A

THESIS

entitled

GEOBOTANY, BIOGEOCHEMISTRY AND GEOCHEMISTRY IN EXPLORATION FOR STRATIFORM COPPER DEPOSITS IN ~~THE~~ LOW TREE AND SHRUB SAVANNA ~~OF~~ IN CENTRAL SOUTH WEST AFRICA

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DOCTOR OF PHILOSOPHY

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by

MALCOLM MASON

Bedford College
London University

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PREFACE

The research on which this thesis is based was undertaken while the author held a bursary under a grant made to Professor M M Cole by the Beta Mining and Prospecting Co, a wholly-owned subsidiary of the Anglo-Transvaal Consolidated Investment Trust Co Ltd, for geobotanical investigations in South West Africa and Botswana.

ABSTRACT

Stratiform copper mineralization was discovered in the Witvlei Area of South West Africa, within the Precambrian metasedimentary Tsumis Formation.

The region has a semi-arid climate and the vegetation is characterised by a low tree and shrub savanna. On a regional scale the classification and species composition of the vegetation is related to the depth and nature of the overburden. The three environments of near surface bedrock, sand covered and calcrete covered are recognised.

Geobotanical, biogeochemical and geochemical studies were carried out in areas of known mineralization in the various environments to determine the most effective use of these techniques in an integrated exploration program.

In the selected areas the geology and soil profiles are recorded from trench sections and wagon drilling, and the copper content of mineralized bedrock and soils determined. The distribution of plant species is recorded along continuous belt transects parallel to the trench sections so that a direct comparison of the geology, geochemistry and geobotany can be made. Geological and geobotanical mapping and geochemical soil surveys were extended over the areas of interest.

Plant samples of leaves, twigs and grasses were collected from the more common species along the transects for copper analyses. Investigation of the rooting habits and seasonal variation in copper content of selected tree and shrub species was also made.

In areas of near surface bedrock the horizons of copper mineralization are most clearly defined by anomalous soil values in the range 200 - 500 ppm., for the minus 80 mesh, and an anomalous vegetation zone dominated by the species Helichrysum leptolepis and Fimbristylis exilis, with the associated grass species Aristida congesta, Eragrostis denudata and Anthephora pubescence. Trees and shrubs and the common grass species of the area, Stipagrostis uniplumis, do not occur within this anomalous vegetation zone.

Leaf and twig samples from several species of trees and shrubs show a high copper content in areas of mineralization. The species Grewia flava and Phaeoptilon spinosum proved the most successful in the detection of biogeochemical anomalies because of their more regular distribution and more consistant values.

Areas suitable for detailed orientation studies could not be located in the regions of deeper overburden of sand and calcrete. No geobotanical indicators of mineralization were found in these areas and the use of biogeochemical techniques is very much restricted by the sporadic distribution of the deeper rooted species.

Acknowledgments

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I am also indebted to the geologists J. Joubert, H. J. Snyman and P.D Steadman for providing the trench sections, wagon drill information and seismic data respectively, which are incorporated in this thesis.

I would like to express my gratitude to Dr. P.D. Toens, Assistant Exploration Manager S.W.A., and P. Vermaak, resident geologist at Witvlei, for the many discussions on the regional and local geology and the exploration techniques used in the Witvlei Concession.

I am grateful to my colleague A. F. Boshoff for providing valuable assistance during the initial phases of the field work in South West Africa, and in the preparation and analyses of plant samples in the Bedford College Laboratory.

I wish to thank the technical staff of the Geography Department Bedford College for their assistance throughout the research project and in particular Mr H. Ansell for the photographic reproduction of all maps and diagrams. I also wish to thank the herbarium staff in Pretoria for the identification of plant specimens collected in the Witvlei area of South West Africa.

Finally I would like to express my sincere thanks to my supervisor Professor M. M. Cole, Department of Geography Bedford College, for introducing the research project, for her guidance in field techniques in geobotany and biogeochemistry and for helpful review and criticism of the maps and diagrams presented in the thesis. I am also grateful to Professor Cole for the kind permission to include several of her photographs of the vegetation.

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Chapter 1

INTRODUCTION

In the Klein Aub district of Central South West Africa economic copper - silver mineralization occurs within a series of calcareous argillites, within the varied sedimentary sequence of the Tsumis Formation. Dr. H.D. le Roex a consulting geologist of the Anglo-Transvaal Consolidated Investment Company Limited, regarded this occurrence as similar to the stratiform deposits of the Zambian-Rhodesian Copper Belt, and that the Tsumis Formation provided a potential area for copper exploration. In addition other Pre-cambrian meta sedimentary sequences trending north-eastwards through Rehoboth, Gobabis and beyond the South West Africa - Botswana Border were also of interest for regional reconnaissance work.

In 1966 and 1967, under the direction of Dr. le Roex, prospectors were engaged to search geologically favourable areas between Klein Aub and Gobabis for stratiform type copper mineralization. During this phase of exploration malachite staining was reported in argillaceous rocks exposed in the foundations for farm buildings at the Okatjirute West Homestead 12 kilometres north of Witvlei. Further copper mineralization in argillite was discovered in a road metal pit beside the Windhoek road about 15 kilometres west of Witvlei.

These initial findings encouraged the Anglovaal Company to embark upon a large scale integrated exploration program in Central South West Africa incorporating geology, photo-geology and geochemistry in the reconnaissance phase.

The success of geobotanical techniques in the somewhat similar environment of the Dugald River Area, Cloncurry District, Australia, (Nicolls, Provan, Cole and Tooms, 1965) prompted Dr. le Roex to invite Professor M.M. Cole, of Bedford College London University, to assess the potential of geobotany in the exploration for stratiform copper deposits in Central South West Africa. Two research assistants of Professor Cole, Misses L.C. Coupland and J. Cudmore, working in Southern Africa under a grant from the National Environmental Research Council for Investigations of Plant Indicators of Mineralization, undertook the initial geobotanical investigations in the Witvlei area. The geobotanical reconnaissance prepared for the area consisted of long walking traverses across the regional strike inferred from aerial photographs (Cole, 1968). Early in the program communities of the small composite plant *Helichrysum leptolepis*, occurring in the narrow zones where the background grasses and herbs were absent, were recognised as anomalous. Pits made in these areas revealed copper mineralization in argillite bedrock 20 - 50 cm. below the surface. Subsequent traverses both across the regional strike and along the zones of *Helichrysum leptolepis* led to the discovery of copper mineralization on the farms Okatjirute and Okatjirute West to the north of Witvlei.

Following the successful application of geobotanical techniques in the Witvlei area and the detection of copper mineralization by geochemical methods, geologists of Anglovaal and other participating companies together with Professor Cole and the research assistants, conducted a reconnaissance survey of the region extending from Windhoek through Witvlei, Gobabis and Ghanzi to Maun in central Botswana. The geology vegetation and general environmental factors were recorded so that the more promising areas and the most applicable exploration techniques could be selected.

The important role of geobotanical and related studies in an integrated exploration program for Central South West Africa and Botswana was recognised and in September 1967 the Anglo-Transvaal Investment Company through their subsidiary Beta Mining and Prospecting Company Limited sponsored two Postgraduate Studentships/ Research Assistantships for geobotanical field work.

The research program was to be carried out at Bedford College, London University under the guidance of Professor Cole. The author of this thesis was awarded one of the Research Assistantships and carried out geobotanical, biogeochemical and geochemical studies in the Witvlei Area.

Chapter 2

PHYSICAL BACKGROUND

The Geology of Central South West Africa

Extending northeastwards from the Klein Aub area, through Rehoboth, Dordabis, Witvlei and Gobabis to the Botswana border (Fig. 1) is an assemblage of pre-cambrian meta-sediments and associated volcanics in which stratiform copper deposits have been found. Along the 400 kilometre belt, bounded on the north by rocks of the Damara System and to the south by Karroo sediments and volcanics, the lithology and succession has been described from several areas. Regional correlations were not attempted by the early authors because of the scattered nature of the outcrops and the increasing cover of Kalahari sand towards the east. The geology of the area is still not fully understood and because of the isolated form of the belt and the lack of age determinations for the formations, no positive correlations have been made with other pre-cambrian systems of Southern Africa. However, tentative correlations, on geographical distribution and lithological similarities have been proposed by many authors and Haughton (1969) suggests that some series or formations within the belt may be equivalent, and that the sediments are possibly coeval with formations in Botswana and Zambia.

