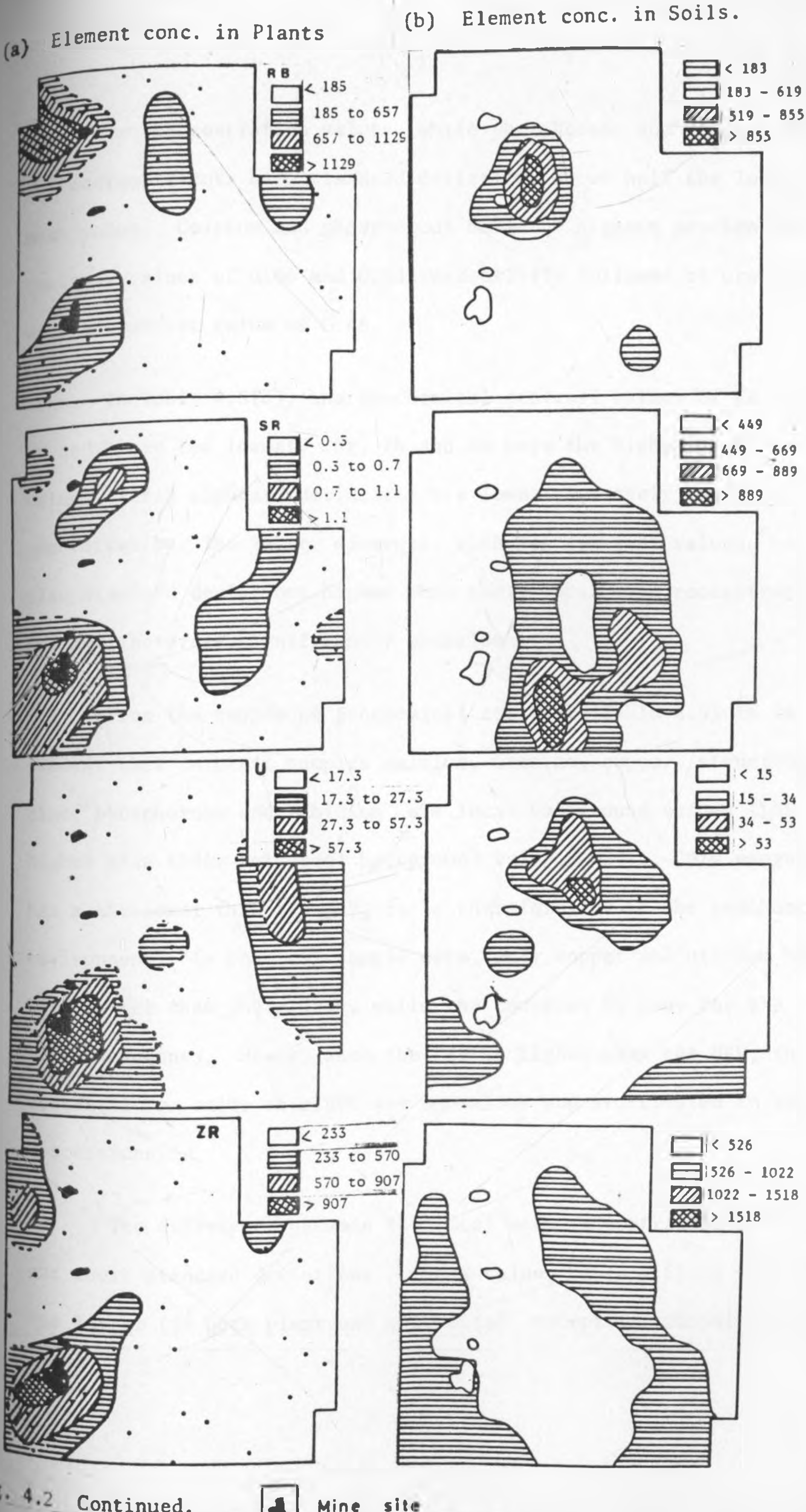


Fig. 4.2 Continued.

local mean concentration values, while phosphorous and calcium which are macronutrients have standard deviations about half the local mean value. Calcium and phosphorous have the highest geochemical contrast values of 0.66 and 0.64 respectively followed by uranium with a contrast value of 0.46.

In Table 4.5(b), the geochemical contrast values of Cu, Ca, Rb and U are the lowest. Sr, Zn and Mn have the highest contrast values, their standard deviations are lower than their local mean concentration. The latter elements, with low contrast values, have also standard deviations higher than their local mean concentrations, and are therefore significantly anomalous.

From the tables of geochemical contrast (Table 4.5) it is evident that in plant samples calcium, uranium, copper, strontium, zinc, phosphorous and rubidium have local background values (LBV) higher than their universal background values (UBV). Only manganese has a LBV lower than its UBV, it is therefore low in the geochemical environment. In the soil sample data, only copper and uranium have LBVs higher than their UBVs, while the converse is true for the rest of the elements. Hence, when the LBV is higher than the UBV, the concentration value obtained are anomalous and are treated in the discussions.

The difference between the local mean concentration of elements and their standard deviations (the d-value, Table 4.5) is lower than the latter (in both plant and soil data), except for rubidium in the

Table 4.5 GEOCHEMICAL CONTRACT OF ELEMENTS IN PLANT (A) AND SOIL (B) SAMPLES.

	ELEMENT	$\bar{X}$	Sd.	d	LTV*	LBV	UBV	G.C+
A) PLANTS	Cu	262	358	96	978	620	190	0.42
	Sr	2942	4058	1116	1.10%	7000	300	0.42
	Zr	233	337	104	907	570	ND	0.41
	Ca	16%	8.1%	7.9%	32.2%	24.1%	3%	0.66
	Zn	394	620	226	1634	1014	900	0.39
	Mn	1596	2956	1360	7508	4552	4815	0.35
	U	17	20	3	57	37	0.6	0.46
	Rb	185	472	287	1102	657	100	0.30
	P	15.2%	8.5%	6.7	32.2%	23.7%	3%	0.64
B) SOILS	Cu	426	589	163	1604	1015	100	0.42
	Sr	449	220	229	889	669	1000	0.67
	Zr	526	196	330	918	722	2000	0.73
	Ca	1.5%	2.1%	0.6%	5.7%	3.6%	1.4%	0.42
	Zn	213	64	149	341	277	300	0.77
	Mn	2122	1053	1009	4288	3175	4000	0.67
	U	15	19	4	53	34	9	0.44
	Rb	183	336	153	855	519	600	0.35
	P	(NOT DETECTED IN SOILS).						

+ G.C. = $\bar{X}$/LBV, and d = Sd. $-\bar{X}$

* LTV rounded to the nearest whole number

(Values in ppm. unless indicated).

plant concentration: this indicates the different behaviour of rubidium in plants.

4.3. The Spectral Anomaly

On the remote sensing data acquired after the opening of the mines (plate 1 and 2), the mining sites are clearly visible because of their high reflectance - due to the stripping of vegetation and subsequent exposure of the sandy soils, hence the radiometric anomaly apparent along the two transects obtained on digitally processed satellite data in fig. 4.3. Similarly, Croton dischogamus with the highest percent spectral reflectance, in the Infra Red (0.8 - 1.1 mm wavelength) channel, also occurs in GBU I' (fig. 4.4 c). Fig. 4.4 b also shows a clear distinction of percent reflectance from plants (leaves) and soil/rock surface. The difference is apparent when values obtained in the spectral bands I to IV are compared for plant and soil surfaces; with plants having higher values in bands III and IV (the Infra Red Bands), and weathered trachytic rocks reflecting highest in the visible bands I and II, and lowest in the IR - channel.

On panchromatic aerial photographs acquired prior to the opening of the mines, the present mining sites have distinct photographic and geomorphic characteristics (Table 4.1). Thus, the zone of mineralization in the Precambrian rocks depicted by GBU I', has a distinct morphological anomaly.

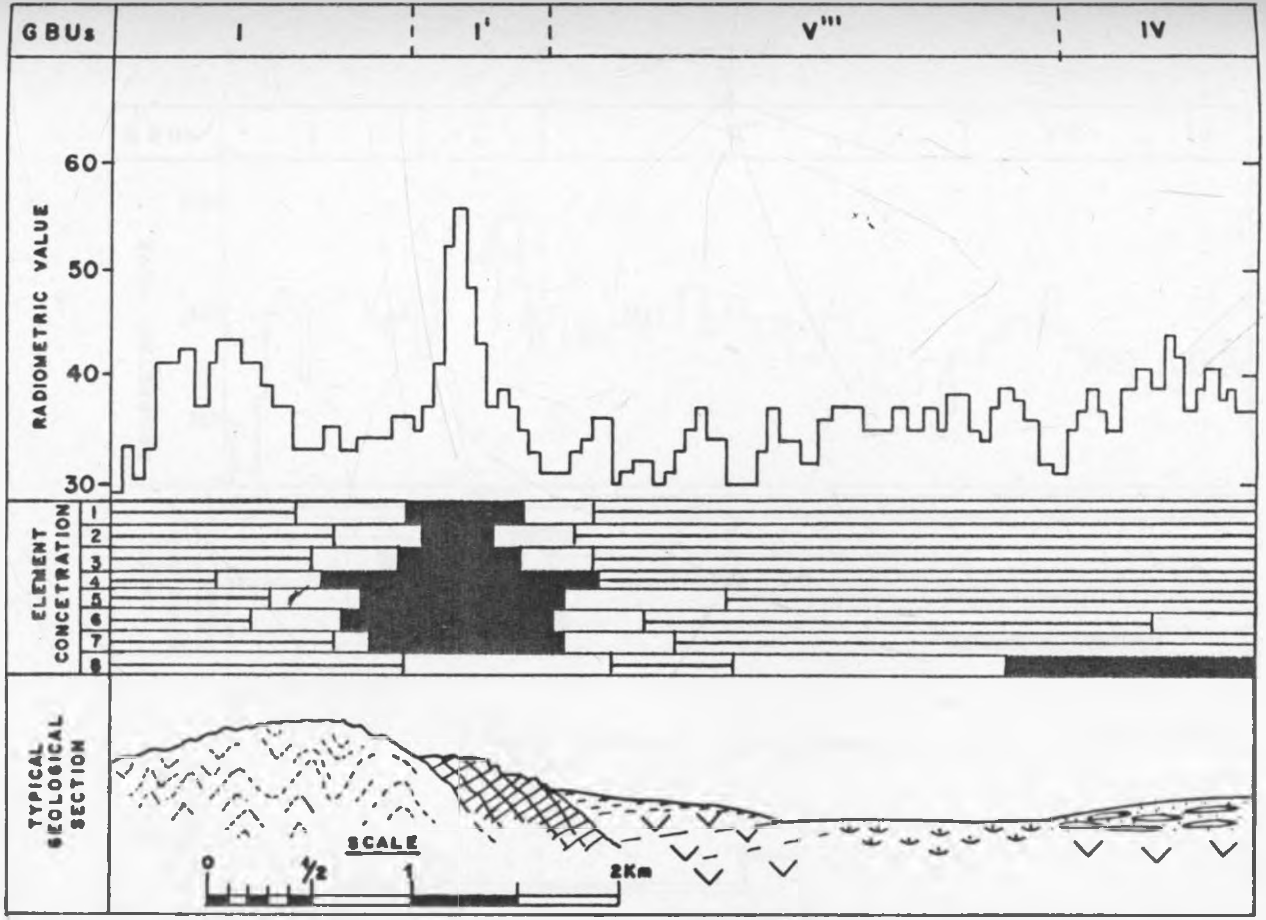


Fig.4·3 (a) –Radiometric values along transects A and B, related to the geology, biogeochemistry and to the geobotanical units. Values obtained from the Digital Imagery Processing System for Channel 6 only.

Lithology: 1 Quaternary to Recent alluvial / colluvial deposit, 2 Flood plain of the Kimwarer River, 3 Soy Sandstone deposit, 4 Tertiary Volcanics, 5 Fluorite Mineralization, 6 Precambrian paragneisses.

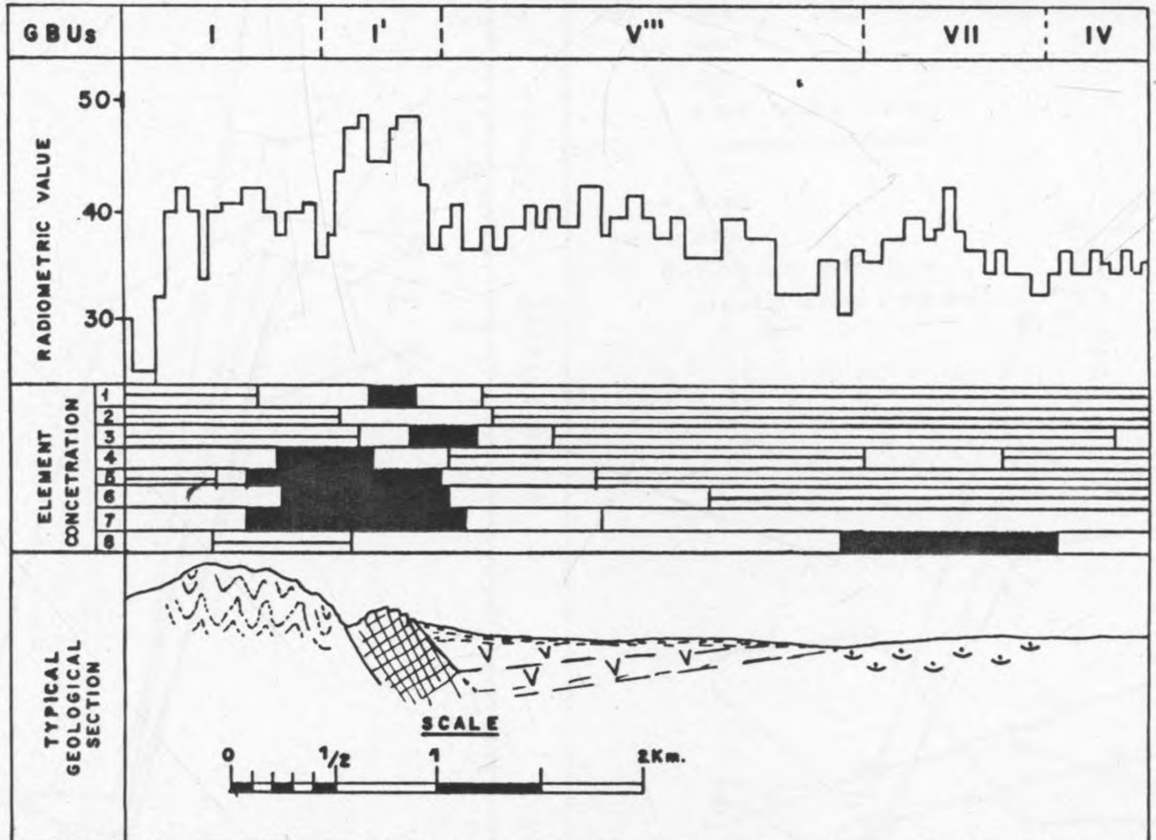


Fig. 4·3 (b) — As in Fig. 4·4 (a) <u>Element Conc. Range:</u> A ▭ Below X+σ,

B ▭ From X+σ to X+2σs, C ■ Above X+2σs.

<u>NB</u>: 1=Zr, 2=Rb, 3=U, 4=Sr, 5=Zn, 6=Cu, 7=Mn, 8=Ca.