The oldest rocks of Central South West Africa, forming the basement complex, consist of phyllites, amphibolites and pure meta-quartzites and occur in the western part of the Rehoboth district (Fig. 1). This assemblage was first described by W.P. de Kock (1934) and collectively termed the Marienhof Formation. An age determination by Nicholaysen, on galena from a lead prospect on the farm Marienhof (Martin 1965), gave a value of 1900 m.y. Much

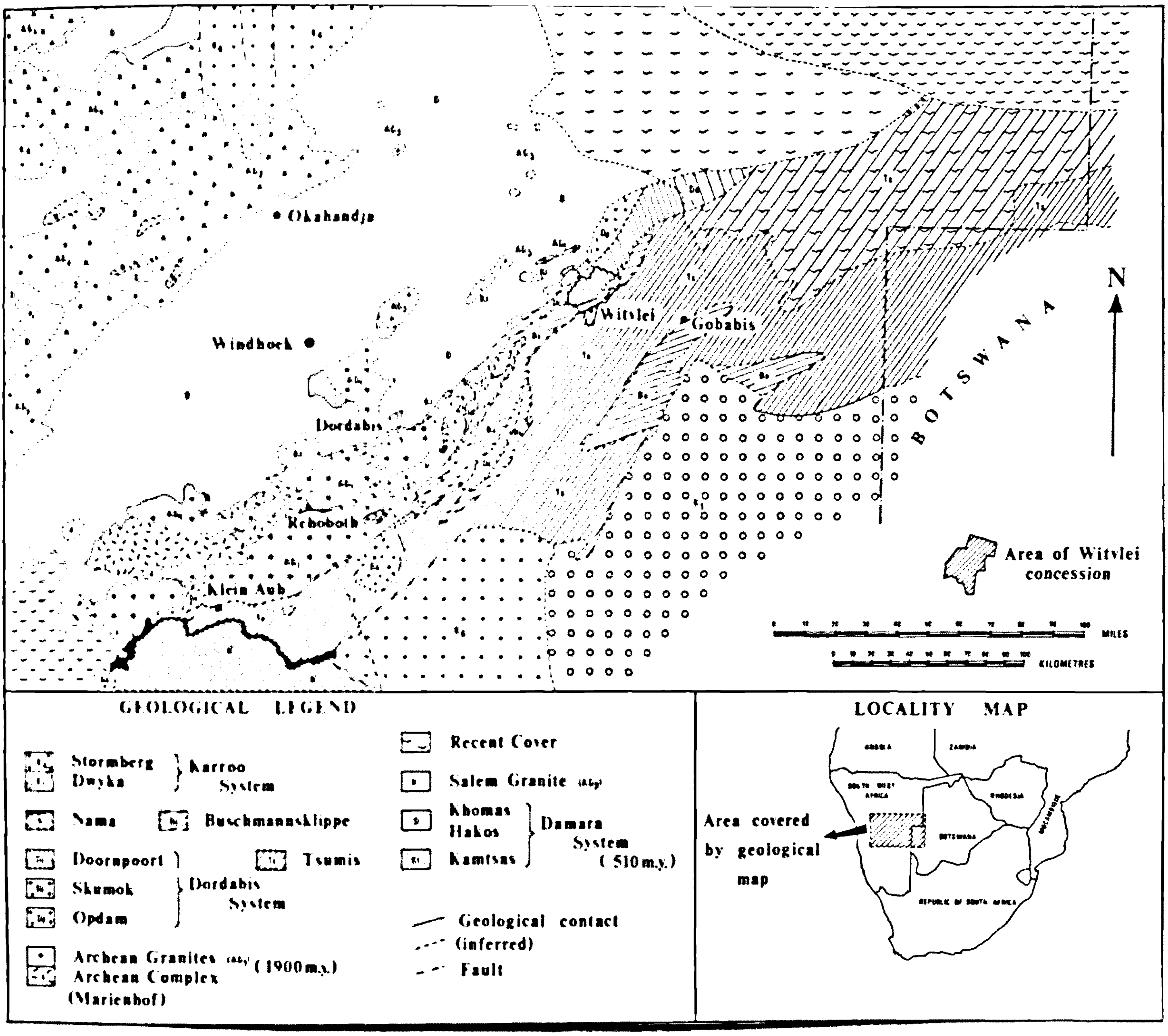


Fig.1 The geology of Central South West Africa (From "Geology of South West Africa" Government Printer, Pretoria).

of the series has been granitized and in places the metasediments and volcanics grade into and are intruded by granite gneiss (AG_1 Fig. 1). Shear zones and quartz stringers near the granite contacts contain traces of gold and copper mineralization.

Surrounding the northeastern section of the Marienhof Formation is an assemblage of volcanic and sedimentary rocks, which were grouped by Geevers (1934) as the Lower and Upper Dordabis Beds. Subsequent mapping by Schalk (1960) showed that the upper division belonged to a younger rock system and that the lower division could be subdivided into three formations, namely the Opdam, Skumok and Doornpoort. Martin (1965) proposed the term Dordabis System for these three formations.

The Opdam Formation has a basal conglomerate which is followed by a succession of phyllites, quartzites and conglomerate lenses, interbedded with epidotised basaltic and amygdaloidal lavas. The succession attains a maximum thickness of 1300 m. in the Dordabis area.

Resting discordantly on the basic lavas of the Opdam are acid volcanics and sediments of the Skumok Formation. The series of rhyolitic and felsitic lavas, with interbedded ignimbrites and quartzites has a basal sedimentary breccia consisting mainly of angular slabs of mafic lava. Along the southern margin the Skumok is intruded by granite, and quartz porphyry sills in the Opdam may be genetically associated with this phase of intrusives.

Acid volcanics are also found in the lower part of the Doornpoort (Schalk 1960) suggesting that the Skumok is in part contemporaneous with the Doornpoort. In the Dordabis area the basal conglomerate of the Doornpoort, containing pebbles of quartz porphyry, transgresses the Skumok onto lower members of the formation. The Doornpoort consists of a succession of fine grained and well bedded quartzites with hard shale bands and limestone lenses. Throughout the sequence the presence of grit bands, ripple marks, mud cracks and clay pellets suggests a shallow water environment during deposition and Schalk gives a thickness of 3,700 m. for the formation.

The group of arenaceous sediments outcropping on the southern side of the basement complex (Fig. 1) were first thought to be the basal beds of the Nama System (de Kock 1934). Korn and Martin (1959) later separated this group to the south and east of Dordabis as the Tsumis Series on the presence of an unconformity at the base of the Schwartzkalk, a type region subdivision of the Nama. The Tsumis succession consists mainly of cross-bedded feldspathic quartzites, with lenses of conglomerates, shales and limestones and attains a maximum thickness of 6,000 m., thinning rapidly towards the margins of deposition. The geological succession has been studied in greatest detail in the Klein Aub Area by Handley (1965), who recognised four major subdivisions or stages;

1. The Lower Quartzite and Conglomerate Stage rests on an irregular surface of Skumok and locally the lower parts of this stage die out against the porphyry hills.
2. The Calcareous Shale Stage; in which ten zones are recognised, including a green shale containing copper mineralization.
3. The Calcareous Quartzite Stage is a monotonous sequence of fine grained pink to maroon quartzites in which the limestone content varies from 2 - 20%.
4. The Upper Quartzite and Conglomerate Stage consists of pink to grey, granular feldspathic quartzites with well rounded pebbles scattered at random throughout the rock.

The rocks of the Tsumis System are folded along a NE - SW axis and in the Klein Aub area display open folds with approximately equal dips of less than 40°. The presence of chlorite and sericite indicate a very low grade of regional metamorphism and minor alteration of quartz and carbonates took place during compaction and folding of the rocks.

To the south of Klein Aub the Tsumis is overlain by

Nama sediments, which in places transgress the Tsumis rocks onto volcanics of the Skumok. The contact is seldom exposed but where seen there is a sharp division between the hard flinty white to grey quartzites of the Nama and the pebbly quartzites or conglomerates of the upper part of the Tsumis.

East and northeast of Dordabis sediments of the Buschmannsklippe Formation rest with slight discordance on rocks of the Tsumis. The lower part of the series consists of dolomitic and oolitic limestones, shales, dolomites and sandstones with abundant ripple marks on the bedding planes indicating a shallow water origin. In the Nossob River valley to the south of Gobabis, a tillite occurs at the base of the series and has a maximum thickness of 500 m. Martin (1965) suggests that this most probably represents a basal moraine from the erosion of unconsolidated Tsumis sediments by ice. In this region, south of Gobabis, the Buschmanns-klippe forms a large syncline and is folded with the Tsumis.

To the north of the basement complex and rocks of the Dordabis System, lies the ENE Damara Belt which is composed of a series of intensely folded and metamorphosed eugeosynclinal sediments. The Damara System was first described by Gevers (1934) who made three major subdivisions; the Quartzite, Marble and Khomas Series. Subsequent studies indicate that these rocks are probably coeval with the Otavi Beds of Northern South West Africa and through a revision in nomenclature Gever's subdivisions are now termed the Nosib, Hakos and Khomas Series, forming the Swakop Facies of the Damara System.

The Nosib Series consists of coarse feldspathic quartzites with conglomerate lenses, laid down in disconnected basins in a pre-Damara topography. The series includes the Kamtsas Quartzites (Fig. 1) to the north of Dordabis, originally assigned to the Upper Dordabis Beds by Gevers. Syngenetic copper mineralization occurs within some parts of the formation. The Hakos Series is a predominently calcareous stage and has been sub-divided by the presence of a tillite. Rocks of the Khomas Series cover large areas of the Damara Belt and consist of a monotonous sequence of schists with several prominent quartzite zones in the lower part. Amphibolite and serpentinite lenses within the sedimentary sequence indicate mafic and ultra-mafic volcanism during this period.

The rocks of the Swakop Facies, within the eugeosynclinal belt, have been subjected to intense metamorphism and are intruded by the Salem granite and pegmatite veins, showing both concordant and discordant features. Age determination on pegmatite minerals by Nicholaysen (Haughton 1969) gave 510 $\pm$ 40 m.y. for this intrusive phase.

Several of the geological formations of Central South West Africa have been tentatively correlated with other systems of Southern Africa. The meta-sediments and volcanics of the Marienhof are correlated with the Abbabis, Epupa and Haub which form other basement complexes in South West Africa (Martin 1965, Schalk 1960). The acid volcanics of the Okumok are possibly equivalent to the Khoabendus Formation of the Kaokoveld and the Negatis and Sinclair Series to the south.

Du Toit (1954) favoured the correlation of the Tsumis with the Waterberg - Matsap System of Botswana and South Africa. Handley (1965) indicates that there are strong lithogical similarities between the Tsumis and the Deweras Series, at the base of the Lomagundi System of Rhodesia and that possibly equivalent inliers occur in Botswana, thus forming a long NE - SW trough of sedimentation of lower Lomagundi age.

Martin (1965) provides strong evidence for the correlation of the Tsumis with the Nosib Series of the Damara System by indicating similarities in lithology, heavy mineral content, NE - SW fold axis and the presence of stratiform copper mineralization. The presence of a tillite at the base of the Buschmannsklippe Formation, which rests on the Tsumis, and a tillite within the Hakos Series, which overlies the Nosib would support the evidence that the Tsumis and Nosib are of equivalent age. This also suggests that the sediments of the Buschmannsklippe and Upper Hakos, which rest on the tillite, were formed during the same period and

Martin (1965) indicates that they most probably represent shelf and eugeosynclinal deposits of the Damara. The Nama System may also be equivalent to the upper part of the Damara and the Buschmannsklippe and as evidence Martin indicates the presence of the Numees, Chuos and basal Buschmannsklippe tillites associated with the three formations. Du Toit (1954) and Haughton (1969) indicate a possible correlation of the Nama with the Matsap and Waterberg systems of Botswana and South Africa.

A more detailed correlation of the geological successions in the Klein Aub, Rehoboth - Dordabis and Witvlei areas was compiled by Toens (Table 1) from the work of Handley (1965), Schalk (1960) and Martin (1965) and geological reconnaissance in the Rehoboth - Witvlei region.

Rocks of the basement complex occur in both the Klein Aub and Rehoboth - Dordabis areas and Archean granites of probably equivalent age form inselbergs about 30 kilometres north of Witvlei. The predominently volcanic series of the Opdam and Skumok exist throughout the belt and shows a maximum development to the southeast of Dordabis, which is the type area for these formations. To the west of Klein Aub only the acid phase of the Skumok is present, whereas in the Witvlei area no clear division between the basic and acid phases is apparent and the volcanic sequence has been grouped as the Opdam - Skumok Formation (Table 1).

The succession of sediments following the volcanics in the Witvlei area, show a marked similarity to the series described by Handley (1965) for the Klein Aub region and the term Tsumis has been adopted for the Witvlei sediments rather than Doornpoort as shown in Fig. 1. The Tsumis A, a basal conglomerate would be equivalent to the Lower Quartzite and Conglomerate Stage of the Klein Aub area and the Tsumis B, which contains horizons of stratiform copper mineralization, equivalent to the Calcareous Shale Stage. In the Rehoboth - Dordabis area the Doornpoort, which follows the volcanic phase of the Opdam and Skumok, is probably equivalent to the lower part of the Tsumis

SOUTH WEST AFRICA								BOTSWANA		ZAMBIA		
KLEIN AUB (Handley 1965)			REHOBOTH-DORDABIS		WITVLEI			MWAKU PAN		(Mendelsohn et al 1961)		
SYSTEM	SERIES or FORMATION	STAGE	SYSTEM	SERIES or FORMATION	SYSTEM	SERIES or FORMATION	STAGE	SYSTEM	SERIES	SYSTEM	SERIES	GROUP
TERTIARY to RECENT	Kalahari Sediments		TERTIARY to RECENT	Kalahari Sediments	TERTIARY to RECENT	Kalahari Sediments		TERTIARY to RECENT	Kalahari Sediments			
KARROO								KARROO	STORMBERG			
									BODIBENG			
NAMA	SCHWARZ-RAND		NAMA	BUSCHMANNS-KLIPPE	NAMA	BUSCHMANNS-KLIPPE				KATANGA	KUNDUL-UNGU	UPPER
												MIDDLE
	SCHWARZ-KALK											LOWER
TSUMIS	KLEIN AUB	Upper Quartzite & Conglomerate		KAMTSAS	TSUMIS	WITVLEI	Tsumis C	GHANZI	(Photogeological studies indicate unconformities between major units)		MINE	MWASHIA
		Calcareous Quartzite					Tsumis B					UPPER ROAN
		Calcareous Shale										LOWER ROAN
		Lower Quartzite & Conglomerate	DORDABIS	DOORNPOORT			Tsumis A					
Basic & Acid Dyke Intrusions												
DORDABIS	SKUMOK			SKUMOK	DORDABIS	OPDAM/ SKUMOK		KWEBE		LEFUBU & MUVA		
				OPDAM								
BASEMENT	MARIENHOF		BASEMENT	MARIENHOF				BASEMENT				

Table 1 Suggested correlations of the geological systems and formations in Central South West Africa, Botswana and Zambia. (after Toens 1970)

succession. The Calcareous Shale Stage or Tsumis B is not developed in this region. The Kamtsas quartzites, now regarded as part of the Nosib Series of the Damara System, which form extensive outcrops to the north of Dordabis are correlated with the Upper Quartzite and Conglomerate Stage or the Tsumis C of the Witvlei area. The Buschmannsklippe Formation extending from Rehoboth through the Dordabis region to Witvlei and Gobabis (Fig. 1) is correlated with the Nama sediments south of Klein Aub.

Trending north-eastwards from the South West Africa - Botswana border through Ghanzi to Lake Ngami, are the Ghanzi Beds of Botswana which form the Mamona and Ghanzi Ridges protruding through the Kalahari sands. From lithological similarities and geographical distribution several workers have correlated these sediments with the Tsumis System of South West Africa. In the Mwaku Pan area stratiform copper mineralization has been located in green argillites, within a series of sediments overlying the Kwebe Porphyry, providing further evidence for correlating the Ghanzi and Tsumis Systems. This also strengthens the proposal that the copper bearing strata of the Tsumis and Nosib series of Central South West Africa are coeval with the Copper Belt formations of Zambia and Rhodesia by indicating a continuous NE - SW trough of sedimentation through northern Botswana.

Climate

The interior of Southern Africa is warmed during the summer and creates the shallow Kalahari Low (Rumney 1968) which causes an inflow of moist air from the Indian Ocean and brings the bulk of the years normal precipitation to South West Africa.

The central region of South West Africa, from Windhoek to Gobabis, has a hot semi-arid climate with the rainfall occurring in the summer months from November to April.

The summer days are hot with an average daily maximum temperature of 33ºC (Schultze 1965), and the nights are warm with an average minimum of 18ºC. The extremes recorded in Windhoek during January are 42ºC and 7ºC. During the winter months the days are warm with a mean maximum of 22ºC but the night temperatures may fall considerably and frosts may occur from mid June to early August.

Throughout the year the region has long hours of sunshine (Table 2) with an annual average of 9.9 hours per day. During the winter months this represents over 90% of the possible hours of sunshine, with a maximum of 97% for the months of July and August. In the summer the cloud cover increases but, the hours of sunshine still represent 65 - 85% of the possible total.

The annual rainfall for the Windhoek - Gobabis area is approximately 350 mm. (Table 3) with the heaviest falls from January to March. There are usually between 40 - 60 rainy days per annum with the precipitation occurring in heavy showers and thunderstorms. Hail is infrequent but, may occur once or twice during the rainy season usually in November or December.

Wide variations are recorded in the seasonal rainfall taken from August to July the following year. The data for the farms Chatjirute West and Chatjirute East (Table 4) shows an approximate three fold variation in the seasonal maximum and minimum values. Although the farms are only 6km. apart the rainfall recorded at the two homesteads for one specific season may vary up to 25%. The heaviest rainstorms can be very localised and represent a large proportion of the seasons total precipitation.