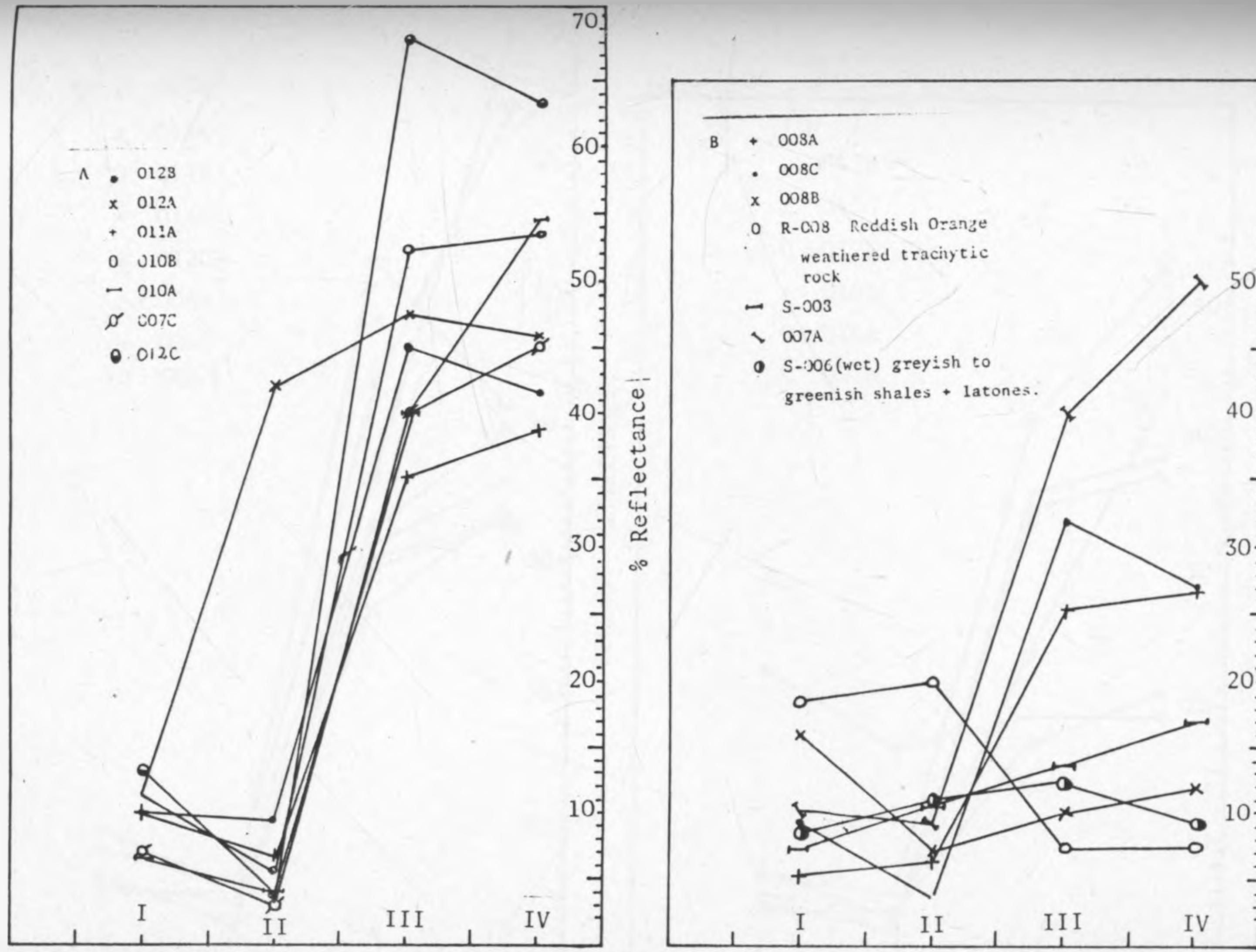


Fig. 4.4 (a) % Reflectance of some plant in the Geobotanical Units.

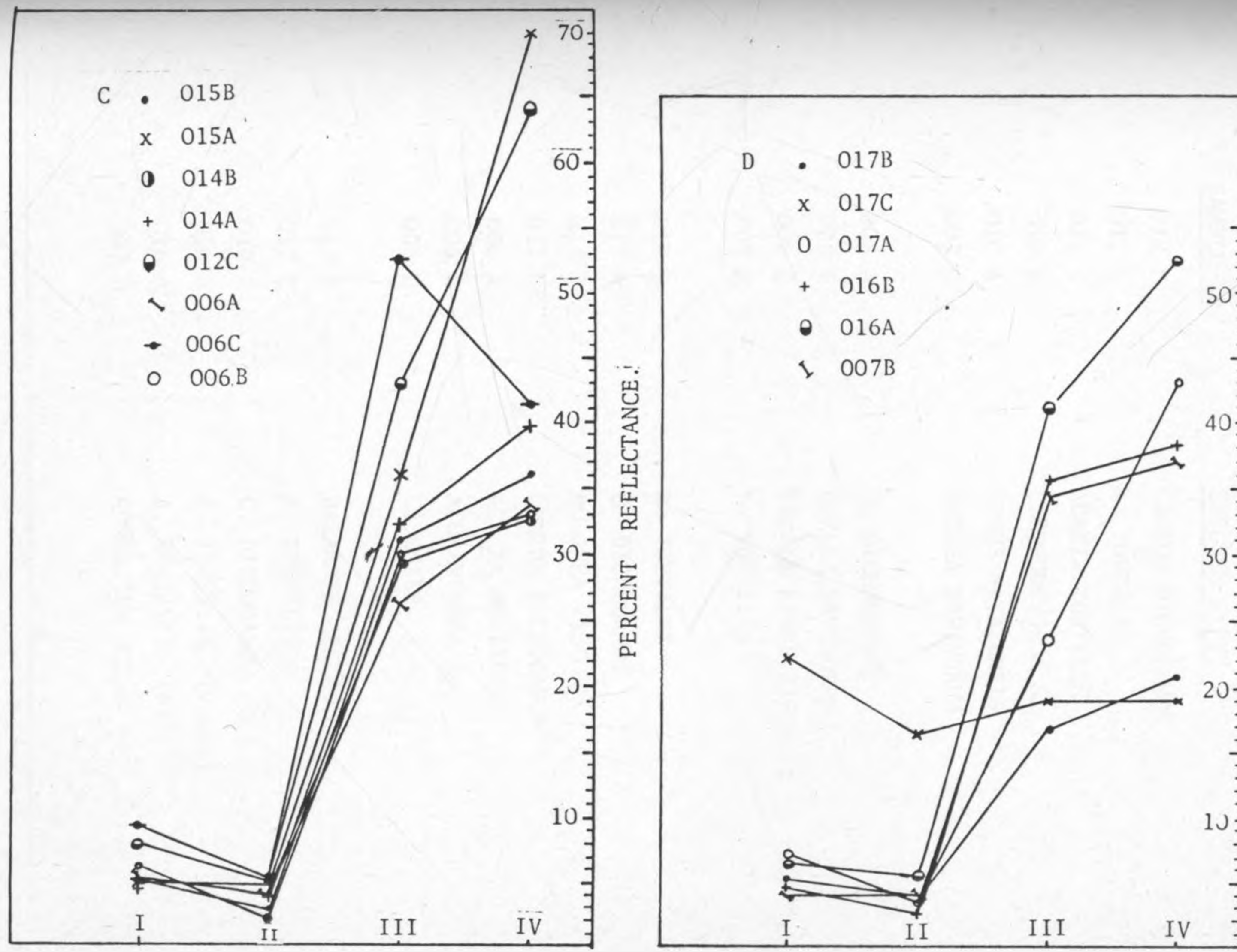


Fig. 4.4 (b) % Reflectance of some plants in the GBUs.

TABLE 4.6 EXPLANATION TO FIG. 4.4

FIG.	SAMPLE NO.	SPECIES TYPE.
A	012 B	CROTON DICHOGAMUS
	012 A	A. TORTILIS
	011 A	ACACIA TORTILIS
	010 B	CLEORODENDRON S.
	010 A	FICUS NATALENSIS
	007 C	EUCLEA DAVINORUM
B	008 A	C. DICHOGAMUS
	008 B	EUCLEA DAVINORUM
	008 C	TECLEA SIMPLISIFORMIS
	007 A	A. TORTILIS
C	015 B	A. TORTILIS
	015 A	C. DICHOGAMUS
	014 B	DODONEA VISCOSA
	012 C	CROTON DICHOGAMUS
	006 A	ACACIA MELLIFERA
	006 B	ACOKANTHERA Sp.
	006 C	C. MOLLE
D	017 B	BALANITE AEGYPTICA
	017 C	A. TORTILIS
	017 A	C. DICHOGAMUS
	016 B	A. TORTILIS (young)
	016 A	A. TORTILIS (old)
	007 B	COMBRETUM MOLLE

In Fig. 4.3, the concentrations of the elements treated in the study, are indicated along the transects. It is apparent that the zone with the highest element concentrations (with values higher than mean plus two standard deviations) coincide with the mineralized geological unit, to the radiometric anomaly, and to GBU I'. Only Ca has the highest concentration on the friable, partly consolidated calcareous Soy sandstone deposits, and a concentration below the Local background value over the mineralized geological unit (GBU I').

CHAPTER 5

DISCUSSIONS AND CONCLUSIONS

5.1 DISCUSSIONS

The results presented in this study, demonstrate the existence of anomalous concentrations of Ca, Cu, Rb, Sr, U and Zr in the vegetation samples around the fluorite mineralization. These ubiquitous trace elements have been used as the pathfinder elements in the localization of the mineralization.

The determination of the mineralization using the pathfinder elements, has been achieved by averaging all the values (for each of the elements in plants) as recommended by Harbaugh (1950), Tooms and Jay (1964), Malyuga (1964), and Kapinsky, 1941 (in Brooks, 1972). In this case, a moving average technique was applied on the data obtained from 63 plant samples. Here, a fixed window 2 cm in diameter, was moved across the field work "photo-map" which contained 54 sample points, to produce 78 uniformly spaced points. The technique merely smooths the data by decreasing the inherent random fluctuations, but does not eliminate any spurious points (Rose, Hawkes and Webb, 1979).

The biogeochemical data presented here, demonstrate the erratic nature of occurrence of trace elements in the biogeochemical samples. The complex pattern of highs and lows could be due to a host of factors such as age, depth of roots of different plant species, variability of element uptake in different species and so on, as indicated in Section 1.5, hence the need to smooth the data.

The ashing of the plant material was performed in a muffle furnace at 450° ± 5°. This preconcentration technique prior to trace element analysis, using the X-Ray Fluoresence analysis , in the samples has been controversial. Tooms and Jay (1964) used 400°C, and Brooks (1972) uses 450°C, while Timperly et al (1970 b) used500°C. Generally however, it is accepted that little loss of trace elements occur at these temperatures (Brooks, 1972). All the trace elements assayed in the study have boiling points well above the ashing temperature (Weast, 1968-9), and so they presumably are not lost during the preconcentration stage.

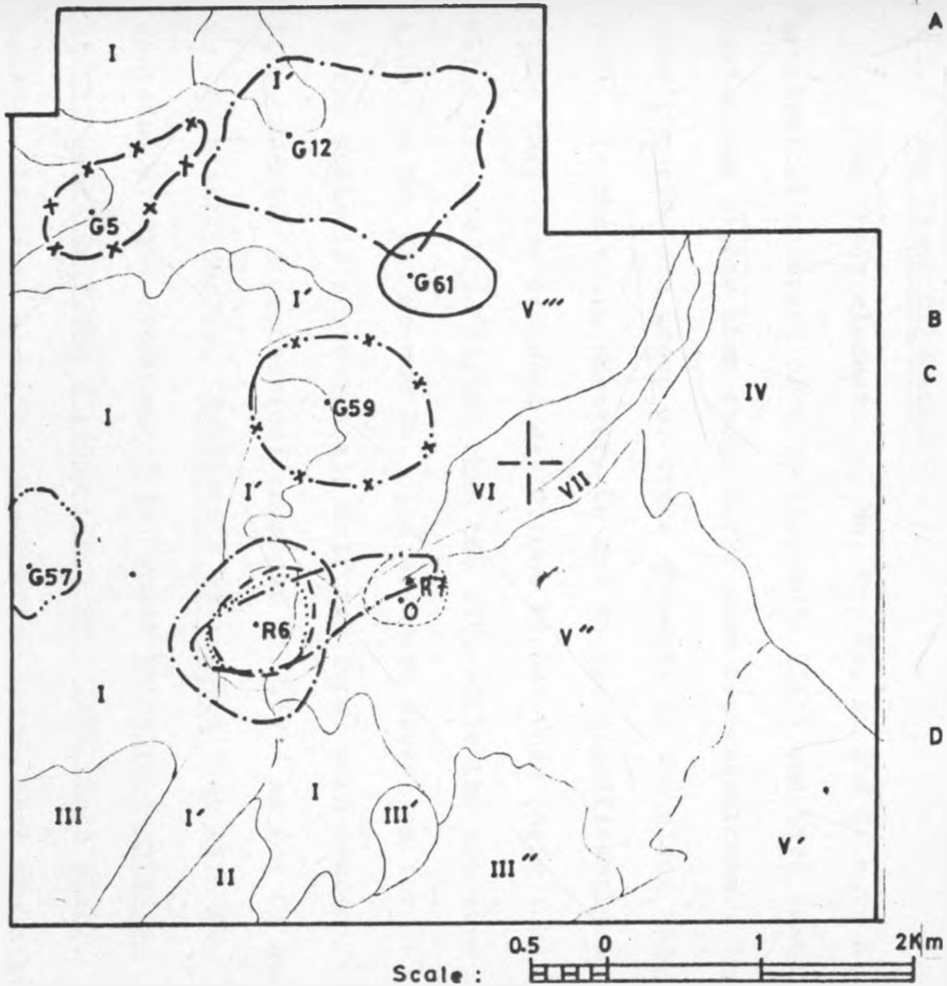
In order to determine geochemically significant anomalies, it is common practice in geochemistry to weigh the mean element concentration in the sampling media in terms of its standard deviations (Sayala, 1979, Marmo, 1953, Rose, Hawkes and Webb, 1979, Siegel, 1974 and Howarth and Martin, 1979). Thus geochemically anomalous concentrations, are the concentration values higher than the mean concentration value plus two standard deviations, i.e the Local Threshold value,(Sayala, 1979, and Marmo, 1953). Other exploration geochemists select different concentration ranges to determine significant geochemical anomalies.

For instance Hawkes and Webb (1962) indicate that values greater than mean plus three standard deviations can be classified as possibly anomalous. This condition is too restricted according to Siegel, 1974, considering that only one value in a thousand will theoretically be higher than mean value plus three standard deviations. In the present study however, the anomalous element concentrations are higher than this limit (Table 4.4, Fig. 5.1).

This limit can therefore be a good threshold value to use in order to "cut-out" any inherent high background fluctuations of element concentrations in the biogeochemical samples.

5.1.1 <u>Calcium and Phosphorous.</u>

The two mineral elements are necessary for growth of plants (Gilbert, 1953). They have a universal background value of 3% (30,000 ppm) in plants. In soils, calcium concentration ranges from 7000 - 500000 ppm, while phosphorous averages 70,000 ppm (Siegel, 1974). In plants assayed from the study area (Table 4.4a), Ca has a local concentration of 16% (160000 ppm), a local threshold value (LTV) of 32.2% (322000 ppm) and a geochemical contrast value (GC) of 0.66; while P has a local mean concentration of 15.2% (152000 ppm), a threshold value of 32.2% and geochemical contrast of 0.64. <u>Acalypha fruiticosa</u>, at site GI in GBU III' contains 32.3% P, while <u>Euclea davinorum,</u> at site G54 in GBU V" contains 42.3% P and 37% Ca respectively.



EXPLANATION

A **Isograds for Anomalous Trace Elements, Drawn at The Local Threshold Value (LTV).**

In Plants: SR, RB, ZR, CU, U, MN

In Soils: CU, U, RB, CA

B I — VII are The Geobotanical Units (GBUs)

C **Element Anomalies in Plant Samples**

Site	GBU	Plant Species	Element	LTV	Conc.
G12	V'''	Balanite aegyptiaca	SR	1.1%	1.63%
R6	I'	Harrsonia abyssinica	U	57	101
			ZR	890	2152
			SR	1.1%	2.96%
			MN	7845	2.21%
G5	I'	Vangueria acutiloba	RB	1144	3710

D **Element Anomalies in Soil Samples**

Site	GBU	pH	mV	Element	LTV	Conc.
G57	I	8.95	0.00	CU	1604	2924
G59	I'	10.60	−90	RB	855	1630
G61	V'''	8.30	+30	U	53	85
O'	V''	8.80	+25	CA	5.7%	9.7%

Fig. 5.1: Summary of Significant Element Concentrations in Plant and Soil Samples as Related to GBU I'.