Throughout the year the mean relative humidity and the mean annual range of relative humidity is low. The recorded values for Windhoek, over a period of nine years, are less than 30% and 20 - 25% respectively. The area is characterised by large diurnal and casual fluctuations, especially in the rainy season. During thunderstorms the relative humidity may reach one hundred percent (100%) and

Month	Mean Daily Hours	% possible total
Jan.	9.3	70
Feb.	9.0	70
March	9.1	74
April	9.1	78
May	10.0	91
June	10.3	95
July	10.5	97
Aug.	11.0	97
Sept.	10.7	90
Oct.	10.3	82
Nov.	9.9	75
Dec.	9.2	69

Table 2. Monthly sunshine duration showing the mean daily hours of sunshine and the percentage of the possible total. Data recorded over an 82 year period at the Windhoek Met. Station. (Schultze, 1965).

Month	Windhoek (41 yrs.)	Witvlei (58 yrs.)	Gobabis (65 yrs.)
Jan.	67.6	70.6	77.1
Feb.	73.4	71.9	81.4
March	76.9	66.3	86.2
April	39.9	30.2	31.2
May	7.8	7.2	6.1
June	1.0	2.2	2.1
July	0.7	4.9	0.4
Aug.	0.5	0.4	0.9
Sept.	2.0	2.5	3.7
Oct.	10.4	12.2	15.3
Nov.	25.7	32.2	33.5
Dec.	45.7	41.6	41.1
Total	351.6	342.2	379.0

Table 3. Mean monthly rainfall in mm. recorded at Windhoek, Witvlei and Gobabis. (Windhoek Met. Station).

Season	Rainfall in mm.	
	Okatjirute West	Okatjirute East
1968-69	347.0	347.0
1967-68	436.5	313.0
1966-67	577.5	471.0
1965-66	331.0	339.0
1964-65	347.0	258.0
1963-64	225.5	251.5
1962-63	391.5	390.0
1961-62	210.5	211.5
1960-61	478.0	342.5
1959-60	303.5	339.0
1958-59	205.5	147.0
1957-58	323.5	338.0
1956-57	223.5	269.0
1955-56	456.5	383.0
1954-55	-	342.5
1953-54	-	522.0
1952-53	-	451.0
1951-52	-	310.5
1950-51	-	318.5
1949-50	-	441.0
1948-49	-	459.0
1947-48	-	208.0
Seasonal average	347.0(14 yrs.)	342.5(22 yrs.)
Seasonal maximum	577.5	522.0
Seasonal minimum	205.5	147.0
Highest individual fall	90.0	77.0

Table 4. Seasonal rainfall for the farms Okatjirute West and Okatjirute East situated in the Witvlei area.

during the dry winter months the daily mean may be less than 10%.

The winds are usually of very low velocity and speeds in excess of 15 m.p.h. are rare. They show a marked diurnal pattern, rising in the late morning and reaching a velocity of about 8 m.p.h. by 2 p.m. The winds then die out steadily towards evening. During the winter months 'dust devils' are common, carrying fine particles into the atmosphere to be transported by the wind.

Physiography and Geomorphology

The region extending north-eastwards from Klein Aub, through Rehoboth, Dordabis to Gobabis and the Botswana border is part of the Great African Plateau (Wellington, 1946) which rises to a general level of 2200 m. (a.s.l.) in the Khomashochland (Fig. 2) and slopes gently eastwards towards the Kalahari Basin. All the rivers of this area have their source in the highlands around Windhoek with the main drainage to the east and southeast into the Kalahari. The Nossob, Olifants and Auob join to form the Molopo which is an intermittent tributary of the Orange River. None of the rivers are perennial and flow only for short periods following prolonged rainfall and then often dry up long before reaching the sea.

The White Nossob, Black Nossob and Seeis Rivers initially flow eastwards and the Seeis disappears completely on the farm Chapanje after a course of only 80 km. The Nossob rivers unite south of Gobabis and keep the channel clear almost up to the Botswana border. The Olifants River rises in the Auas Mountains south of Windhoek at an approximate elevation of 1950 m. (a.s.l.) and continues as a well marked erosion channel cut into solid bedrock (Marbutt, 1955). At Koanus, 1680 m. (a.s.l.), it enters a region of windblown sand and eventually disappears as a feature of the landscape on the farms Otjimukona and Rainhof (Gevers, 1942). The Usib,

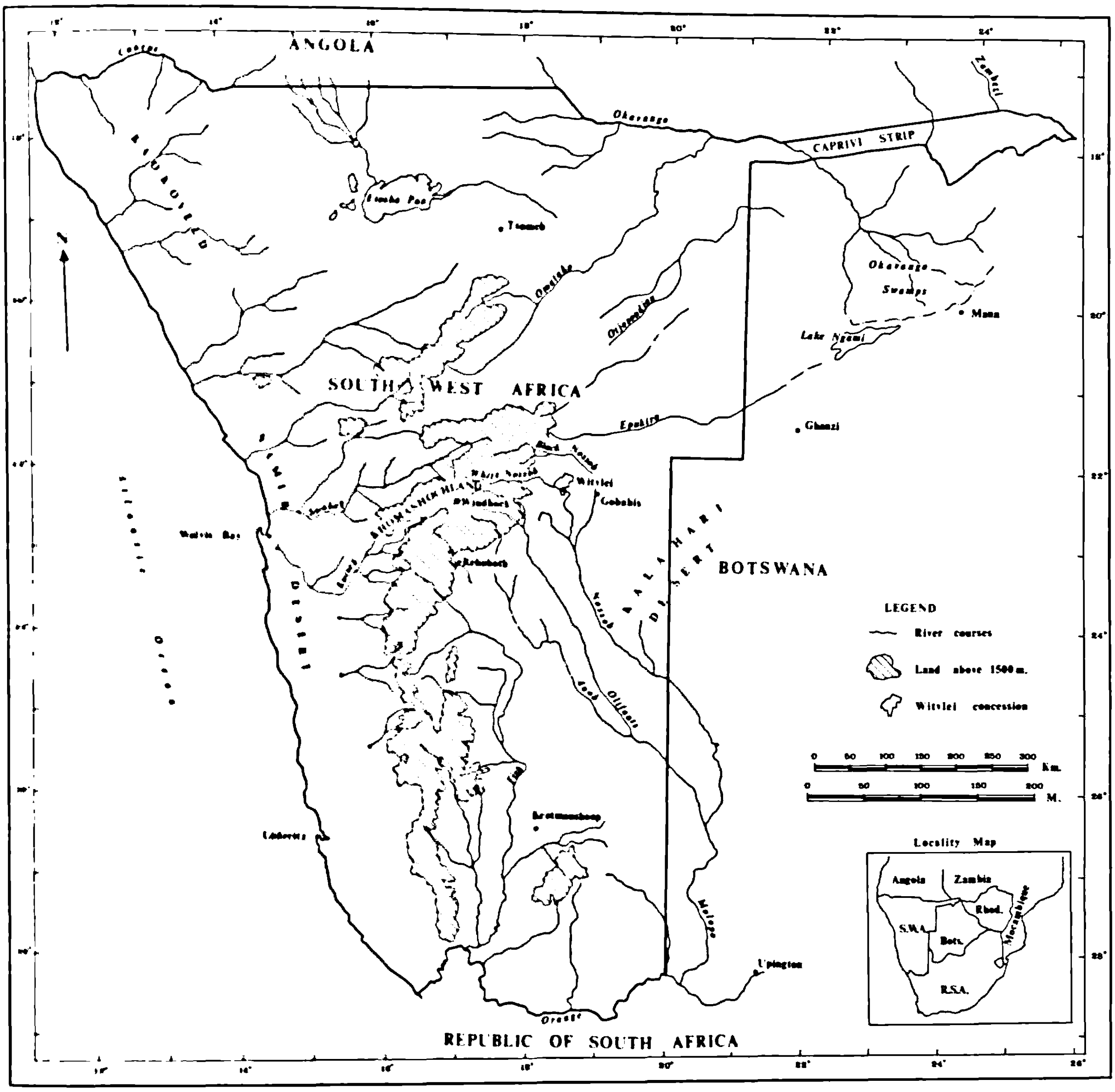


Fig. 2 The main river courses of South West Africa and land above 1500m. a.s.l. (from Index Map, South West Africa, T.S.O., Pretoria).

Rehoboth and Schaf Rivers, once tributaries of the Auob rise in the hills between Rehoboth and Dordabis and flow southwards across the structural lineations and disappear into the sand covered region of the Rehoboth Depression.

The Swakop and Kuiseb Rivers have their source in the hills around Windhoek and deeply dissect this part of the Khomashockland forming a maze of dry valleys. The rivers cut impressive canyons and keep their courses open across the coastal Namib Desert to reach the Atlantic Ocean near Walvis Bay.

Fossil river channels show that the Epukiro and Otjisondu (Fig. 2) once continued north-westwards across the northern Kalahari to join the river systems of the Okavango and the waters of Lake Ngami.

A striking feature of the drainage system is that all the rivers rising in the hills to the south of Windhoek flow southwards across the geological structure and have cut impressive gorges through the more resistant formations. The Usib River has eroded the massive quartzite series of the Damara System, to form the Nauas Poort.through the Nauas Range,to the north of Rehoboth. The Klein Nauas Gap to the South of Dordabis shows the course of a former river which deeply dissects quartzites of the Doornpoort. The present river systems probably represent a superimposed drainage, with the antecedent drainage originating on a surface above the present one. Martin (1965) suggests that the drainage may have formed on a Karroo surface, resulting from uplift along the Khomas Axis. Later warping produced the parallel consequent streams of the White and Black Nossob and Seeis flowing eastwards along the structure.