In the soil assay data, the Ca concentration (9.71%) in the mill tailings (sample 01 sol, with a pH 8.80 and ± 25 mV) at site O' is higher than the LTV (5.64%) and the UBV (1.4%). Phosphorous has not been detected in the soil samples. Notably however, sample $S\text{-}01_3$, at site G57 on the Precambrian paragneisses, which has pH (9.50) and 0.00 mV, the Ca content is 0.04% (400 ppm), the lowest Ca concentration detected in the soil samples: thus Ca is least available in the Precambrian paragneisses, away from the mineralised marble ($CaCO_3$)

5.1.2. The Trace Elements.

The trace elements Cu, Mn, Zn, Rb, Sr and Zr have a mean geochemical contrast of 0.38 (Appendix VIII) and have standard deviations higher than their local mean concentrations. They thus comprise one group of trace elements in the plant assay data. In the soils however, Cu and Rb are significantly anomalous since they have standard deviations higher than their local mean value and are also higher than the LTV, while the converse is true for Mn, Zn, Sr and Zr. The standard deviation for Sr in the soils is approximately half its local mean concentration, and has a geochemical contrast of 0.67 - as for Ca and P in the plant samples. Harrisonia abyssinica at site R6, contains 2.96% (29600 ppm) Sr, while Balanites aegyptiaca at G12 contains 1.63% (16300 ppm) Sr. Both these plant species therefore have Sr concentration values that are significantly anomalous (i.e values higher than the local threshold value).

In soil data sample S-002 at site G 50 in geobotanical unit III, contains 975 ppm Sr. This concentration value which is significantly anomalous occurs in the soil sample with pH 9.85 and -50 mV conductivity, is the only soil sample with significant Sr concentration.

Vangueria acutiloba at site G5 in GBU I, near Kabokbok mine with mainly the purple variety of fluorite, contains 3720 ppm Rb. While soil sample s-015 at site G59 in GBU I' contains 1630 ppm Rb, a value higher than the local threshold value (LTV). This soil has pH 10.60 and - 90 mV. Other soils contain non-significant amounts of this trace element.

In the study area, local mean copper concentration in the plants assayed in 252 ppm, a value lower than its standard deviation. Harrisonia abyssinica in GBU I' contains 2369 ppm Cu, while Ipomoea spathulata in GBU V' has 1740 ppm Cu. These concentrations are higher than the local threshold value (LTV) and the universal background value (UBV) and are therefore significant anomalies in these samples that localise the mine sites. In the soil sample Cu is only significantly anomalous element in sample $S\text{-}01_3$ (pH 8.95 and 0.00 mV) at site G57, which contains 2924 ppm Cu, and occurs in the Precambrian paragneisses.

The geochemical contrast of Cu in soils (0.42) is similar to that in plants (0.41) and in both media, the standard deviation is higher than the local mean Cu concentration; either sampling medium can therefore be used to prospect for copper in the area.

Manganese, an essential trace element for plant nutrition (Gilbert, 1953), has a local mean concentration of 1933 ppm in the plant samples, a value lower than the universal background value (UBV) of 2956 ppm. Only Harrisonia abyssinica in GBU I' at Kimwarer mine site, has a value of 2.21% (22100 ppm) which is higher than the local threshold value (LTV) and the universal background value (UBV). However, in terms of uptake of mineral elements, Uvaria lucida at site R9 in GBU V''' does not contain Mn or Fe, as compared to a similar species at G1 in the same geobotanical unit'. The universal background value for Mn is higher than its local background value in the plant samples, and therefore the values obtained are lower than expected even in non-mineralized areas. In the soil samples, all the Mn concentrations obtained are below the local threshold value (LTV), indicating non-significant geochemical anomaly of Mn in the soils. The geochemical contrast of Mn in soils is 0.67. It has a standard deviation lower than its local mean concentration value. In the plants assayed, Mn has a geochemical contrast value of 0.40, and a standard deviation higher than its local mean concentration.

The local mean zinc concentration in the geobotanical samples is 386 ppm, a value lower than the local threshold value (LTV) of

1626 ppm Zn. In these samples, Harrisonia abyssinica in GBU I' contains 5148 ppm Zn - a value higher than the local threshold value (LTV). In GBU II at site G51 soil sample S-003 (pH 6.95 and + 125 mV) contains 387 ppm Zn, the only soil with Zn concentration higher than the local threshold value (LTV). The geochemical contrast of Zn in plants is 0.38, while its standard deviation is higher than the local mean concentration. In soils the contrast is approximately twice that in plants, while the standard deviation is lower than the local mean Zn concentration.

Zirconium has not been well studied in plants (Brooks, 1972) hence no universal background value is given in Fig. 4.1 and in Table 4.5 (a). However, a local mean Zr concentration value of 216 ppm has been realized. Harrisonia abysssinica in GBU I' contains 2152 ppm Zr, indicating a significant geochemical anomaly of the trace element. In soils however, concentrations indicate a non-significant Zr anomaly, since all values are below the local threshold value (LTV).

The geochemical contrast in soils is 0.83, while in plants it is equal to 0.39. In the latter case, the standard deviation is lower than the local mean Zr concentration, while the converse is true in the former case.

5.1.3 Uranium

Unlike the foregoing trace elements with a geochemical contrast of approximately 0.38, and calcium and phosphorous with a contrast value of 0.65, uranium has a contrast value of 0.46 in the plant samples, and 0.44 in soil samples. A value of 101 ppm has been obtained in Harrisonia abyssinica in GBU I', a value higher than the local threshold value of 57 ppm. The local background value (LBV) is established as 37 ppm U in the plants ashed and assayed . This LBV is notably much higher than the universal background value (UBV) of 1 ppm U. Soil sample S-017 at G61 in GBU V''' contains 85 ppm U, a value which is also above local threshold value (LTV). The standard deviation in the plants is higher than the local mean concentration: this is true also for the soil samples with a similar geochemical contrast (cf. 0.44).

The biogeochemical data summarised above indicate anomalous trace element concentrations (values higher than the local threshold value, LTV) in GBU I', on the Precambrian paragneisses with the fluorite mineralization. The calcium concentration in the geobotanical samples assayed, locates the friable partly consolidated Soy Sandstone deposits, east of the study area. Over the Kimwarer, Kamnaon and Kabokbok fluorite mine sites, the calcium content in the geobotanical samples is far below the local threshold value (LTV) and below its local mean concentration. This indicates a negative geochemical anomaly of calcium over the fluorite mineralization. In this case therefore, a negative geochemical anomaly indicates a significant anomaly of calcium over the fluorite mineralization.

The erratic nature of the biogeochemical data illustrates the complexity of the geobotanical technique in mineral prospecting. Furthermore, the statistical correlation of the element concentration in plants (value close to ± 1; Appendix X) show the elements that probably interact with each other. The high estimated correlation coefficients possibly reflect the operation of a single process, the geochemical characteristic, or a master variable, as proposed by Rose, Hawkes and Webb (1979), in terms of uptake of the trace element:
This is possibly true for elements with high correlation with each other such as Zn - Mn - Cu - Sr - U - Zr in the plant samples. All 'r' values are significant at 99% confidence limit. Rubidium - Strontium, and rubidium - zirconium are the least interdependent (r = + 0.02 respectively), while rubidium has also a low correlation with manganese (r = + 0.12), copper (r = + 0.13) and zinc (r = + 0.19) in the geobotanical samples; these values are not significant at 95% confidence limit. In the soil sample, Ca - Sr have the highest positive correlation coefficient (+ 0.47) significant at 95% confidence limit, and Ca - Zr have the highest negative 'r' value of -0.57, a value which is significant at 99% confidence limit, i.e a high inverse relationship.

The statistical treatment applied to the biogeochemical data is adequate in as far as it focuses on the geochimically significant or non-significant concentrations of the trace elements around the

the fluorite mineralization (Fig. 4.2, 4.4 and 5.1). Other statistical analyses such as multivariate analysis could be used but based on the relationship between the concentrations of the chemical elements in the biogeochemical samples and other variables. Thus, the background values would change with geological conditions; one then works with a corrected background value for each sampling site (Siegel, 1974).

The technique of plant analysis of trace elements for mineral prospecting suffers a major drawback since the absorption and uptake of metallic trace elements is a complex phenomenon (Cannon, 1960 b). However, it is apparent that the depth of root-penetration permits sampling of a deeper horizon not accessible to soil samples. The technique permitted trace element analysis in areas where residual soils are varied or non-existent by assuming a constant geochemical background value. Cannon (1960 b) observed that, in cases where indicator plants are known, geobotanical prospection is superior to all methods since no analytical work is required, and maps of mineralised ground may be drawn by observing the distribution of the indicator plants. The analysis of herbarium samples would enable trace element concentration plots for large areas, or regional geobotanical reconnaissance exploration surveys. The analysis of plant material is much easier than soil and rock samples, the vegetation samples are much quicker to collect, and are much ligher to carry in the field.

5.2 Conclusion.

The study establishes that the geobotanical method applied localizes the fluorite mineralization along the foot slopes of the Keiyo Escarpment.

The geochemical contrast however, does not indicate whether an anomaly is significant or not, but it does indicate the variation between the local threshold value and the individual concentration values: when it is high (about 0.65 ± 0.01 in plants as for calcium and phosphorous; and 0.71 ± 0.06 in soils as for strontium, zirconium, zinc and manganese) the sampling medium enhances the occurrence of the element in the geochemical environment, and the medium is appropriate for prospecting purposes for particular elements. Secondly, when the geochemical contrast is low (about 0.38 ± 0.04 in plants as for copper, strontium, zirconium, zinc and manganese; and 0.41 ± 0.01 in soils as for copper and calcium), the sampling medium does not enhance the occurrence of an element and therefore the medium is not appropriate for prospecting purposes. Lastly, when the geochemical contrast is approximately constant in both sampling media (plant ash and soil samples), Table 4.5; either medium can be used to ascertain the occurrence of an element in a given geochemical environment.

Further, in plant assay data, the local background value is higher than the universal background value for the elements copper, strontium, zirconium, calcium, zinc, uranium, rubidium and phosphorous, save only for manganese. In soils, the foregoing is true only for the elements copper, calcium and uranium, the rest of the elements in the soils have universal background values that are higher than the local background values, these elements are therefore not significatly anomalous..

The variability of the number of elements detected by the plant assay from that in soils (about 8 to 3) indicates that , plants enhance more elements than soils, but soils on the contrary bring out only the elements that are strongly associated with the fluorite mineralization (namely copper, calcium and uranium).

The local background value indicates the concentration level of the elements in the geochemical environment as compared to those occurring in non-mineralized terrains (the universal background values). Hence, the fact that the local background value is higher than the universal background for some elements is importtant since, it indicates that the study area occurs in a mineralized geochemical environment. The converse (that the universal background value is higher than the local background value) then establishes that, the trace element does not occur in the study area in significant concentrations - that is, the area is not mineralized with respect to the element in question, since the concentration values obtained are lower than those expected in non-minerized terrains.

This geobotanical study, coupled with quantitative biogeochemical techniques therefore establishes the occurrence of copper, uranium and calcium anomalies over the fluorite mineralization which coincides with geochemical unit (GBU) I'. The concentrations of these three elements are consistently higher than their universal background values (Fig. 5.1) in both sampling media. Unlike soil samples however, plant analyses also establish the occurrence of strontium, zirconium, zinc and rubidium anomalies around the mineralised geobotanical unit; indicating the association of these trace elements with the hydrothermally metamorphosed limestone. For instance calcium would be associated with apatite. zirconium with eudialyte, and uranium with apatite, or eudialyte.

Further, the concentration of calcium, a major essential plant macronutrient, in the plants is inversely related to calcium concetration in the soil samples (Appendix V). It is thence propounded that, this relationship between soil and plant calcium concentration could be responsible for the negative geochemical anomaly of calcium over the fluorite mineralization in this biogeochemical study. This behaviour is also true for zirconium. Strontium in soil and in plants seem to have a small direct relationship, in that a soil increase would be accompanied by an increase in the plant concentration. Such that, in areas where high strontium values are detected in plant ash, we would expect high strontium values in the soil.

The high correlation of elements in plants (Appendix X a and b) indicates possibly that there are factors that strongly associate them within the plants: While in soils, calcium concentration is inversely related to zirconium and zinc concentrations and directly related to strontium concentration. Strontium concentrations in soil in turn are directly related to manganese concentrations, whilst zirconium relates directly to zinc concentrations in the soil.

Further, the plant species Croton dichogamus which widely occurs in geobotanical, unit I' has the highest percent reflectance in the Infra Red Channel (0.8 -1.1 mm wave length, Band 7) of the electromagnetic spectrum (Fig. 4.4 c). Thus, although the species does not indicate any anomalous element concentrations, it does offer a good possibility of using its distinct percent reflectance value in digital mapping of the mineralized geobotanical unit, using remote sensing techniques.

Finally, it is notable that with a team of two persons, no field vehicle, and with minimum finances; sampling, analysis , and interpretation of the biogeochemical data, and localization of the fluorite mine sites took only about sixty days. Therefore, considering the area covered and the time taken to complete data analysis and interpretation, it is apparent that the technique of plant analysis for mineral (fluorite) exploration is both rapid and cost-effective.

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Plate III (a). The unconsolidated alluvial/colluvial fan (GBU V''') at Kimwarer. GBU I and I' are to the left (west) of the photo.

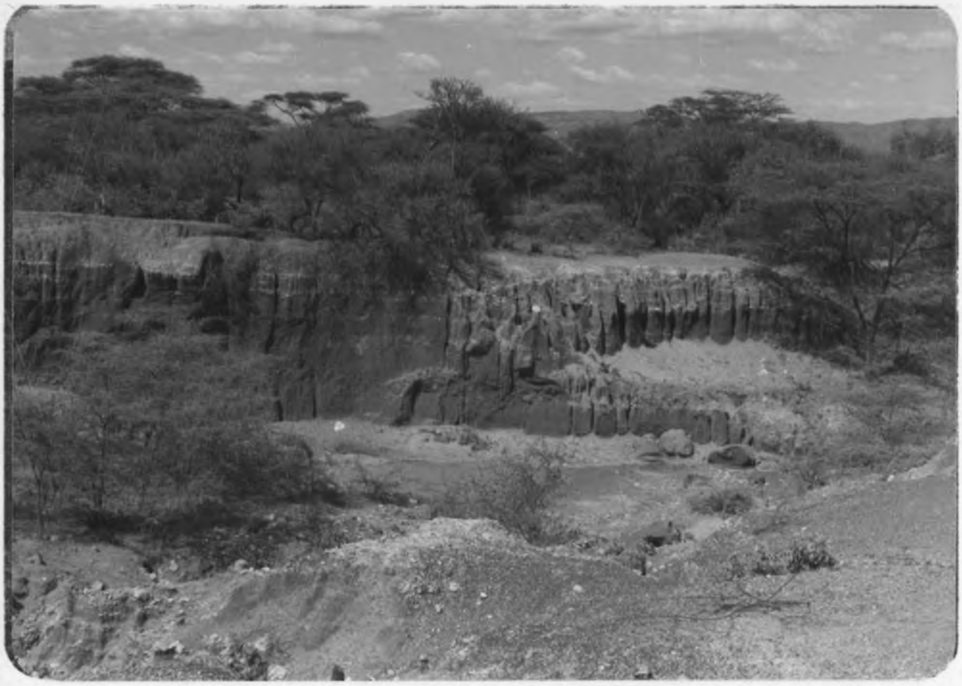
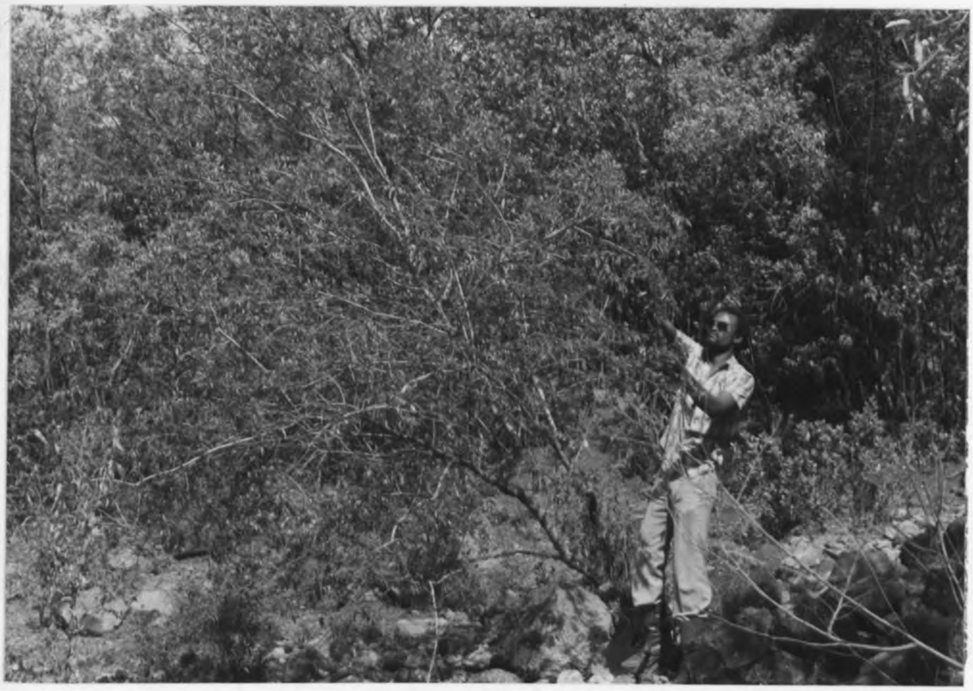


Plate III (b). Severe gully erosion in GBU V''' (above); composed of Acacia-Croton-Balanite-Cissus vegetation community.