In the Windhoek area numerous ranges of hills forming the Khomashockland rise 400 - 600 m. above the general plateau surface. The region is formed of steeply folded rocks of the Damara System consisting mainly of biotite, sericite, quartzose and garnetiferous schists and quartzite lenses. The highlands are bounded on the west by the Great Escarpment and the Namib Desert and eastwards slope gently towards the Kalahari Basin. The summit levels from

2000 - 2200 m. (a.s.l.) and topographical features indicate several erosion surfaces planed across these formations of varying resistance. The hills decrease in elevation eastwards and the Bismarkberg and Otjozonjati mountains 30 - 40 km. east of Windhoek eventually disappear beneath the Kalahari sediments (Gevers, 1942). Further eastwards however the more resistant Kamtsas Quartzites of the Nosib Series form inselbergs (Plate 1) which extend north-eastwards through Omitara. The last remnants of the former land surface are shown by the Otjihaenena Inselbergs, composed of rocks of the basement complex, 30 km. north of Witvlei.

To the south of Windhoek the mountains are less dissected and gradually descend to the Rehoboth area. The Auas Mountains, built up of a series of quartzite lenses within the biotite schists, form a rugged mountain range with peaks between 2200 and 2650 m. (a.s.l.) and the highest point in South West Africa, the Moltkeblick, occurs in this range.

The Kharubeam Hills to the south-east and west of Dordabis have a general elevation of 1800 m. (a.s.l.) and are formed of the more resistant Doornpoort Quartzites. To the east of Rehoboth a series of jagged hills of Skumok volcanics protrude through the mantle of Kalahari sands. Low ridges of Nama and Buschmannsklippe extend north-eastwards from the Rehoboth-Dordabis area towards Gobabis and the Botswana border. The basal conglomerate of the Buschmannsklippe Formation also forms a prominent ridge which passes through the town of Witvlei.

The present landscape has been formed through a series of geological events, including folding and warping along the Khomas Axis, which caused the cyclic erosion of these rocks of varying resistance, over a long period of time throughout changing climatic conditions. The former plain shown by the summit levels of the Khomas hills and inselbergs and the present Kalahari surface are the result of prolonged denudation and planation of the older geological formations.

In the late Carboniferous - early Permian the area experienced an extensive continental glaciation with the ice

Plate 1 View westwards from the Witvlei Area showing inselbergs of Kamtsas Quartzites rising above the plateau surface planed across inclined strata of the Tsumis Formation. (Ref. MM/SWA, 22/4A.)

movement from the highlands around Windhoek (Du Toit, 1954). The Triassic and Jurassic were warmer climatic periods with the erosion and planation of the older formations. In the basinal areas the older structures were buried beneath the accumulating sediments.

Uplift occurred along the Khomas Axis in the late Cretaceous - early Tertiary period, the Gondwana earth movements of King (1948), forming the Gondwana Surface which is shown by the summit levels in the Khomashockland. Only the Auas Mountains to the south of Windhoek rise above this surface.

The river systems draining southwards from the Khomas mountains were probably initiated during this period on a higher surface of Nama and Karroo sediments. Continued down-cutting and erosion in the highlands has subsequently removed these sediments to reveal the old land surface.

The Kalahari Beds consisting of marls, sandstones and limestones were deposited during the Tertiary period and are thought to be partly fluvatile and partly formed by chemical precipitation in more arid climates. The channels of the Auob and Nossob Rivers are incised into the lower sediments of the formation, probably a reflection of further arching along the Khomas Axis (Marbutt, 1955).

The Kalahari sands forming dunes and covering the plateau surface probably accumulated during the later arid cycles of the Tertiary period. The advancing sands arrested the flow of the rivers and tributaries draining southwards from the highland region and an internal drainage system in the form of pans developed.

Towards the end of the Caenozoic period an uplift of between 1300 - 1600 m. occurred along the western margin of the South West African Highlands to form part of the Great African Plateau. The deep gorges of the Orange and Cunene Rivers resulted from these earth movements (King 1948).

Overburden and Soils

The nature and thickness of the overburden throughout the region is extremely variable and the soils which are of the arid red-earth type exhibit little or no profile differenciation.

In the highland areas and inselbergs the weathered material is rapidly removed during periods of heavy rainfall and angular to sub-angular gravels of the more resistant quartzites and vein quartz accumulate at the foot of the slope. The finer material is removed by sheet wash into the stream courses and carried by the river systems during floods onto the plains. Thus in the mountainous areas there is a large proportion of outcrop with angular fragments of weathered rock on the surface and no soil development.

On the plateau surface the overburden varies from a thin cover of possibly residual red-brown sandy soil to many metres of Kalahari sands or calcrete. Trench sections have shown that in areas of near surface bedrock a layer of variable thickness, of angular to sub-angular gravel, of quartz and quartzite, is usually present, resting on the uneven bedrock surface (Plate 2). The contact between the gravel and the overlying sandy soil is generally distinct and planar. The soil horizon may contain a small proportion of small rounded quartzite pebbles but the bulk of the material is a fine to medium grained sand. The silt and clay content of the soils is very low and never forms more than 10% of the total. Distinct horizons are not developed within the soil profiles and the varying bedrock lithology appears to have little effect on the composition and structure of the overlying soils. The surface material may represent an admixture of windblown Kalahari sands and weathered bedrock.

The Kalahari sands form both extensive plains south and west of Witvlei and Gobabis and long parallel dunes covering an area of 60,000 sq. km. across the Aoub, Olifants and Nossob valleys. Well rounded quartz grains form more than 90% of the sands and the light red-brown colour is due to a coating of iron oxides on the grains. Partially rounded accessory minerals of zircon, garnet, feldspar tourmaline and illmenite have been identified (Lewis, 1936). The

Plate 2 Soil in an area of near surface bedrock. A layer of angular to sub-angular gravel of quartz and quartzite followed by fine to medium grained sands rests on the uneven bedrock surface. (Ref. MMC/SWA, 31/5.)

dunes are generally 20 - 25 m. in height and spaced 150 - 1000 m. apart. The sands of the dune crests are well sorted in the range 50 - 90 mesh and the coarser material and extreme fines are found in the straats between the dunes. Vegetation has now arrested the movement of the dunes but there is no development of soil horizons in the surface sands.

Calcrete occurs throughout the region and is extremely variable in thickness and extent. In some areas it forms only a thin capping on the ridges whereas in other parts it occurs as extensive sheets many metres in thickness. In trench sections calcrete has been observed over all rock-types although in places there appears to be a selective replacement of the limestones and calcareous shales. It occurs in both a massive and nodular form, often with vein quartz pebbles cemented in the lower sections of the profile. Wagon drilling and trenching has shown that calcrete is often present beneath the surface soils and the deeper accumulations of Kalahari sands. In several areas near Witvlei calcrete is much more extensive along fossil drainage lines, marking former tributaries of the White Nossob, and forms the floor of several large pans (Plate 17).

The nature and chemical composition of calcrete deposits is described by Goudie (1972) who defines calcrete as "terrestial materials composed dominantly but not exclusively of calcium carbonate, and involving the cementation of, accumulation in and/or replacement of greater or lesser quantities of soil, rock or weathered material primarily within the vadose zone." It is an important superficial accumulation in current semi-arid areas and is also being recognised in a large number of ancient sedimentary environments. The analyses for 82 South African calcretes gave an average composition of 79.13% $CaCO_3$ and 11.83% SiO_2, with minor quantities of Al_2O_3, Fe_2O_3 and $MgCO_3$. One of the main components of calcrete is an insoluble residue consisting of amorphous silica, clastic quartz grains and clay minerals. The very low percentage of insoluble material has led to the theory that calcium carbonate not only fills the voids of the parent sediment but that the growth of calcium carbonate disperses the original sand grains so that they are no longer in contact.

Some Kalahari calcretes, especially in the vleis and pans, contain appreciable amounts of diatomaceous material which is rich in silica. Others have a high content of Kalahari - type aeolian sand which decreases as one moves into wetter and more humid climatic zones. The mean pH for 104 samples of calcrete from the Kalahari region is 8.01 (Goudie, 1972).

Vegetation

There have not been any detailed studies of the vegetation of Central South West Africa and only broad classifications exist. Pole-Evans (1936) classified the vegetation occurring east of the Windhoek highlands and extending into the Kalahari as "Thorn Country", consisting of thorn bush and thorn trees in deep sandy soil. Adamson (1938) and Acocks (1953) included this area as a sub-division of Savanna Vegetation under the terms Bush Savanna and Kalahari Thornveld respectively.

Under the proposed savanna terminology, on a world scale, of Cole (1963) the vegetation of the region falls within two main classes;

1) Low tree and shrub savanna - communities of widely spaced low growing perennial grasses with abundant annuals and studded with widely spaced low growing trees and shrubs often less than 2 metres high.
2) Savanna parkland - tall mesophytic grassland with scattered deciduous trees.

Many sub-divisions of these classes can be established for the region on the species composition of the tree and shrub layer, as shown for the Witvlei area Chapter 4. The species composition of the plant communities is particularly dependant upon the nature and depth of the overburden and soils.

In the areas of near surface bedrock strong lineations and banding in the tree and shrub layer outline the geological structure. A low tree and shrub savanna occurs throughout these regions and in areas of level terrain the dominant tree and shrub species are Acacia mellifera, A. hereroensis, A. hebeclada, Grewia flava and Phaeoptilum spinosum (Plate 3). Stipagrostis uniplumis is the main perennial grass species in this environment with numerous annual grasses and herbs appearing during the rainy season.

Over the elevated outcrops of the more resistant formations, where there is very little soil cover, the species Combretum apiculatum, Albizia anthelmintica and Grewia flavescens dominate the tree and shrub layer. The ground vegetation is sparse in this environment and fewer species are present.

Where the bedrock is masked by calcrete the low tree and shrub savanna is dominated by the shrub species Catophractes alexandri, with Acacia mellifera and Tarchonanthus camphoratus and in some areas Boscia albitrunca. Along the drainage features and pans floored by calcrete Acacia karroo and A. hebeclada are the main shrub species. The grass species and herbs in areas of calcrete are generally specific to this environment. Enneapogon cenchroides, E. brachystachus, Fingerhuthria africana and Stipagrostis cilliata are grasses commonly found over areas of calcrete and the herbs Leucosphera bainsii, Hermannia damarana and Leuchas pechuellii occur in association with the above grass species.

In regions covered by deep Kalahari sands the vegetation is predominently a low tree and shrub savanna with relatively minor areas of savanna parkland. The association of the tree and shrub species Acacia giraffae, Terminalia sericea, Tarchonanthus camphoratus and Grewia flava is very common throughout this environment and the dominant perennial grass species are Stipagrostis uniplumis and Schmidtia pappophoroides. In the areas of savanna parkland Acacia giraffae is generally the only tree species

Plate 3 An area of low tree and shrub savanna in a region of near surface bedrock. View southwards from the Witvlei - Windhoek road 15 km. west of Witvlei. (Ref. MMC/SWA, 3/30.)

Plate 4 An area of savanna parkland with the tree species <u>Acacia giraffae</u> in a region of deep sand cover. View southwards from the Windhoek - Gobabis road 20 km. west of Gobabis. (Ref. MMC/SWA, 3/5.)

varying in height up to 10 metres (Plate 4). Many annual grasses and herbs occur in the sand covered areas but the variety of species is more limited than in the areas of near surface bedrock.

Tall trees of Acacia karroo and sometimes A. giraffae occur along the main water courses throughout the region and Ziziphus mucronata, Diospyros lycioides and Acacia hebeclada are common around the pans.

The growing period for all the plant species in this region is during the summer months from November to April when the rains occur. Many of the trees and larger shrubs flower in late September and October but do not come into leaf until after the first rains which are usually in November. The majority of the shrubs react quickly to the rains and come into leaf and flower soon afterwards. The flowering period for all trees and shrubs is extremely short but the leaves are retained throughout the summer months until the night temperatures fall rapidly and frosts occur, which is generally in May or early June.

Many of the herbs and grasses flower more than once during the growing season and produce vast amounts of seed. Some species notably Tribulus zeyheri flower after each period of heavy rainfall. Bulbous plants such as Pseudogaltonia clavata and Nerine laticoma produce a flower and seeds before the leaves appear and then die back quickly to form the bulb for the following season.

Chapter 3

THE ROLE OF VEGETATION IN MINERAL EXPLORATION

Vegetation characteristics have been used in several ways as a guide to the discovery of ore bodies. The early methods of prospecting were based on the physical appearance of the vegetation or on the absence or presence of particular plant species. These techniques form the basis of geobotany. Subsequent methods which include the identification of plant species and their chemical analyses form the study of biogeochemistry.

The toxic effect of ore deposits and mineralization on the vegetation was recognised by M.V. Lomonosov in 1763 (Malyuga, 1964) who noted that, "in mountains which ores or other minerals are present, growing trees are usually not healthy" and that, "the grasses growing over the ore veins are pale and shorter". The depressed nature of the flora led Tyson to the discovery of chrome deposits in Maryland and Pennsylvania in 1818 (Cannon, 1960) and more recently "copper clearings" in the Congo, where the savanna woodland is replaced by shrubs and grasses, have been used as a guide for locating copper occurrences. Other more distinct morphological changes in the vegetation have since been described in the vicinity of ore bodies.

The high metal content of the soils may cause yellowing or mottling of the leaves (chlorosis), dwarfism, gigantism or abnormal flowers or fruits. Chlorosis is usually an indication of iron deficiency in the plant, often caused by the antagonistic effect of excessive amounts of Ni, Co, Cr, Mn, Cu or Zn in areas of mineralization. In an area of copper rich soils in Ely, Vermont U.S.A., Cannon (1960) records that the leaves of maple trees exhibit chlorotic symptoms with green veins. Stunted vegetation is another commonly recorded phenomena but can be the result of either the deficiency or excess of one or several elements. The relative stunting of Protea goetzeana can be used as a guide to the concentration of copper in the soils of Katanga and on extremely toxic ground a creeping sterile form of this species develops (Duvigneaud, 1958). In areas rich in boron plants 2 - 3 times their normal size, with larger greener leaves, have been observed (Cannon, 1960) and gigantism in 29 species was recorded by Vostokova et al (Brooks, 1972) from an area of bituminous soils. The white apetalous forms of two plant species have been used to locate nickel - cobalt mineralization in the Southern Urals (Cannon, 1960) and many abnormalities in plant growth and structure are recorded from areas rich in radioactive minerals.

In the vicinity of copper ores Malyuga (1964) noted distinct changes in the petals of the poppy Papaver commutatum which had black spots often elongated and reaching the end of the petal. The plants showing the abnormal petals were restricted to a ravine where the soil had been enriched in copper and molybdenum by groundwater.

It has long been recognised that characteristic floras occur over certain specific rock types and that geological boundaries can be delineated by observing the changes in composition of the vegetation. Limestone and dolomite bedrock often give rise to calciphilous floras which are usually very rich and differ markedly in species composition from the vegetation over adjacent rock-types.

Ultramafic rocks have an extreme effect on the vegetation and in densely forested areas their presence can be recognised, and extent outlined, from aerial photographs by the light tonal areas due to the sparseness of vegetation. The resulting serpentinite floras have been attributed to excessive amounts of Cr, Co and Ni, Ni alone and also to the low calcium level in the soils (Brooks, 1972). The vegetation growing in soils with a high Cu, Pb or Zn content may show similarities to serpentinite floras. The plant communities are often sparse and stunted forms may be present. Zinc or galmei floras were recognised by the early miners in Western Germany and Belgium over 100 years ago and used in prospecting as a guide to ore deposits.

Within the characteristic floras individual plant species may outline areas of mineralization for one or more ore metals. These indicator plants have been recognised for many elements including Cu, Pb, Zn, Ag, Ni, Fe, B and Se and the literature is most extensive for Cu, Zn and Se. Vogt (Malyuga, 1964) records that one of the earliest indicators was the copper plant (kisplant), probably Viscaria alpina, used by Scandinavian miners in medieval times in the search for copper and pyrite ores.

Indicator plants are assigned to two groups depending on their distribution. Universal indicators always show the presence of a specific element and will not grow in unmineralized regions, whereas local indicators have adapted to tolerate mineralized ground within the limits of a given district but will grow elsewhere provided there is no great competition from other species. The indicator species, both universal and local, which have been used in the exploration for copper deposits are shown in Table 5.

The copper indicators belong mainly to three plant groups the mosses, the pink family Caryophyllaceae, and the mint family Labiatae. Examination of herbarium localities for the moss Viscaria alpina, used by the early miners for locating copper and pyrite, led to the discovery of three copper deposits in Sweden. Polycarpea spirostylis, belonging to the pink family, was first discovered in Queensland, Australia, in 1858 by Babbage and referred to as the copper plant by Skertchly in 1897 (Brooks, 1972) who noted that the plant was "always on ore or close to copper deposits, or along water courses charged with copper in solution". The species was recently recognised by M.M. Cole in 1962 (Cole et al, 1968) growing in the savanna woodlands of the Waimuna Springs area of the Northern Territory. Also in Australia, in the Cloncurry District of Queensland, Tephrosia sp. nov. was found to be a useful indicator of soil copper anomalies below 2000 ppm. (Nicolls et al, 1965) and in the same area Polycarpea glabra grows

*	Species	Locality	Author	Year
L	Ameria maritima	Scotland	Henwood	1857
L	Polycarpea spirostylis	Australia	Skertchly Bailey	1897 1899
U	Viscaria alpina	Norway	Vogt	1942
U	Merceya latifolia	Montana Sweden	Perrson	1948
L	Eschscholtzia mexicana	Arizona	Lovering	1950
U	Gypsophila patrini	U.S.S.R.	Neavetaylova	1955
L	Elscholtzia haichowensis	China	Tsung-Shan	1957
U	Acrocephalous roberti	Katanga	Duvigneaud	1958
U	Becium homblei	Rhodesia	Anon	1959
L	Astralagus declinatus	Armenia	Malyuga	1959
L	Tephrosia sp. nov.	Queensland	Nicolls et al	1965

* U - universal
  L - local

Table 5. Indicator plants which have been used in the exploration for copper deposits. (after Cannon 1960, Malyuga 1964 and Brooks 1972)

over soil copper anomalies exceeding 2000ppm. Strong lead and zinc anomalies also occur in this locality.