Plate IV (a) Spoils of the fluorspar mining at Kimwarer in GBU I'. Note normal faulting to the left (west) of photo.



Plat IV (b) Woodfordia uniflora in a combretum-acacia woodland, indicator species of the nephelinitic (p-type) phonolite south of Mong River.

Plate V. Abnormal morphological growth form in the Stem of Combretum molle, with the graminae Laudetia kagerensis in GBU I'.

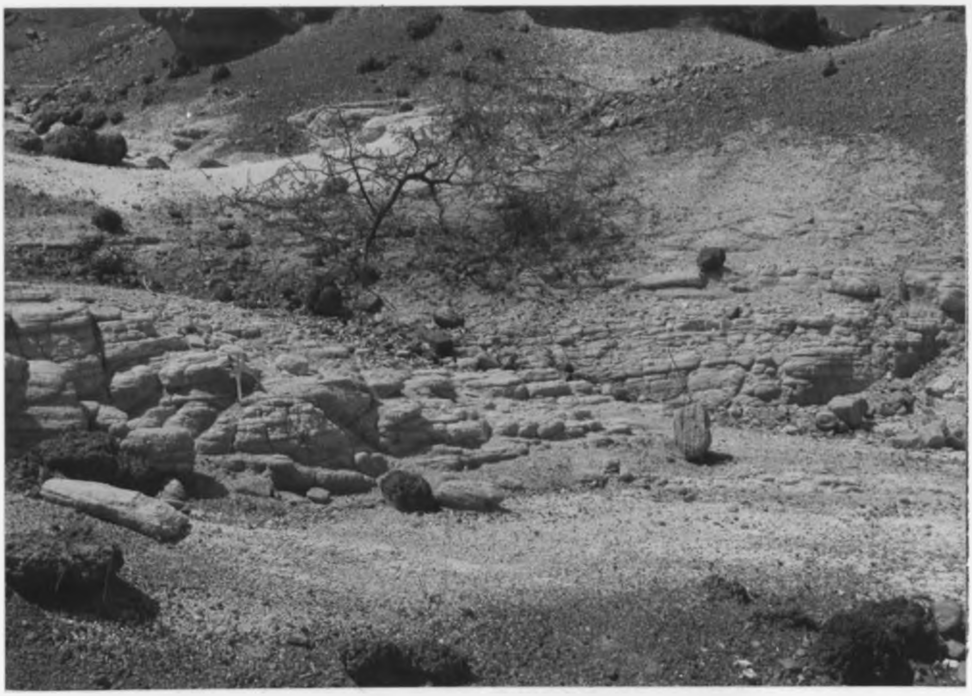


Plate VI (a) Friable calcareous Soy white Sandstone deposit in GBU IV, possibly Plio-Pleistocene in age, a Croton-Balanite - Acacia - Tamarindus vegetation community.

Plate VI (b) Spheroidal weathering of the Kimwarer red sandstone formation which forms a GBU II.

Plate VII   Oblique stereopair showing the cultivated down-stepped platform around Turesia market, and GBU II - the cuesta landform unit SW of the fluorite mill.

Plate VIII (a) Kimwarer red sandstone formation (arrowed) overlying the vegetated Precambrian rocks.

Plate VIII (b) The Portable Field Radiometer, with a white target for measuring energy incident upon an object.

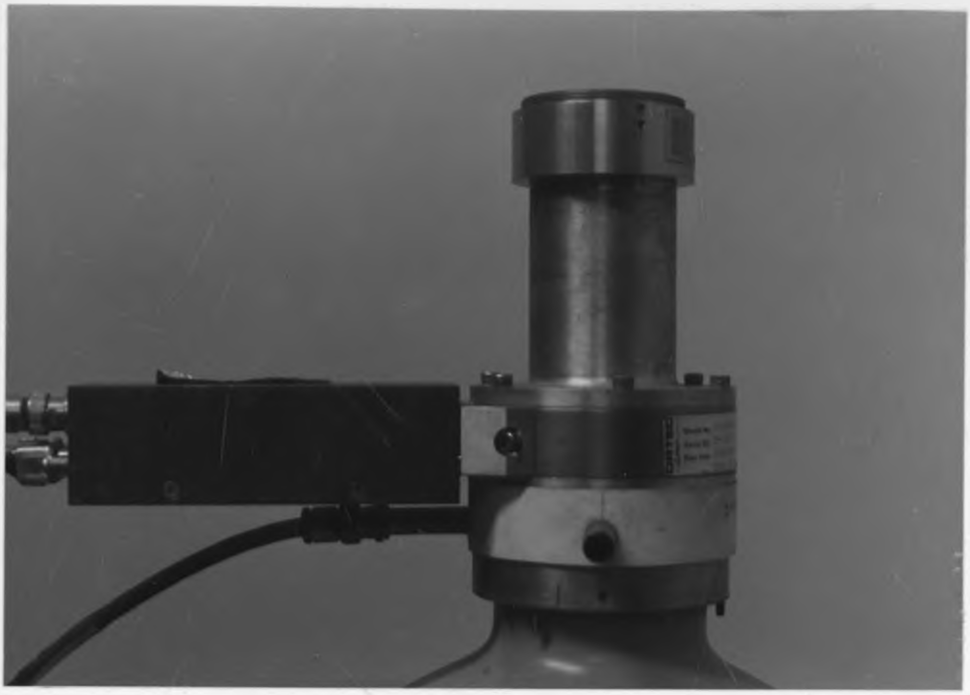


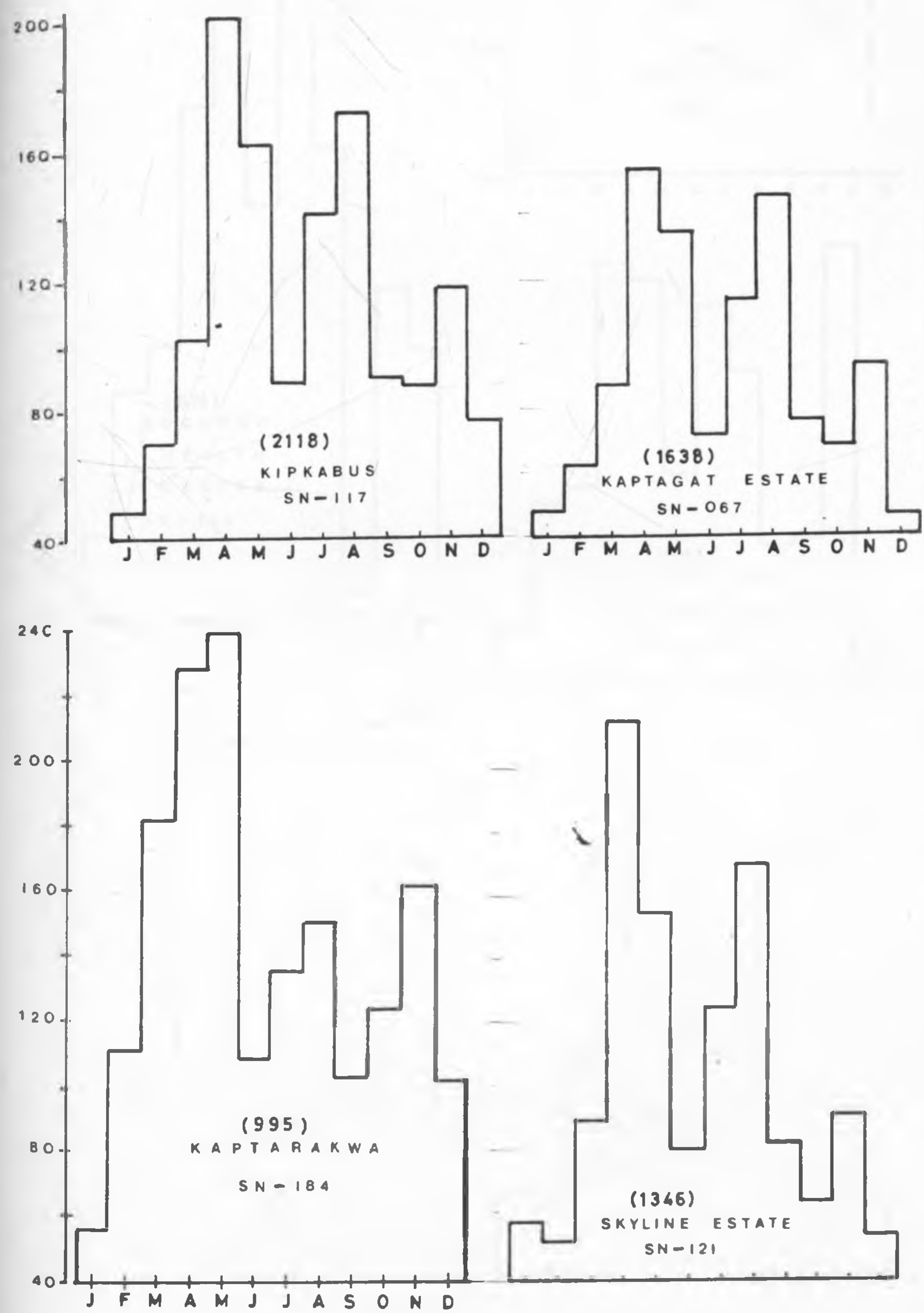
Plate IX (a) Silicon-lithium Detector of the multichannel Analyser, with (i) being the ^{109}Cd Source, (ii) are the pre-amplifier elements, (iii) a vacuum cryostat operated at 77 K.

Plate IX (b) A CRT Spectral Display of a plant sample as displayed on the MCA, shows range of excitation from 0.3 KeV to 22.7 KeV with the ^{109}Cd Source.

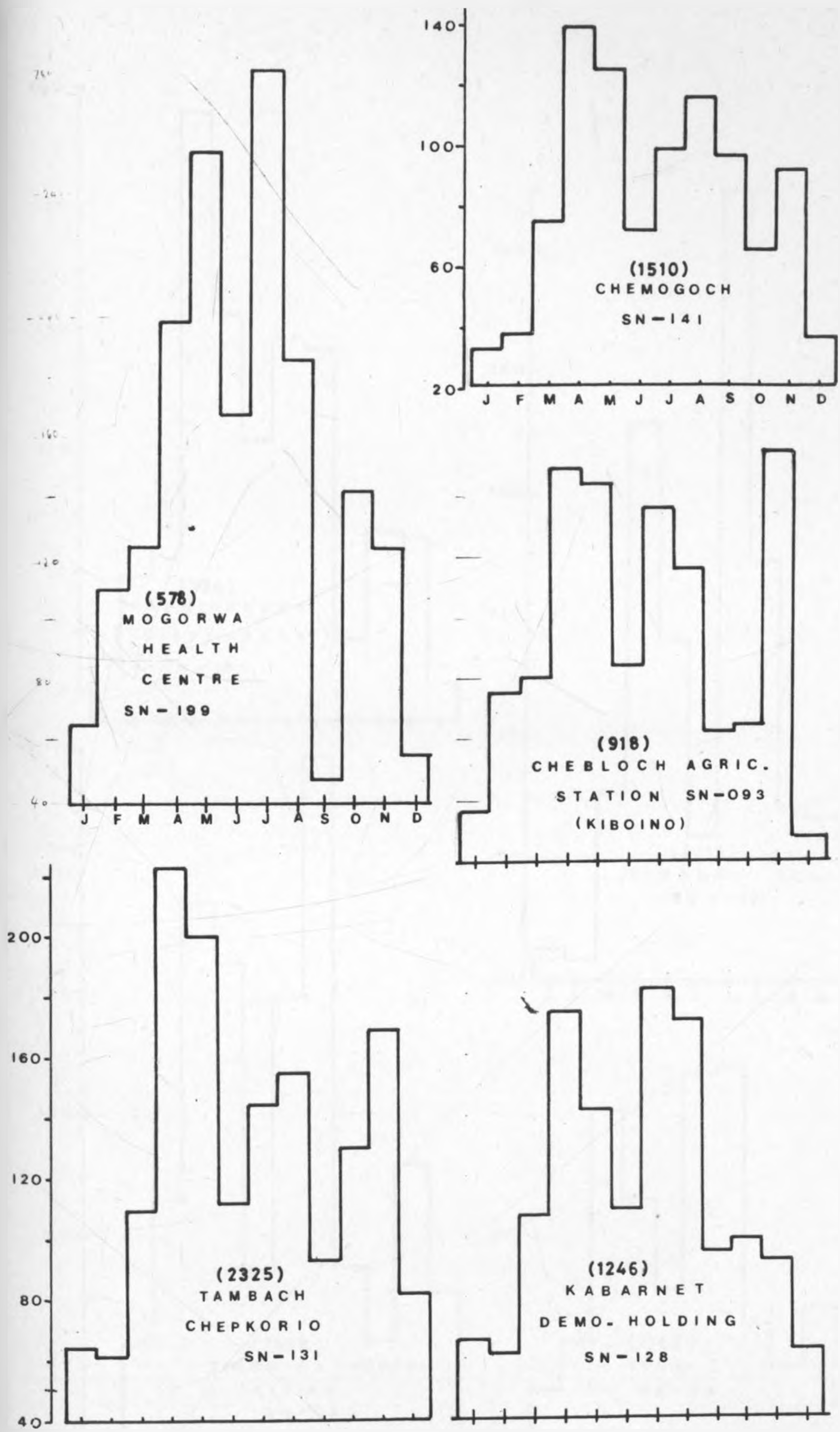
APPENDIX I

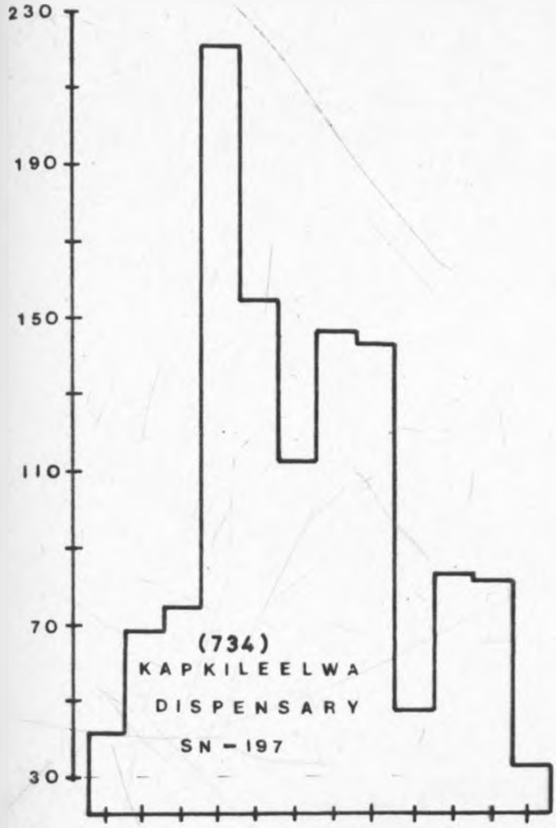
Mean Monthly Annual Rainfall.