In the Soviet Union the copper indicator Gypsophila patrini, of the pink family, was studied by Nesvetaylova (Brooks, 1972) who found that the species flourishes in soils varying in copper concentration from 300 - 1000 ppm., and is totally absent in soils above 1000 ppm. and below 30 ppm. copper.

The association of Becium homblei with copper deposits in Katanga was first investigated in 1949 and by 1954 observations had been made at 32 copper occurrences (Wehrmann, 1959). In all but two areas Becium homblei was present and in these two cases the soils were deeply leached. The distribution of the plant was mapped and the "flower charts" were found to be identical to the underlying copper deposits. Seeds of this species would not germinate in cultures of less than 50 ppm. copper and the optimum conditions were 600 ppm. The growing plant needs a minimum of 100 ppm. copper in the soil and will tolerate up to 5000 ppm. (Horizon, 1959). Occurrences of Becium homblei noted during exploration in the Rhodesian and Zambian Copper Belt have led to the discovery of several ore deposits.

Ecological studies were carried out by Duvigneaud (1958, 1963) within these extensive areas of copper flora of Katanga. He was able to classify plant species into four main categories by their distribution in respect to copper content of the soils.

1. Cuprophytes - species growing on the highest copper values and in some cases confined copper sub-outcrops.
2. Cuprophile - species growing on lower copper areas but not restricted to copper soils.
3. Cuproresistant - species tolerant to all levels of copper and have an ubiqùitous distribution.
4. Cuprifude - species which never occur in copper soils.

Similarly Wild (1968) established three main groups for the classification of plant species observed over 28 Rhodesian copper deposits; 1. Polycuprophites, 2. Cuprophiles, 3. Eucuproresistant.

The term "guide plants" has been adopted by Jacobsen (1968) for species indicative of ranges of copper values in the soils within the Mangula Area, Rhodesia. The specific indicator value is calculated for each species from copper soil values in which the plant was observed. Vellosia tormentosa was found to be an excellent guide to soils containing 300 - 1200 ppm. copper.

The biogeochemical method of prospecting has been successful in locating several ore deposits (Malyuga, 1964) and the method is particularly suited to areas where overburden masks the bedrock. In these regions the deep rooted plants often penetrate the layer of overburden and derive their nutrients from the soils and mineral solutions in contact with the bedrock.

The fundamental researches in biogeochemistry were carried out in the U.S.S.R. and Sweden by V.I. Vernadsky A.P. Vinogradov and V.M. Goldschmidt, during the period 1930 - 1940, who recognised the value of plant analyses in the search for buried mineral deposits. N.H. Brundin and S. Palmquist applied biogeochemistry in prospecting for Cu, Pb, Ni, Mo and Sn in Sweden and England and in 1939 Brundin was issued a U.S. patent for "A method of locating metals and minerals in the ground", which described the collection of vegetation samples along traverse lines for chemical analyses (NASA, 1968).

In Canada biogeochemical investigations were pioneered by H.V. Warren and his co-workers from 1945 onwards, resulting from Warrens observations of root systems penetrating through overburden which was being removed from an area of possible mineralization. The majority of the more recent researches in biogeochemistry have been carried out by the geological survey of the U.S.S.R., Canada and the U.S.A. and University departments throughout the world but the method has not received wide application by exploration companies.

From the early work and subsequent studies it was apparent that many factors affect the elemental uptake by plants and the accumulation in plant tissues. The more significant factors are; the species selected, the part of the plant collected for analyses, time of collection in relation to growing season, the rooting habits of the species, nature and thickness of the overburden and the pH of the soil. Other features such as rainfall, soil temperature, aspect of the location site, drainage within the soils and the health of the plant have a minor significance in bigeochemistry and can often be eliminated by selective sampling.

Many workers have investigated the varying levels of elements in different plant species. Robinson et al (1943) found that hickory leaves contain greater levels of the rare earth elements than the leaves of any other species sampled. Warren and Delavault (1949) showed that the threshold level for copper varied with the species sampled, being 12 ppm. (dry wt.) for the conifers and 40 ppm. for the alders. The background levels of several elements, including copper, are listed by Brooks (1972) for more than 100 commonly occurring species in Canada, Australia and New Zealand. Cannon (1960) lists the mean copper content of five types of vegetation growing in unmineralized ground as 119, 118, 223, 249 and 133 ppm. (ash wt.) for grasses, herbs, shrubs (leaves), deciduous trees (leaves) and conifers (needles) respectively.

The variation in the elemental content of plant species with the levels in the soil has also received detailed studies. Nicolls et al (1965) illustrate the varying responses of several species to increasing contents of Cu, Pb and Zn in the soil. Some species are able to limit the uptake of certain toxic elements whereas in others there is a gradual increase in the element content of the plant with the increasing element level in the soil. From the analysis of mature twigs of trees and shrubs collected over an area of copper mineralization in Rhodesia, Jacobsen (1968) found that the various species followed four main trends in the copper content of the twigs with increasing values in the soil; a) steady refusal throughout, b) slow irregular increase, c) quick undulating increase to a maximum then refusal, d) decreasing uptake. The species of groups a) and c) would be of no use in biogeochemical prospecting as the copper level of the twigs is either constant or decreases with increasing copper values in the soil.

Extensive studies have been carried out in mining districts and unmineralized regions of British Columbia to determine the most suitable part of the plant for biogeochemical work with regard to the metal content, consistency of values and strongest anomalies produced. The initial work of Warren and Howatson (1947) showed that the fruits, buds, leaves and needles had a greater copper content than the twigs; the bark and young twigs contained more copper than the old wood, which was very low in mineral content, and that the green material showed a much wider variation in copper content. They suggested that the most practical part of the plant for biogeochemical exploration was the twigs of 3 - 6 mm. in diameter. In more recent work Warren (1962) indicates that the leaves show a very wide seasonal variation in copper and that the young twigs of the preceeding years growth give the best results. The analyses also showed that there was no simple relationship between the copper content of the leaves, 1st. or 2nd. year twigs or other parts of the plant.

Sampling of the leaves or fruits has the disadvantage that these parts are only available for a limited period throughout the year and wide seasonal variations in the element content, usually increasing up to exfoliation, have been recorded. M. Guha (Brooks, 1972) studied the variation of nine elements in the leaves of 18 tree species throughout a twelve month period and found increases in B, Fe and Mn during the growing season whereas the levels of Cu, Mo and Zn decreased in many cases. In New Zealand where there is a twelve month growing season the element content of the leaves of evergreens is much more consistent throughout the year.

The rooting habit of a species will have a marked effect on the uptake of minor elements, especially in areas of overburden, and may be a deciding factor in the selection of a species for biogeochemical prospecting. Phreatophytic species derive their moisture from the zone of saturation below the water table and in arid areas these species often have a deeply penetrating tap root. Xerophytic species depend on surface water from rainfall and usually have a widely spreading lateral root system which effectively samples a large area around the base of the plant.

Although the root systems may penetrate deeply into the surficial material the nature and depth of the overburden can severely restrict the successful application of biogeochemical exploration. Impermeable clays in glacial deposits greatly restrict the upward migration of metals in solution and Fortescue and Hornbrook (Wolfe, 1971) found that vegetation samples collected over the Texas Gulf Sulphur Cu-Pb-Zn-Ag deposit at Timmins Ontario, masked by 6 - 20 m. of varved lacustrine clays, gave consistently negative results. Wolfe suggests that biogeochemistry would be most effective in areas of permeable ground moraine, where coarse sandy tills allow maximum dispersion by metal bearing ground waters.

The pH of the soils can have a significant effect on the availability of elements for uptake by plants and Warren and Howatson (1947) report that much lower copper values in vegetation may be significant in neutral to alkaline soils. However provided that the range of pH in the soils of the survey area is not too great the biogeochemical results will not be seriously affected.