APPENDIX I MEAN MONTHLY ANNUAL RAINFALL FROM SURROUNDING METEOROLOGICAL STATIONS.

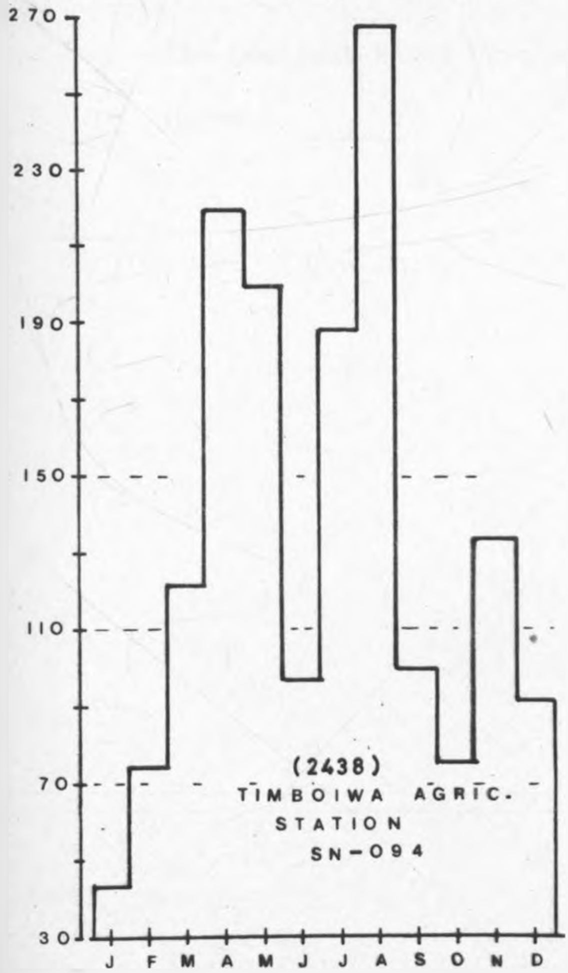


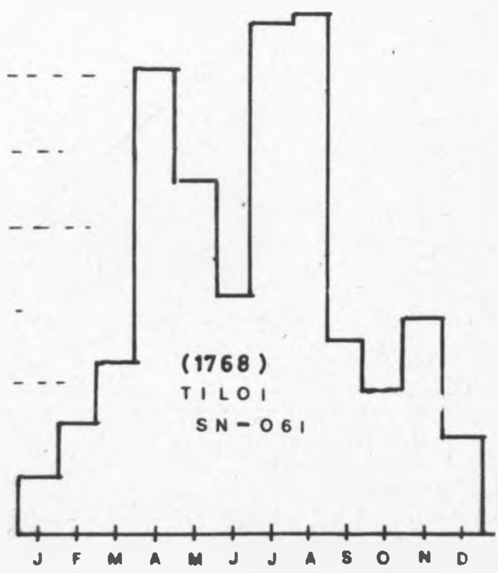
Note: Figures in ( ) indicate the mean annual rainfall in mm.


(578)
MOGORWA
HEALTH
CENTRE
SN - 199
40
J F M A M J J A S O N D
140
100
60
20
(1510)
CHEMOGOCH
SN - 141
J F M A M J J A S O N D
(918)
CHEBLOCH AGRIC.
STATION SN-093
(KIBOINO)
200
160
120
80
40
(2325)
TAMBACH
CHEPKORIO
SN-131
(1246)
KABARNET
DEMO- HOLDING
SN-128


230
190
150
110
70
30
(734)
KAPKILEELWA
DISPENSARY
SN-197


280
240
200
160
120
80
40
(2218)
TORONGO SCH.
SN - 145
J F M A M J J A S O N D


270
230
190
150
110
70
30
(2438)
TIMBOIWA AGRIC.
STATION
SN-094
J F M A M J J A S O N D


(1768)
TILOI
SN-061
J F M A M J J A S O N D

APPENDIX II

The Dominant Plant Species In The Geobotanical Units.

APPENDIX II

	GBU I							
	G57	R1	G2	R5	G5	R11	G58	G60
ACACIA AMARA								
A. DREPANOLOBIUM								
A. KIRKII								
A. MELLIFERA		X						
A. SENEGAL								
A. SEYAL					X			
A. TORTILIS	X		X		X	X		X
ACALYPHA FRUITICOSA								
ACOKANTHERA FRIESIORUM								
ALBIZIA AMARA								
ANNONA SENEGALENSIS								
ALOE Spp.						X		
BALANITE AEGYPTIACA								
CAPPARIS TOMENTOSA								
CASSIA OCCIDENTALIS								
CISSUS ROTUNDIFOLIA		X	X					
CISSUS QUADRANGULARIS			X					
CLEORODENDRON Spp.								
COMBRETUM MOLLE								
COMMIPHORA AFRICANA								
COMMIPHORA CORIACAE								
CROTON DICHOGAMUS	X	X		X	X	X		
DODONEA VISCOSA							X	
EUCLEA DAVINORUM								
EUCLEA NATALENSIS		X						
EUPHOBIA GOSSYPINA								
EUPHOBIA NYIKAE		X						
FICUS NATALENSIS								
GARDENIA Spp.								
HARRISONIA ABYSSINICA								
IPOMOEA SPATHULATA	X	X		X		X		

APPENDIX II

	GBU I							
	G57	R1	G2	R5	G5	R11	G58	G60
INDIGOFERA BREVICALYX								
JUSTICIA FLAVA								
LANNEA TRIPHYLLA						X		
LIPPIA JAVANICA					X			
LAUDETIA KAGERENSIS								
PELLAEA ADIANTOIDES								
PELLAEA CALOMELANOS								
PLECTRANTHUS Spp.								
PSIADIA ARABICA						X		
PTERIDIUM Spp.								
RHYNCHOSIA Spp.								
RHUS NATALENSIS								
SOLANUM INCANUM								
SPHAERANTHUS UKAMBENSIS								
TAMARINDUS INDICA								
TECLEA SIMPLISIFORMIS								
TERMINALIA OBICULARIS							X	
TERMINALIA PRUNIODIES								
UVARIA LUCIDA								
VANGUERIA ACUTILOBA				X	X			
ZIZIPHUS MAUTIRIANA								
PHYLLANTHUS Spp.								

APPENDIX II

	GBU I'					GBU II	
	G59	R6	G4	R13	G6	G15	G51
ACACIA AMARA							
A. DREPANOLOBIUM							
A. KIRKII							
A. MELLIFERA							
A. SENEGAL			X				
A. SEYAL							
A. TORTILIS	X	X	X	X			
ACALYPHA FRUITICOSA			X	X			
ACOKANTHERA FRIESIORUM			X				
ALBIZIA AMARA							
ANNONA SENEGALENSIS							
ALOE Spp.						X	
BALANITE AEGYPTIACA			X				
CAPPARIS TOMENTOSA							
CASSIA OCCIDENTALIS							
CISSUS ROTUNDIFOLIA							
CISSUS QUADRANGULARIS			X				
CLEORODENDRON Spp.							
COMBRETUM MOLLE				X*	X*	X*	X*
COMMIPHORA AFRICANA				X*			
COMMIPHORA CORIACAE							
CROTON DICHOGAMUS	X	X	X				
DODONEA VISCOSA					X	X*	X
EUCLEA DAVINORUM							
EUCLEA NATALENSIS				X	X	X	X
EUPHOBIA GOSSYPINA							
EUPHOBIA NYIKAE							
FICUS NATALENSIS							
GARDENIA Spp.						X	
HARRISONIA ABYSSINICA		X					
IPOMOEA SPATHULATA		X	X				

APPENDIX II

	GBU I'					GBU II	
	G59	G6	G4	R13	G6	G15	G51
INDIGOFERA BREVICALYX					X		
JUSTICIA FLAVA				X*	X		
LANNEA TRIPHYLLA							
LIPPIA JAVANICA			X				
LAUDETIA KAGERENSIS					X		
PELLAEA ADIANTOIDES					X		
PELLAEA CALOMELANOS					X		
PLECTRANTHUS Spp.					X		
PSIADIA ARABICA				X			
PTERIDIUM Spp.		X					
RHYNCHOSIA Spp.					X		
RHUS NATALENSIS				X			
SOLANUM INCANUM							
SPHAERANTHUS UKAMBENSIS							
TAMARINDUS INDICA							
TECLEA SIMPLISIFORMIS							
TERMINALIA OBICULARIS				X			
TERMINALIA PRUNIODIES							
UVARIA LUCIDA			X				
VANGUERIA ACUTILOBA		X					
ZIZIPHUS MAUTIRIANA							
PHYLLANTHUS Spp.							

NOTE: Species marked with an 'asterik' have a swollen stem.

APPENDIX II

	III'	GBU III''								
	G50	B1	G64	G65	R41	G1	R12	R40	G52	G56
ACACIA AMARA										
A. DREPANOLOBIUM										
A. KIRKII										
A. MELLIFERA				X	X					
A. SENEGAL										
A. SEYAL				X						
A. TORTILIS	X			X						X
ACALYPHA FRUITICOSA	X					X				
ACOKANTHERA FRIESIORUM	X				X					
ALBIZIA AMARA										
ANNONA SENEGALENSIS							X			
ALOE Spp.										
BALANITE AEGYPTIACA		X								
CAPPARIS TOMENTOSA										
CASSIA OCCIDENTALIS										
CISSUS ROTUNDIFOLIA										
CISSUS QUADRANGULARIS										
CLEORODENDRON Spp.										
COMBRETUM MOLLE			X		X	X	X	X	X	
COMMIPHORA AFRICANA										
COMMIPHORA CORIACAE										
CROTON DICHOGAMUS	X			X			X	X		X
DODONEA VISCOSA			X						X	
EUCLEA DAVINORUM		X	X	X				X		
EUCLEA NATALENSIS							X			
EUPHOBIA GOSSYPINA										
EUPHOBIA NYIKAE										
FICUS NATALENSIS										
GARNEDIA Spp.										
HARRISONIA ABYSSINICA										
IPOMOEA SPATHULATA.						X				

APPENDIX III

	III'	GBU III''								
	G50	B1	G64	G65	R41	G1	R12	R40	G52	G56
INDIGOFERA BREVICALYX										
JUSTICIA FLAVA										
LANNEA TRIPHYLLA		X								
LIPPIA JAVANICA										
LAUDETIA KAGERENSIS										
PELLAEA ADIANTOIDES										
PELLAEA CALOMELANOS										
PLECTRANTHUS Spp.										
PSIADIA ARABICA										
PTERIDIUM Spp.										
RHYCHOSIA Spp.										
RHUS NATALENSIS									X	
SOLANUM INCANUM										
SPHAERANTHUS UKAMBENSIS										
TAMARINDUS INDICA										
TECLEA SIMPLISIFORMIS			X			X				
TERMINALIA OBICULARIS				X			X			
TERMINALIA PRUNIODIES										
UVARIA LUCIDA						X				X
VANGUERIA ACUTILOBA	X									
ZIZIPHUS MAUTIRIANA										
PHYLLANTHUS Spp.						X				

APPENDIX II

	GBU IV						V'			V''		
	R16	R17	G7	G8	R18	G9	G54	R42	G63	O'	O''	G53
ACACIA AMARA					X							
A. DREPANOLOBIUM												
A. KIRKII											X	
A. MELLIFERA				X								
A. SENEGAL	X		X			X		X	X			
A. SEYAL												
A. TORTILIS	X			X		X				X	X	X
ACALYPHA FRUITICOSA												
ACOKANTHERA FRIESIORUM		X		X					X			
ALBIZIA AMARA	X		X									
ANNONA SENEGALENSIS												
ALOE Spp.	X											
BALANITE AEGYPTIACA			X	X		X			X			
CAPPARIS TOMENTOSA												
CASSIA OCCIDENTALIS										X		
CISSUS ROTUNDIFOLIA												
CISSUS QUADRANGULARIS	X			X								
CLEORODENDRON Spp.												
COMBRETUM MOLLE	X				X							X
COMMIPHORA AFRICANA												
COMMIPHORA CORIACAE	X											
CROTON DICHOGAMUS	X	X	X	X	X	X	X	X				
DODONEA VISCOSA												
EUCLEA DAVINORUM							X	X				X
EUCLEA NATALENSIS												
EUPHOBIA GOSSYPINA		X	X									
EUPHOBIA NYIKAE	X											
FICUS NATALENSIS												
GARDENIA Spp.												
HARRISONIA ABYSSINICA												
IPOMOEA SPATHULATA				X							X	

APPENDIX II

	GBU IV						VI			V''		
	R16	R17	G7	G8	R18	G9	G54	R42	G63	O'	O"	G53
INDIGOFERA BREVICALYX	X											
JUSTICIA FLAVA												
LANNEA TRIPHYLLA	X				X							
LIPPIA JAVANICA												
LAUDETIA KAGERENSIS												
PELLAEA ADIANTOIDES												
PELLAEA CALOMELANOS												
PLECTRANTHUS Spp.												
PSIADIA ARABICA												
PTERIDIUM Spp.										X		
RHYCHOSIA Spp.												
RHUS NATALENSIS				X				X				
SOLANUM INCANUM												
SPHAERANTHUS UKAMBENSIS												
TAMARINDUS INDICA					X			X				
TECLEA SIMPLISIFORMIS							X					
TERMINALIA OBICULARIS					X							
TERMINALIA PRUNIODIES												
UVARIA LUCIDA												
VANGUERIA ACUTILOBA												
ZIZIPHUS MAUTIRIANA												
PHYLLANTHUS Spp.												

APPENDIX II

	GBU· V'''										
	R2	R9	R10	R19	R20	G10	R21	G11	G12	G62	G61
ACACIA AMARA											
A. DREPANOLOBIUM							X				
A. KIRKII											
A. MELLIFERA					X						
A. SENEGAL											
A. SEYAL							X				
A. TORTILIS	X	X			X	X		X		X	X
ACALYPHA FRUITICOSA											
ACOKANTHERA FRIESIORUM							X	X			
ALBIZIA AMARA											
ANNONA SENEGALENSIS											
ALOE Spp.					X		X				
BALANITE AEGYPTIACA	X			X	X	X	X		X	X	X
CAPPARIS TOMENTOSA											
CASSIA OCCIDENTALIS											
CISSUS ROTUNDIFOLIA	X			X	X		X				
CISSUS QUADRANGULARIS											
CLEORODENDRON Spp.											
COMBRETUM MOLLE				X							
COMMIPHORA AFRICANA											
COMMIPHORA CORIACAE											
CROTON DICHOGAMUS	X	X	X	X	X		X	X			X
DODONEA VISCOSA											
EUCLEA DAVINORUM											
EUCLEA NATALENSIS											
EUPHOBIA GOSSYPINA											
EUPHOBIA NYIKAE											
FICUS NATALENSIS	X										
GARDENIA Spp.											
HARRISONIA ABYSSINICA											
IPOMOEA SPATHULATA						X					

APPENDIX II

	GBU V'''										
	R2	R9	R10	R19	R20	G10	R21	G11	G12	G62	G61
INDIGOFERA BREVICALYX											
JUSTICIA FLAVA							X				
LANNEA TRIPHYLLA											
LIPPIA JAVANICA		X									
LAUDETIA KAGERENSIS											
PELLAEA ADIANTOIDES											
PELLAEA CALOMELANOS											
PLECTRANTHUS Spp.											
PSIADIA ARABICA											
PTERIDIUM Spp.											
RHYNCHOSIA Spp.											
RHUS NATALENSIS											
SOLANUM INCANUM						X					
SPHAERANTHUS UKAMBENSIS						X					
TAMARINDUS INDICA											
TECLEA SIMPLISIFORMIS											
TERMINALIA OBICULARIS											
TERMINALIA PRUNIODIES											
UVARIA LUCIDA	X				X						
VANGUERIA ACUTILOBA	X	X									
ZIZIPHUS MAUTIRIANA											
PHYLLANTHUS Spp.											

APPENDIX II

	VII						Total
	G55	R7	R8	G3	R3	R4	OCC
ACACIA AMARA							1
A. DREPANOLOBIUM							1
A. KIRKII							1
A. MELLIFERA							5
A. SENEGAL							6
A. SEYAL		X				X	5
A. TORTILIS	X	X	X			X	29
ACALYPHA FRUITICOSA		X			X		6
ACOKANTHERA FRIESIORUM		X	X				10
ALBIZIA AMARA							2
ANNONA SENEGALENSIS							1
ALOE Spp.							5
BALANITE AEGYPTIACA		X				X	16
CAPPARIS TOMENTOSA				X			1
CASSIA OCCIDENTALIS					X		2
CISSUS ROTUNDIFOLIA							6
CISSUS QUADRANGULARIS							4
CLEORODENDRON Spp.	X						1
COMBRETUM MOLLE							14
COMMIPHORA AFRICANA							1
COMMIPHORA CORIACAE							1
CROTON DICHOGAMUS		X	X		X		32
DODONEA VISCOSA							6
EUCLEA DAVINORUM							7
EUCLEA NATALENSIS							6
EUPHOBIA GOSSYPINA							2
EUPHOBIA NYIKAE							2
FICUS NATALENSIS	X	X					3
GARDENIA Spp.							1
HARRISONIA ABYSSINICA			X				2
IPOMOEA SPATHULATA		X					11

APPENDIX II

	VII						Total
	G55	R7	R8	G3	R3	R4	OCC
INDIGOFERA BREVICALYX							2
JUSTICIA FLAVA							3
LANNEA TRIPHYLLA			X				5
LIPPIA JAVANICA							3
LAUDETIA KAGERENSIS							1
PELLAEA ADIANTOIDES							1
PELLAEA CALOMELANOS							1
PLECTRANTHUS Spp.							1
PSIADIA ARABICA							2
PTERIDIUM Spp.							2
RHYNCHOSIA Spp.							1
RHUS NATALENSIS							4
SOLANUM INCANUM							1
SPHAERANTHUS UKAMBENSIS							1
TAMARINDUS INDICA							2
TECLEA SIMPLISIFORMIS						X	4
TERMINALIA OBICULARIS			X				2
TERMINALIA PRUNIODIES							2
UVARIA LUCIDA						X	6
VANGUERIA ACUTILOBA		X	X			X	9
ZIZIPHUS MAUTIRIANA							
PHYLLANTHUS Spp.							1
							244

APPENDIX III

(a) Other Elements Determined in Plant Samples

(b) Other Elements Determined in Soil Samples

(c) Detection Limit of the Elements Analyzed by the XRF Analytical System.

APPENDIX III (a) OTHER ELEMENTS CONCENTRATION

G.B.U.	SITE	PLANT SPECIES	SAMPLE NO.	S
I	R1	ACACIA MELLIFERA	KV/BD-029	1.67
	R4	A. TORTILIS	KV/BD-056	-
	G2	CISSUS QUADRANGULARIS	-"- 026	ND
	G5	VANGUERIA ACUTILOBA	-"- 031	-
	R1	EUPHOBIA NYIKAE	-"- 021	-
	G60	A. TORTILIS	016B	1.80
	G57	CROTON DICHOGAMUS	012B	2.70
	G57	C. DICHOGAMUS	012C	1.20
I'	R6	HARRISONIA ABYSSINICA	-"- 099	0.97
	G6	INDIGOFERA BREVICALYX	-"- 109	ND
	G4	CROTON DICHOGAMUS	-"- 093	2.20
	G4	BALANITE AEGYPTIACA	KV/BD-094	-
	G56	CROTON DICHOGAMUS	0118	1.30
	G59	C. DICHOGAMUS	015A	2.00
	G6	DODONEA VISCOSA	KV/BD-112	-
	R13	EUCLEA NATALENSIS	-"1 120	-
	G6	JUSTICIA FLAVA	-"- 131A	0.90

CL	K	SC	TI	V	CR	FE	CO	NI
2.19	17.16	ND	ND	ND	ND	1444	ND	66
-	-	-	-	ND	ND	2212	ND	ND
ND	6.83	1.35	0.04	70	ND	1544	ND	ND
-	-	-	-	461	ND	5204	ND	ND
-	-	-	-	3242	ND	382	ND	1
2.10	14.10	2.90	ND	ND	ND	2869	ND	70
9.10	21.50	ND	ND	125	ND	3298	ND	ND
2.40	17.90	1.30	1.50	ND	27	4378	ND	ND
2.64	17.10	2.00	0.03	ND	ND	29600	ND	236
ND	12.30	0.80	0.13	ND	ND	6422	ND	35
8.60	31.10	2.40	2.50	662	ND	3019	ND	44
-	-	-	0.07	357	ND	1285	ND	ND
9.30	25.70	1.40	1.70	ND	ND	5426	ND	76
6.00	19.50	0.55	ND	109	ND	2383	ND	5
-	-	-	-	976	ND	5899	ND	19
-	-	-	0.08	ND	ND	4514	ND	50
4.30	13.00	0.80	0.81	476	ND	4428	86	10

APPENDIX III (a) Cont.

G.B.U.	SITE	PLANT SPECIES	SAMPLE NO.	S	CL	K	SC	TI	V	CR	FE	CO	NI
II	R15	DODONEA VISCOSA	-"- 104	0.52	1.80	13.30	0.73	0.10	ND	ND	5789	ND	16
III	R41	COMBRETUM MOLLE	006C	1.20	1.80	6.30	1.10	0.18	129	142	1496	ND	12
	R40	CROTON DICHOGAMUS	004B	0.20	3.10	14.30	0.70	1.60	ND	ND	3684	ND	ND
	G51	DODONEA VISCOSA	003A	5.90	1.00	23.00	0.60	0.95	394	ND	10000	ND	96
	G52	RHUS NATALENSIS	005C	0.80	3.80	18.98	0.79	1.50	ND	ND	3162	ND	ND
III'	G1	ACALYPHA FRUITICOSA	KV/BD-005	ND	ND	19.04	ND	1.66	220	ND	11	ND	20
	B1	BALANITE AEGYPTIACA	P-001	1.10	9.80	20.20	0.92	ND	ND	ND	3876	ND	ND
	G50	CROTON DICHOGAMUS	002A	0.86	5.80	15.30	1.20	0.02	ND	ND	2674	ND	ND
	G1	IPOMOEA SPATHULATA	KV/BD-004	5.50	0.97	4.96	1.20	0.16	ND	ND	4672	ND	58
	G1	I. SPATHULATA	-"- 020	-	-	-	-	-	ND	ND	11964	ND	100
	G50	VANGUERIA ACUTILOBA	002C	0.15	0.16	2.50	0.09	ND	303	ND	4776	ND	23
	G1	UVARIA LUCIDA	KV/BD-003	-	-	-	-	-	645	ND	8515	ND	14
IV	G7	ACACIA AMARA	-"-143	-	-	-	4.40	3.20	ND	ND	13146	ND	ND
	G8	A. MELLIFERA	-"-139	-	-	-	-	0.05	ND	ND	1738	ND	23

APPENDIX III (a) OTHER ELEMENTS CONCENTRATION

G.B.U.	SITE	PLANT SPECIES	SAMPLE NO.	GA
I	R1	ACACIA MELLIFERA	KV/BD-029	ND
	R4	A. TORTILIS	KV/BD-056	ND
	G2	CISSUS QUADRANGULARIS	-"- 026	ND
	G5	VANGUERIA ACUTILOBA	-"- 031	ND
	R1	EUPHOBIA NYIKAE	-"- 021	0.30
	G60	A. TORTILIS	016B	ND
	G57	CROTON DICHOGAMUS	012B	ND
	G57	C. DICHOGAMUS	012C	ND
I'	R6	HARRISONIA ABYSSINICA	-"- 099	ND
	G6	INDIGOFERA BREVICALYX	-"- 109	ND
	G4	CROTON DICHOGAMUS	-"- 093	8
	G4	BALANITE AEGYPTIACA	KV/BD-094	ND
	G56	CROTON DICHOGAMUS	0118	2
	G59	C. DICHOGAMUS	015A	ND
	G6	DODONEA VISCOSA	KV/BD-112	ND
	R13	EUCLEA NATALENSIS	-"- 120	ND
	G6	JUSTICIA FLAVA	-"- 131A	ND

GE	BR	Y	MO	PB	AS	NB
ND	103	ND	34	ND	14	
ND	ND	575	ND	ND	17	
ND	ND	ND	ND	ND	15	
ND	ND	ND	ND	ND	19	
ND	ND	4	3	ND	8	
ND	112	ND	73	301	ND	ND
ND	223	ND	ND	ND	20	ND
ND	182	2	752	ND	15	ND
ND	3643	70	125	139	ND	ND
ND	ND	2840	17	ND	12	24
8	647	10	ND	32	ND	ND
ND	ND	ND	ND	37	ND	ND
ND	815	ND	ND	ND	21	ND
6	715	2	16	ND	12	ND
ND	ND	ND	17	ND	15	ND
ND	ND	24	76	ND	7	ND
ND	73	21	19	ND	18	19

APPENDIX III (a) Cont.

G.B.U.	SITE	PLANT SPECIES	SAMPLE NO.
II	R15	DODONEA VISCOSA	-"-104
III	R41	COMBRETUM MOLLE	006C
	R40	CROTON DICHOGAMUS	004B
	G51	DODONEA VISCOSA	003A
	G52	RHUS NATALENSIS	005C
III'	G1	ACAPLYPHA FRUITICOSA	KV/BD-005
	B1	BALANITE AEGYPTIACA	P-001
	G50	CROTON DICHOGAMUS	002A
	G1	IPOMOEA SPATHULATA	KV/BD-004
	G1	I. SPATHULATA	-"- 020
	G50	VANGUERIA ACUTILOBA	002C
	G1	UVARIA LUCIDA	KV/BD-003
IV	G7	ACACIA AMARA	-"-143
	G8	A. MELLIFERA	-"-139

GA	GE	BR	Y	MO	PB	AS	NB
ND	ND	ND	20	99	ND	14	ND
0.40	ND	32	4	ND	28	ND	ND
12	ND	70	10	ND	31	ND	ND
3	ND	175	869	67	66	ND	ND
ND	3	53	4	21	56	ND	ND
ND	ND	ND	15	ND	9	ND	ND
ND	ND	293	2	ND	ND	7	ND
ND	ND	307	ND	ND	ND	ND	ND
ND	8	ND	2842	28	ND	5034	ND
ND	ND	ND	ND	45	ND	6	ND
ND	ND	44	17	10	ND	29	ND
2	ND	ND	ND	ND	ND	17	ND
ND	ND	ND	ND	75	ND	20	27
ND	ND	ND	ND	25	ND	12	ND

APPENDIX III (a) Cont.

G.B.U.	SITE	PLANT SPECIES	SAMPLE NO.
	R16	COMMIPHORA CORIACEA	-"-156
	G8	CISSUS QUADRANGULARIS	-"-136
	G17	CROTON DICHOGAMUS	-"-148
	R16	C. DICHOGAMUS	-"-160
	G9	C. DICHOGAMUS	-"-074
	R18	C. DICHOGAMUS	-"-132
	G7	EUPHOBIA GOSSYPINA	-"-142
	G7	IPOMOEA SPATHULATA	-"-145
	R18	LANNEA TRIPHYLLA	-"-134
	R17	TERMINALIA PRUNIOIDES	-"-151
V'	R7	ACACIA SEYAL	-"-063
	G53	A. TORTILIS	007A
	R7	ACALYPHA FRUITICOSA	KV/BD-062
	G53	COMBRETUM MOLLE	007B
	O''	IPOMOEA SPATHULATA	019p
	O'	PTERRIDIAM Spp.	013
	R7	IPOMOEA SPATHULATA	KV/BD-067

S	CL	K	SC	TI	V	CR	FE	CO	NI
ND	ND	2.76	0.75	0.02	ND	ND	902	ND	ND
ND	ND	0.79	ND	ND	ND	ND	522	ND	ND
2.90	3.20	16.40	1.10	ND	ND	ND	3850	ND	14
1.20	5.80	18.40	1.30	ND	286	ND	5256	ND	12
2.10	3.60	16.80	0.90	0.01	108	ND	4397	ND	83
-	-	-	-	0.04	145	ND	2443	ND	23
-	-	-	-	-	ND	ND	790	ND	2
-	-	-	-	1.92	ND	ND	1996	10	9
-	-	-	-	-	ND	ND	5460	ND	ND
ND	ND	26.61	-	0.87	0.13	ND	1855	ND	4
-	-	-	-	0.03	145	ND	3225	ND	22
0.40	2.30	6.00	1.20	2.00	ND	93	4346	ND	ND
-	-	-	-	0.11	ND	83	4863	ND	ND
ND	23.50	35.60	2.50	ND	ND	ND	2421	ND	83
1.10	1.90	13.40	1.20	1.50	179	ND	12000	ND	ND
2.10	8.20	24.92	0.19	0.02	318	29	5483	ND	3
ND	ND	33.85	2.21	0.06	4	ND	2897	ND	9

APPENDIX III (a) Cont.

G.B.U.	SITE	PLANT SPECIES	SAMPLE NO.
	R16	COMMIPHORA CORIACEA	-"-156
	G8	CISSUS QUADRANGULARIS	-"-136
	G17	CROTON DICHOGAMUS	-"-148
	R16	C. DICHOGAMUS	-"-160
	G9	C. DICHOGAMUS	-"-074
	R18	C. DICHOGAMUS	-"-132
	G7	EUPHOBIA GOSSYPINA	-"-142
	G7	IPOMOEA SPATHULATA	-"-145
	R18	LANNEA TRIPHYLLA	-"-134
	R17	TERMINALIA PRUNIOIDES	-"-151
V'	R7	ACACIA SEYAL	-"-063
	G53	A. TORTILIS	007A
	R7	ACALYPHA FRUITICOSA	KV/BD-062
	G53	COMBRETUM MOLLE	007B
	O''	IPOMOEA SPATHULATA	019p
	O'	PTERRRIDIAM Spp.	013
	R7	IMPOMOEA SPATHULATA	KV/BD-067

GA	GE	BR	Y	MO	PB	AS	NB
ND	ND	ND	ND	ND	11500	ND	ND
ND	ND	ND	7	ND	8	ND	ND
7	1	144	8	ND	31	ND	3
ND	ND	274	4	ND	34	ND	ND
7	ND	1084	24	ND	7	ND	ND
5	ND	626	41	ND	41	5	4
ND	ND	ND	6	24	ND	13	4
2	40	ND	31	ND	ND	11	3
ND	ND	ND	47	ND	ND	ND	ND
ND	1.50	ND	1	ND	ND	8	ND
9	ND	ND	27	74	ND	32	ND
ND	ND	101	9	ND	ND	12	ND
ND	ND	ND	ND	ND	ND	21	2
ND	ND	145	25	ND	ND	43	ND
ND	ND	40	22	82	79	ND	14
ND	ND	68	8	190	ND	14	ND
ND	ND	ND	ND	ND	ND	42	ND

APPENDIX III (a) Cont.

G.B.U.	SITE	PLANT SPECIES	SAMPLE NO.
V''	G54	CROTON DICHOGAMUS	008B
	G54	EUCLEA DAVINORUM	008A
	G54	TECLEA SIMPLISIFORMIS	008C
V'''	* G61	BALANITE AEGYPTIACA (i)	017B(i)
		-"-	017B(ii)
	G12	-"-	KV/BD-161
	R21	-"-	-"-172
	R19	COMBRETUM MOLLE	-"-185
	G11	CISSUS ROTUNDIFOLIA	-"-167
	R2	CROTON DICHOGAMUS	-"-011
	R10	-"-	-"-041
	R9	UVAIRA LUCIDA	-"-045
	R9	VANGUERIA ACUTILOBA	-"-043

* Duplicate Analysis

S	CL	K	SC	TI	V	CR	FE	CO	NI
3.20	8.80	26.00	1.90	ND	ND	ND	3321	ND	45
1.60	7.80	18.80	0.90	ND	228	63	2502	ND	35
0.54	1.20	24.30	1.40	ND	ND	ND	3367	ND	22
3.00	11.30	18.20	1.30	1.00	188	20	2300	ND	12
3.60	14.10	21.90	1.20	1.30	256	24	2687	ND	14
ND	ND	22.78	1.40	ND	177	ND	2753	ND	52
-	-	-	2.11	ND	186	12	1356	77	37
-	-	-	-	ND	ND	ND	3634	ND	16
-	-	-	-	ND	4030	ND	1523	ND	4
1.30	8.20	16.20	0.92	0.01	73	ND.	4319	ND	12
-	-	-	-	ND	ND	ND	1993	ND	ND
-	-	-	-	0.80	4672	ND	ND	ND	ND
-	-	-	-	2.30	ND	ND	2427	ND	22

APPENDIX III (a) Cont.

G.B.U.	SITE	PLANT SPECIES	SAMPLE NO.
V''	G54	CROTON DICHOGAMUS	008B
	G54	EUCLEA DAVINORUM	008A
	G54	TECLEA SIMPLISIFORMIS	
V'''	G61	BALANITE AEGYPTIACA(i)	017B(i)
*		-"-	017B(ii)
	G12	-"-	KV/BD-161
	R21	-"-	-"-172
	R19	COMBRETUM MOLLE	-"-185
	G11	CISSUS ROTUNDIFOLIA	-"-167
	R2	CROTON DICHOGAMUS	-"-011
	R10	-"-	-"-041
	R9	UVAIRA LUCIDA	-'-045
	R9	VANGUERIA ACUTILOBA	-"-043

* Duplicate Analysis

GA	GE	BR	Y	MO	PB	AS	NB
5	ND	403	ND	9	35	ND	ND
ND	ND	11	14	50	ND	17	ND
ND	ND	10	ND	49	44	ND	ND
ND	ND	475	18	ND	ND	17	ND
ND	ND	598	19	ND	ND	18	ND
ND	ND	ND	14	ND	37	ND	ND
ND	2	ND	14	ND	ND	1	ND
ND	ND	151	16	ND	ND	36	ND
ND	ND	ND	ND	9	ND	10	1
ND	ND	631	6	ND	27	ND	4
ND	ND	ND	45	ND	ND	21	ND
ND	ND	ND	ND	ND	60	ND	ND
ND	ND	ND	ND	6	ND	ND	4

G.B.U.	SITE	PLANT SPECIES	SAMPLE NO.	S	CL	K	SC	TI	V	CR	FE	CO	NI
VI	G55	UNNAMED	010B	2.70	8.70	31.20	1.50	ND	ND	ND	7837	ND	67
---	---	ANON	---	-	-	-	2.00	ND	ND	ND	1566	ND	ND
	* (G64	COMBRETUM MOLLE	020(i)	1.00	2.50	22.50	0.91	ND	374	ND	2780	ND	ND
	(-"-	----"---	020(ii)	0.66	1.70	19.00	0.79	ND	386	ND	2621	ND	ND
	G65	CROTON DICHOGAMUS	0188	1.90	7.30	22.50	0.63	0.07	328	ND	2470	ND	ND

* Duplicate Analysis

APPENDIX III (a) Cont.

G.B.U.	SITE	PLANT SPECIES	SAMPLE NO.	GA	GE	BR	Y	MO	PB	AS	NB
VI	G55	UNNAMED	010B	8	8	322	4	ND	ND	ND	9
---	---	ANON	---	ND	ND	ND	ND	ND	ND	ND	ND
	*(G64	COMBRETUM MOLLE	020(i)	7	29	49	6	ND	ND	13	11
	(-"-	---"---	020(ii)	7	31	49	13	ND	ND	12	13
	G65	CROTON DICHOGAMUS	0188	ND	ND	531	40	19	75	ND	ND

* Duplicate Analysis

APPENDIX III (b) OTHER ELEMENT CONCENTRATIONS IN SOILS

G.B.U.	SITE	SAMPLE NO.	pH	mV	AL	SI	K	SC	FE	TI	V	CR	NI	GA	GE	Y	MO	PB	NB
					%						ppm								
III'	B1	S-001	9.10	-20.00	-	0.47	1.10	-	8.20	1.05	1139	ND	82	32	ND	120	66	747	174
	G50	S-002	9.85	-50.00	2.80	1.40	0.08	0.01	11.60	0.14	3958	192	134	22	15	38	ND	39	ND
II	G51	S-003	6.95	125.00	-	17.20	4.00	-	13.70	1.40	975	910	155	5	10	31	ND	327	82
III''	R40	S-004	8.45	45.00	27.00	14.60	1.20	-	11.20	1.30	457	779	259	3	ND	42	10	71	103
III'	G52	S-005	9.25	0.00	27.80	24.90	2.70	0.09	13.00	1.80	820	329	59	24	ND	58	ND	41	133
	R41	S-006	10.50	-65.00	-	26.00	4.50	0.05	11.50	0.16	ND	489	56	39	ND	78	ND	78	210
V'	G53	S-007	10.10	-65.00	-	25.10	-	0.20	13.50	2.30	1723	4476	201	15	ND	ND	24	76	148
V''	G54	S-008	8.30	55.00	15.10	11.20	1.22	0.24	11.00	1.40	712	3453	35	48	12	36	ND	38	208
	R42	S-009	10.60	-90.00	-	23.00	2.70	0.03	9.30	1.30	457	204	33	15	ND	97	38	75	222

APPENDIX III (b) Cont.

%

G.B.U.	SITE	SAMPLE NO.	pH	mV	AL	SI	K
I	G56	S-011	9.70	-20.50	-	31.70	2.68
	G57	S-012	10.60	-70.00	5.60	6.80	0.39
		S-013	8.95	o.00	0.79	0.83	0.13
		S-014	9.05	-10.00	19.21	16.01	1.08
I'	G59	S-015	10.60	-90.00	-	17.00	1.56
I	G60	S-016	9.20	0.00	18.20	15.60	1.50
V'''	G61	S-017	8.30	30.00	9.79	9.76	1.71
		S-018	10.30	-55.00	9.90	12.50	9.81
Tail	O'	S1So1	8.80	25.00	14.70	25.10	1.00
V''	G65	S-020	3.05	-35.00	-	15.10	2.80

ppm

SC	FE	TI	V	CR	NI	GA	GE	Y	MO	PB	NB
-	10.70	1.28	477	391	88	23	21	19	9	31	62
-	11.00	1.40	ND	48	35	19	ND	39	9	14	15
40	10.60	0.06	553	187	70	9	2	102	ND	43	200
0.07	13.90	0.44	556	811	149	9	ND	63	ND	10	36
0.05	9.60	0.84	301	434	108	19	ND	24	ND	ND	32
-	10.00	0.80	ND	301	67	18	9	43	152	ND	26
0.06	3.37	0.90	970	390	111	29	13	98	140	87	109
-	4.70	0.20	227	ND	ND	24	9	39	ND	40	173
0.22	3.00	0.45	749	ND	50	ND	ND	17	ND	ND	25
-	4.29	0.44	ND	ND	ND	28	ND	80	ND	37	288

APPENDIX III (c) DETECTION LIMITS OF THE X-RAF FLUORESENCE ANALYSIS SYSTEM FOR THE ASSAYED ELEMENTS.

ELEMENT	Ca	Cu	Fe	Mn	Sr	U	Zn	Zr
D. LIMIT	4	5	2	2	3	30	3	4
ELEMENT	Al	K	Fe	Cr	Ni	Co	Ge	Ca
D. LIMIT	40	20	2	2	2	2	3	3
ELEMENT	As	Cd	Sc	Se	Si	V	Y	Pb
D. LIMIT	3	9	4	3	35	2	12	18
ELEMENT	Nb	Mo	Ti	Si				
D. LIMIT	4	5	2	35				

NB: All units in ppm. Source: Brooks, 1972, p. 164.

APPENDIX IV

Comparison of X-Ray Fluoresence (XRF) Analysis and Atomic Absorption Spectrophotometry (AAS).

APPENDIX IV COMPARISON OF ANALYSES BY XRF & AAS.

SAMPLE	METHOD	MN	Ce	Cu	Pb	Cr	Ca%
004B	XRF	3684	ND	265	31	Nd	13
	AAS	1060	16	100	30	6	21
008C	XRF	1115	Nd	244	44	Nd	16
	AAS	380	10	52	28	6	15
003A	XRF	3653	ND	268	66	Nd	10
	AAS	620	6	48	18	8	5
KV/011	XRF	807	ND	197	27	Nd	19
	AAS	254	14	92	32	8	21
011B	XRF	587	ND	229	Nd	Nd	16
	AAS	240	12	72	34	4	22
S-008	XRF	457	ND	494	Nd	Nd	0.22
	AAS	120	14	72	20	90	0.5
S-006	XRF	3422	ND	308	Nd	Nd	0.95
	AAS	2040	44	118	22	56	1.2
S-014	XRF	4010	ND	685	Nd	Nd	2.0
	AAS.	1760	54	300	18	166	1.1
S-015	XRF	1372	ND	328	Nd	Nd	1.6
	AAS	500	32	134	24	92	1.6
		± 1:3		1:36	1:2		1:1

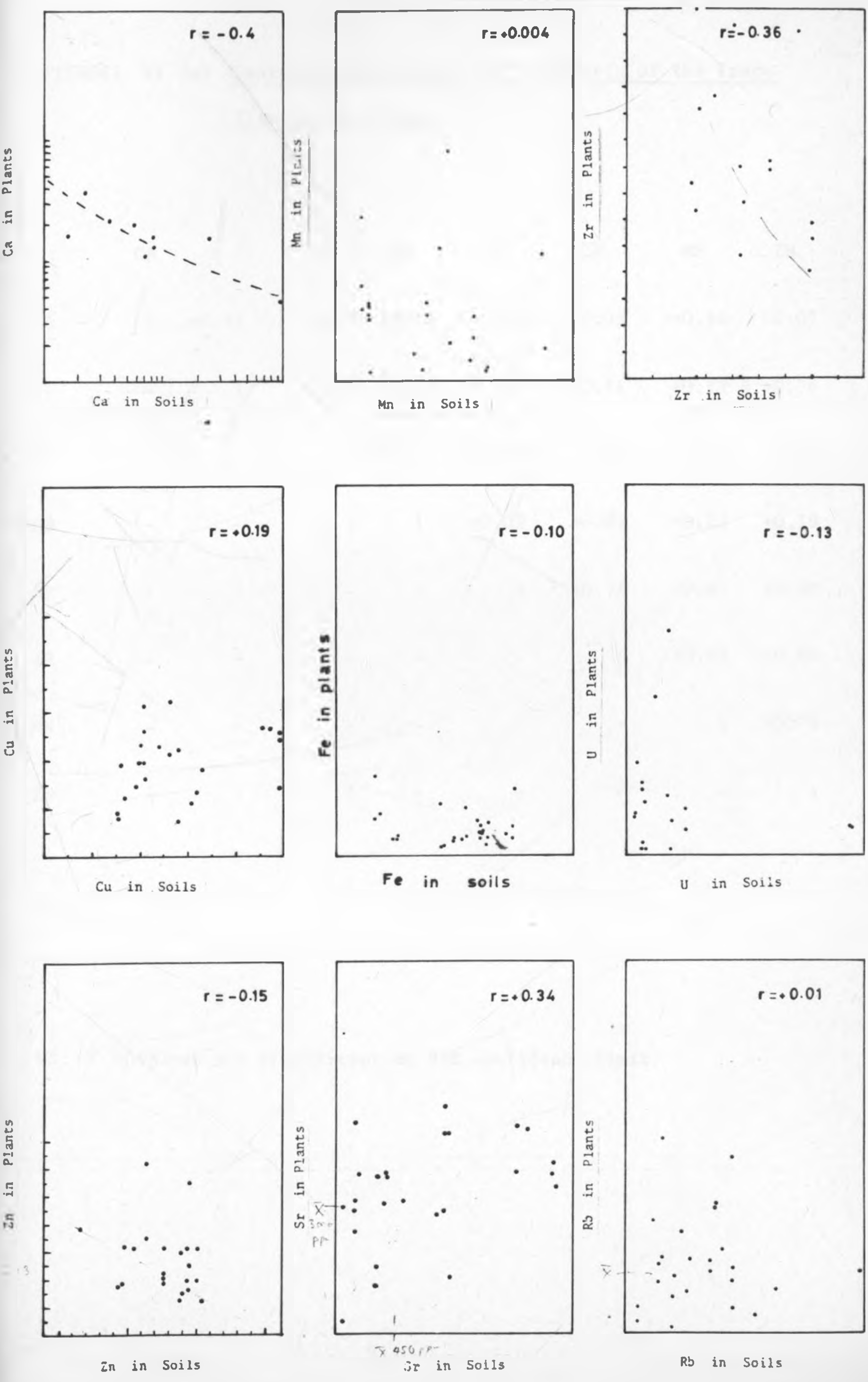
NOTE: ND = Not Assayed for

Nd = Not detected by the XRF Analysis

APPENDIX V

Pearson's Rank Correlation Coefficient "r" for the Soil-Plant Element Concentrations, and students t - values for the correlations.

APPENDIX V **PEARSON RANK CORRELATION COEFFICIENT "r" FOR THE SOIL v/s PLANT ELEMENT CONCENTRATIONS.**



APPENDIX VI (a) Pearson Rank Correlation 'r' matrix of the Trace Elements in Plants.

	CA	U	CU	RB	SR	ZR	MN	ZN
CA	1	+0.13	+0.12	+0.05	+0.95	-0.03	+0.94	-0.07
U	-	1	+0.49	+0.59	+0.64	+0.71	+0.72	+0.76
CU	-	-	1	+0.13	+0.59	+0.59	+0.60	+0.77
RB	-	-	-	1	+0.02	+0.02	+0.12	+0.19
SR	-	-	-	-	1	+0.74	+0.67	+0.80
ZR	-	-	-	-	-	1	+0.67	+0.80
MN	-	-	-	-	-	-	1	+0.78
ZN	-	-	-	-	-	-	-	1

NB: r - values are significant at 99% confidence limit.

APPENDIX VI (b) Pearson Rank Correlation 'r' matrix of the Trace Elements in Soils

	CA	U	CU	RB	SR	ZR	MN	ZN
CA	1	-0.05	-0.17	-0.03	+0.47	-0.57	-0.09	-0.47
U	-	1	+0.20	-0.14	-0.17	+0.10	+0.24	-0.04
CU	-	-	1	-0.03	-0.04	+0.21	+0.21	+0.25
RB	-	-	-	1	-0.03	-0.06	-0.14	-0.20
SR	-	-	-	-	1	-0.06	+0.39	-0.01
ZR	-	-	-	-	-	1	+0.10	+0.44
MN	-	-	-	-	-	-	1	+0.10
ZN	-	-	-	-	-	-	-	-

NB: r - values significant at 95% confidence limit.

APPENDIX VI(c) Students t-values for the correlation in plants(a) and in soils (b).

(a)

	ZN	RB	ZR	U	Mn	Ca	Sr	Cu
Sn	1.00	/	5.66*	4.96*	5.29*	/	5.66*	5.12*
Rb	-	1.00	/	3.10+	/	/	/	/
Zr	-	-	1.00	4.28*	3.83*	/	4.67*	3.10+
U	-	-	-	1.00	4.40*	/	3.53+	2.39°
Mn	-	-	-	-	1.00	11.69*	3.83+	3.18+
Ca	-	-	-	-	-	1.00	12.95*	/
Sr	-	-	-	-	-	-	1.00	3.10+
Cu	-	-	-	-	-	-	-	1.00

(b)

	Ca	Sr	Zr	Mn	Zn
Ca	1	2.26	2.94*	/	2.26
Sr	-	1	/	/	/
Zr	-	-	1	/	2.08°
Mn	-	-	-	1	/
Zn	-	-	-	-	1

Note* * significatnt at 99.9% confidence limit

\+ " " 99% confidence limit

° " " 95% confidence limit

/ Not significant at 95% confidence limit.

APPENDIX VI

(a) Typical Spectrum obtained from a plant Sample, Using XRF Analysis, with a ^{109}Cd source.

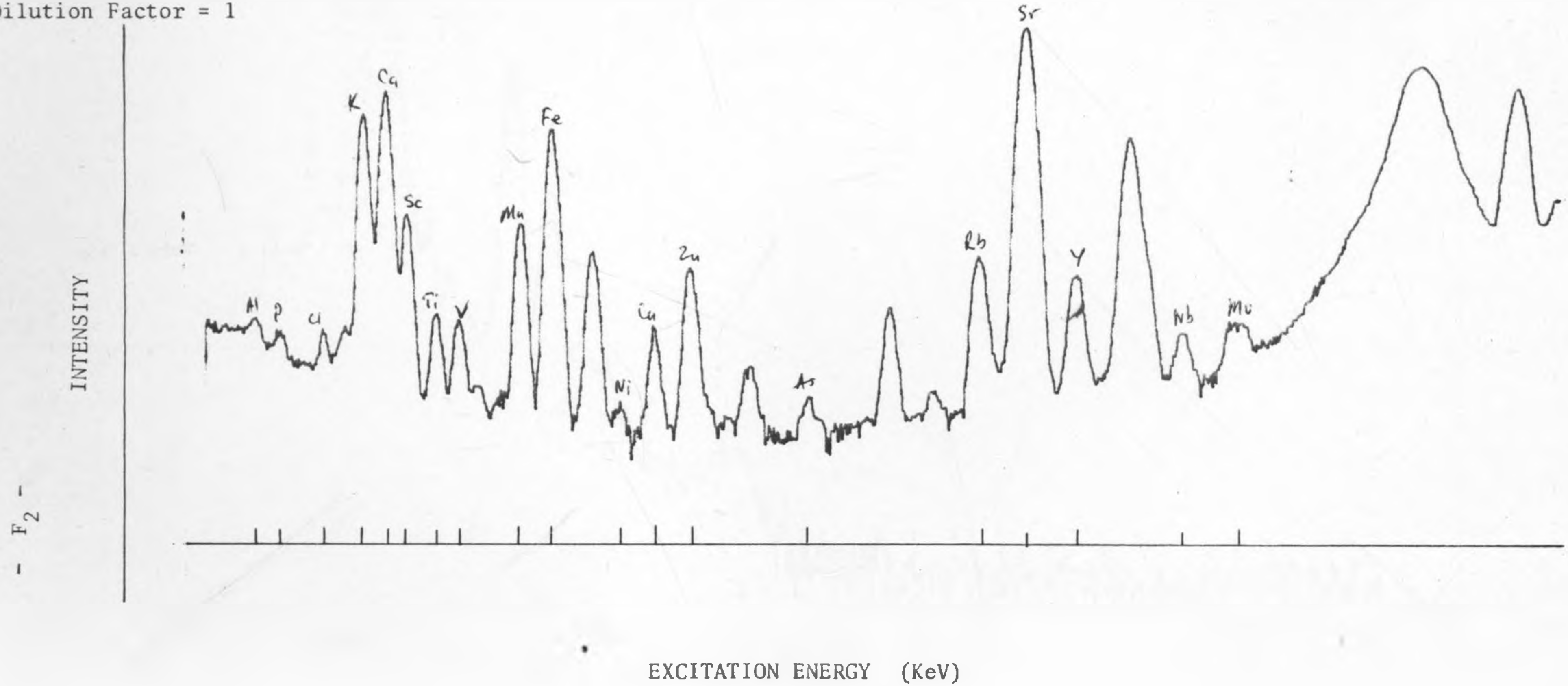
(b) Spectrum as above, but with a ^{55}Fe Source.

Sample No. = KV/BD - 109

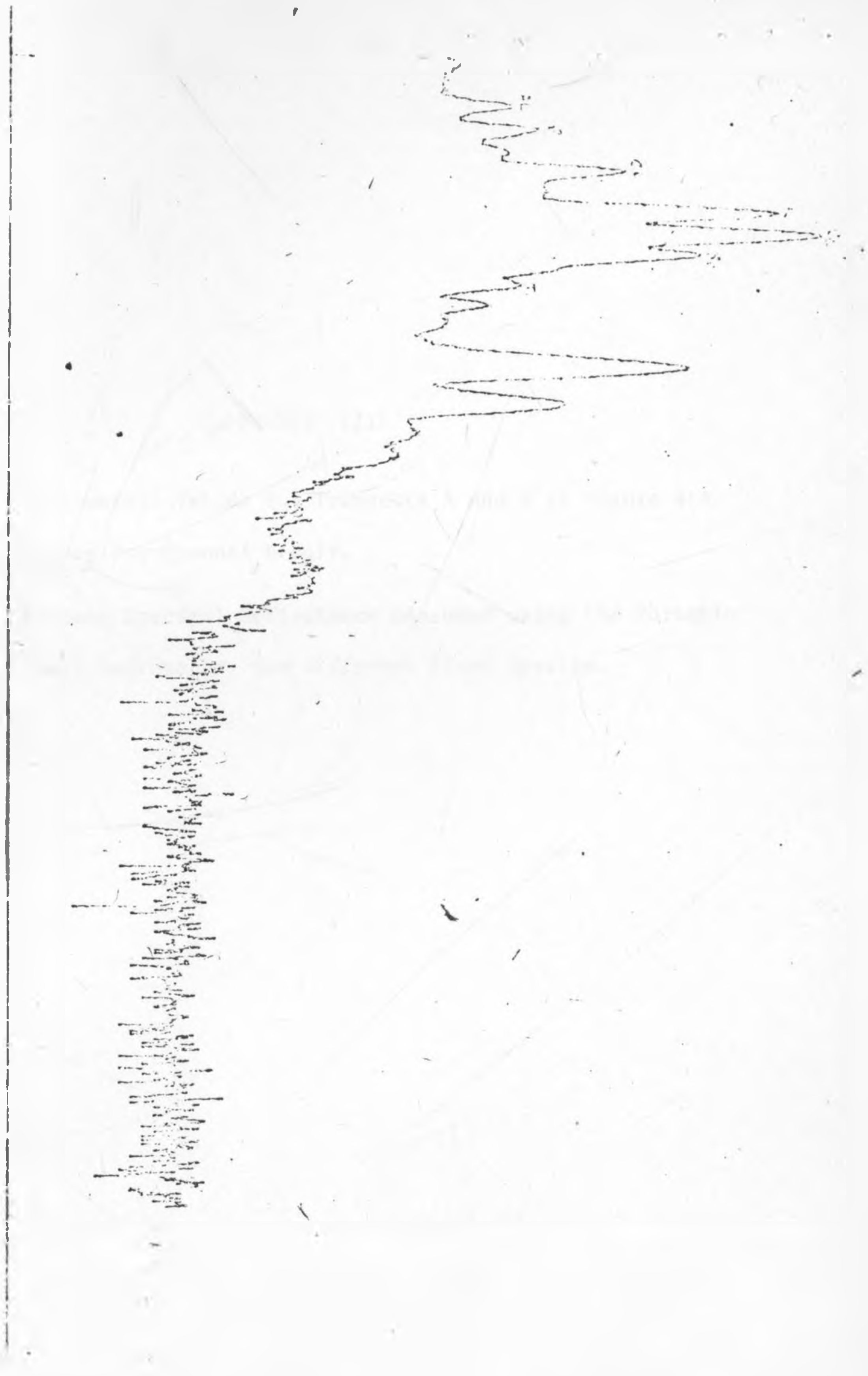
Species name = Indigofera brevicalyx

Weight = 0.17600g

Dilution Factor = 1



APPENDIX VI (a) TYPICAL SPECTRUM FROM A PLANT SAMPLE OBTAINED FROM THE XRF ANALYSIS USING ^{109}Cd SOURCE.



APPENDIX VIII

(a) Radiometric Values for Transects A and B in Figure 4.4. Values for Channel 6 only.

(b) Percent Spectral Reflectance measured using the Portable Field Radiometer, for different Plant Species.

APPENDIX VIII (a) TABLE OF RADIOMETRIC VALUES FOR TRANSECTS A AND B, AS OBTAINED THE INTERACTIVE DIGITAL ANALYSIS SYSTEM. CHANNEL 6 VALUES ONLY

TRANSECT A

WEST			
28	36	35	35
33	35	37	34
30	37	34	37
33	41	34	39
41	52	30	38
41	55	30	36
42	48	30	36
42	43	33	32
37	37	37	31
41	39	34	35
43	37	34	37
43	35	32	39
41	33	32	37
41	31	36	35
39	31	37	39
37	31	37	39
33	33	37	41
33	34	35	39
33	36	35	44
35	36	35	42
33	30	37	37
33	31	35	EAST
34	32	37	
34	30	35	
34	31	38	
36	33	38	

TRANSECT B

WEST			
30	43	36	35
25	37	36	35
32	39	40	33
40	41	40	33
42	37	38	35
40	37	38	37
34	39	33	35
40	37	33	33
41	39	33	35
41	39	36	EAST
42	41	36	
42	39	31	
40	41	37	
38	39	35	
40	39	35	
40	43	37	
41	43	37	
36	38	39	
38	40	39	
44	40	37	
48	42	39	
49	40	43	
45	38	39	
45	38	37	
48	40	37	
49	36	37	

APPENDIX VII (b) DATA FOR SPECTRAL CURVES (FIG. 4.5)
TABLE OF PERCENT REFLECTANCE AS MEAS. BY THE
PORTABLE FIELD RADIOMETER.

SITE	SAMPLE NO.	% COVER	% RELECTANCE I	II	III	IV	REMARKS
R41	006A	10	5.2	3.8	26.3	33.8	006C assay.
	006B	15	6.1	2.2	30	32.9	ed. GBU III
	006C	20	9.5	4.7	52.9	46.3	S-006(wet)grey-
	S-006	45	8.8	10.9	12.1	8.98	greenish shaly Lston.
G53	007A	25	10	9.2	40	49.2	
	007B	20	4.2	3.8	34.8	36.9	007A & B Assayed.
	007C	10	7.0	4.4	40	45.3	GBU V'
G54	008A	25	5.2	6.3	25.2	26.9	GBU V''
	008B	15	16.1	7.1	13.6	16.97	R-008 = Reddish
	008C	±10	9.4	3.9	31.9	26.9	orange weathered
	S-008	30	7.2	10.3	13.6	16.97	trachyte boulder.
	R-008		18.5	20	7.3	7.3	008A Assayed.
G55	010A	30	6.4	4	40.4	54.5	GBU V, 010B =
	010B	10	13.3	3.6	68.4	63.2	Cleorodandron sp.
G56	011A	ND	10	6.6	35	38.8	s-011 = Sandy
	011B	ND	10	9.5	45.2	41.9	soils of feldhorbl- gneisse GBU I'
G57	012A	ND	11.3	42.1	47.3	45.9	
	012B	ND	11.3	5.7	52.3	53.3	GBU I
	012C	ND	8	5	48	64.7	

SITE	SAMPLES NO	% COVER	% REFLECTANCE				REMARKS
			I	II	III	IV	
G58	012A	80	4.7	4.1	32.2	34.9	S-014 2%
	014B	10	5.2	4.1	29.2	32.7	cover, GBU I
G59	015A	30	5	5	41	70	
	015B	40	5	3	31	41	GBU I'
G60	016A	60	6.9	5.9	41.1	52.4	
	016B	30	4.6	2.7	35.8	38.1	GBU = I
G61	017A	10	7.2	3.6	28.9	42.9	
	017B	20	5.2	3.9	17.0	20.7	
	017C	60	22.3	16.5	19.0	19.0	GBU =

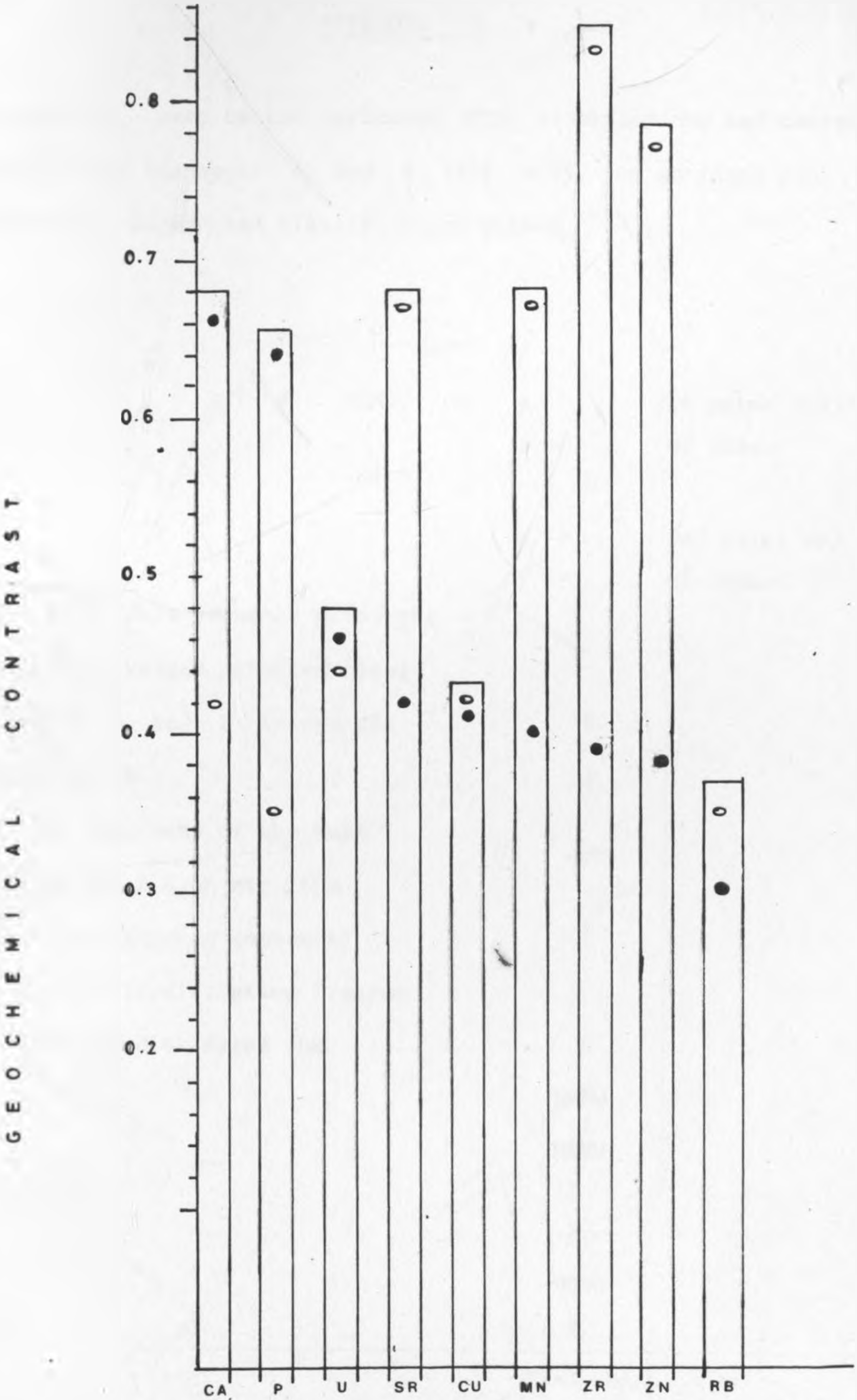
NOTE: Feldhorbl = Feldspathoidal hornblende gneiss

lstone = Limestone

IX

APPENDIX IX

Geochemical contrast in Plant and Soil Samples.



Geochemical Contrast in Plant (•) and Soil (○) Samples

APPENDIX X

Sequence X_1 used on the Pericolor 1000 to obtain the Radiometric Values along Transects A and B (Fig. 4.4), on an image processed by a Supervised classification method.

6 L M_1 →

I_1

I_2 T $ MENU @ x = ... 1st point start

y = ... of line.

J_1 D

J_2 x = ... 2nd point end

y = ... of line.

NOTE: (1) This sequence gives the Radiometric values obtained along transects A and B in the NIR part of the EMS.

(2) The functions of the keys (symbols eg. Z,C, # etc., the processing sequence commands) are in the Classification Program PC SPOT, in disk drive DØ.

E

#

#

Z

C

MENU

!

MENU

T

Z

MENU

@

TRAG BALL

(to read values along transect)

(END)