Sample collection, preparation and analysis provided many problems for the early workers in biogeochemistry and are often given as a serious drawback in its application to exploration. White (1950) states that the anomalous variation for certain species was within the limits of experimental error and field analytical techniques used by Warren et al (1949) showed a variation of upto ± 50%. Advances in analytical equipment with improved precision have greatly alleviated these problems and the stages in biogeochemical analyses usually consist of ashing plant material in a thermostatically controlled muffle furnace, acid digestion of plant ash, and element determination by atomic absorption spectrophotometry. Digestion of dry plant material by strong acids is also used and multi-element analysis can be carried out on plant ash by X-ray fluorescence or emission spectrography.

It is apparent that detailed orientation studies are a necessary preliminary stage to the application of biogeochemistry in exploration for mineral deposits. The studies should determine in particular the most favourable species for sampling and the best part of the plant to collect for analysis. For regional scale projects seasonal and environmental factors should be considered in the interpretation of biogeochemical results.

The method appears to have the greatest use in areas of transported overturden where chemical analysis of the deep rooted species could be expected to reflect the bedrock geochemistry and indicate areas of mineralization.

Part II

THE WITVLEI AREA

Chapter 4

THE PHYSICAL BACKGROUND

Geology

The seven farms of the Witvlei Concession lie within the NE - SW trending belt of the Dordabis System, Tsumis and Buschmannsklippe Formations (Fig. 1). Seeger and Schalk (1967) carried out regional mapping in this area and defined the boundaries and structure of the main formations, grouping the rocks with the Opdam, Doornpoort, Kamtsas and Buschmannsklippe formations.

A more detailed photogeological interpretation of the region was compiled by Jarskie (1969) for the Anglovaal Company and this is incorporated in the geological map of the Witvlei Area (Fig. 3). Following the divisions suggested by Toens (1970), for this pre-cambrian belt of volcanics and meta-sediments the Witvlei succession is assigned to the Opdam-Skumok, Witvlei and Buschmannsklippe Formations of the Dordabis, Tsumis and Nama Systems respectively.

The series of predominantly volcanic rocks of the Opdam-Skumok Formation occur in the western section of the farm Okatjepuiko and extend into northern Eskadron and Okatjirute West. The volcanics form a domal structure elongated along a NE - SW axis and are overlain by and faulted against rocks of the Tsumis Formation. Three subdivisions of the Opdam-Skumok are recognised in this area

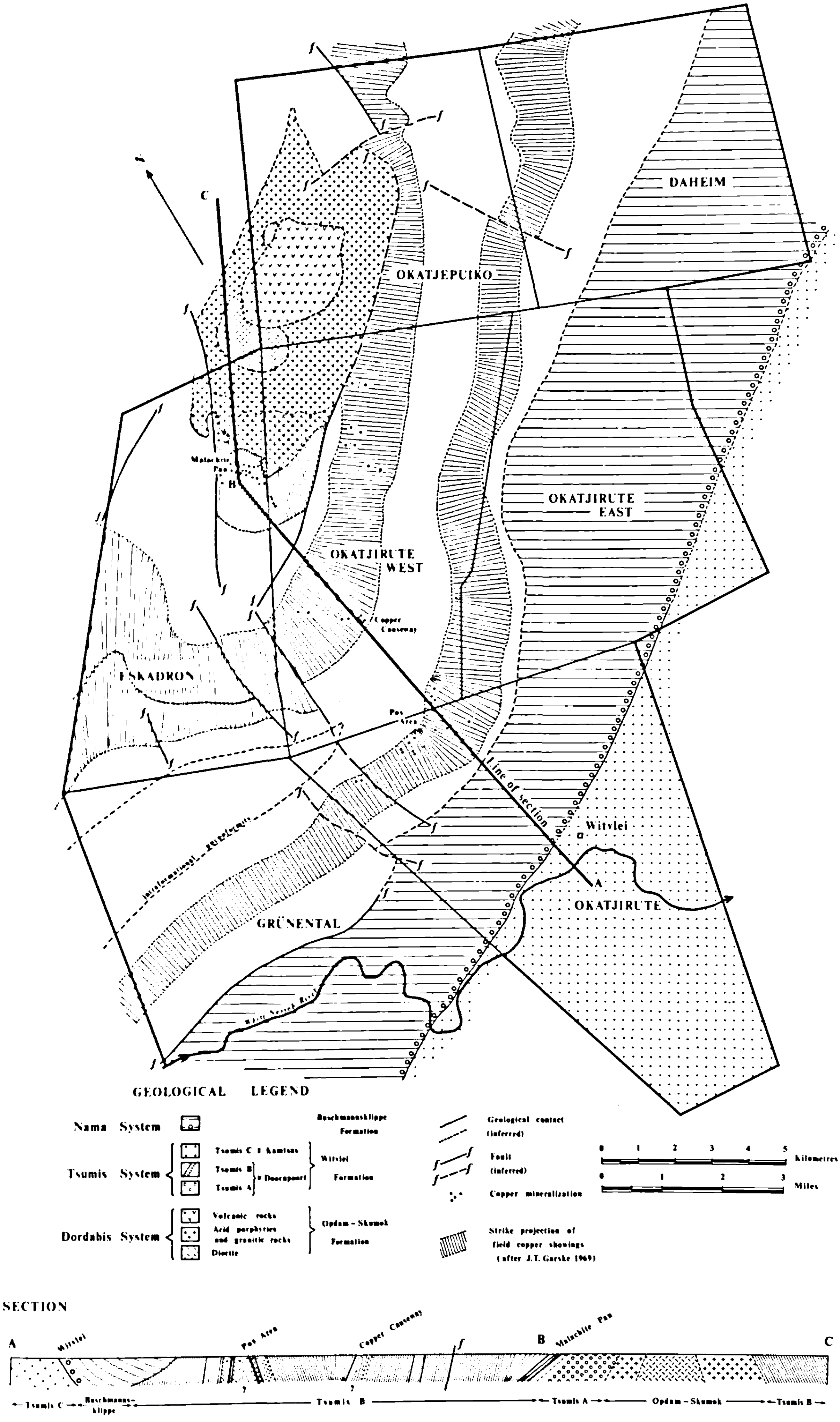


Fig. 3 Geology of the Witvlei Area.

but because of the scattered nature of the outcrops and the extensive cover of calcrete and sand the inter-relationships have not been determined.

Volcanic and meta-sedimentary rocks are exposed around the edges of a large pan on Okatjepuiko (Plate 17). The lavas consist of black epidotised basalts, interbedded with arenaceous sediments, sedimentary breccias and tuffs. Malachite and specularite occur frequently in the basalts. Surrounding the basic volcanics are scattered outcrops of acid porphyries and granitic rocks and on the boundary of Okatjepuiko and Okatjirute West several outcrops of diorite are present.

Seeger and Schalk (1967) indicate that the Opdam series of basic volcanics also occurs to the north of this region and forms a much more extensive and continuous NE - SW belt.

Trending north-eastwards across the central part of the concession is a series of meta-sediments, consisting mainly of conglomerates, quartzites and shales which form the Tsumis A and B of the Witvlei Formation. As discussed in Chapter 2 this sequence is possible equivalent to the three lower stages of the Tsumis outlined by Handley (1965) and forms the Doornpoort Formation as mapped by Seeger and Schalk.

The rocks dip at angles from 35 - 70 degrees around the volcanic sequence but for the major part of the belt the strata are steeply dipping to vertical and overturned beds occur in several places. In the Copper Causeway and Pos areas there is evidence of tight isoclinal folding and a large syncline is apparent from the structural lineations on the farm Eskadron.

The conglomerates of the Tsumis A wrap around the southern part of the Opdam - Skumok Formation in northern Eskadron and Okatjirute West. The pebbles of the conglomerate in the Malachite Pan area (Fig. 3) are sub-angular to rounded and vary in size to a maximum diameter of 10 cm. They consist of quartzites, siltstones and argillites, dark coloured mafic volcanics and quartz and feldspar porphyries.

Other conglomerates, similar in composition and appearance to those of the Malachite Pan Area, form distinct outcrops to the north of the Copper Causeway and in the Pos Area (Fig. 3 Section ABC). The broad outcrops of conglomerate in these two areas may be equivalent to Tsumis A or represent distinct facies changes during Tsumis B sedimentation.

The Tsumis B series extends over most of Eskadron Grünental, Okatjirute West and parts of Okatjepuiko and Daheim. The major part of the sedimentary sequence consists of calcareous and feldspathic sandstones, with minor horizons of interbedded siltstones, limestones and calcareous argillites. The copper mineralization of the Malachite Pan, Copper Causeway and Pos areas occur within this stage.

In north-western Eskadron and to the west of the Pos area the quartzites form low hills or ridges which range in elevation from 10 - 30 metres above the general level of the terrain. Traverses across the outcrops in these areas show a monotonous succession of hard, well bedded quartzites with occasional bands of grit and pebble washes. Cross-bedding and heavy mineral layers are particularly well marked within this sequence.

Microscopic investigations by Ross (1968), Anhaeusser and Button (1969) showed that quartz was by far the most abundant clastic mineral, followed in importance by feldspars and carbonates. The grain size of the constituents varies from 0.01 - 0.40 mm. with an average diameter of 0.08 mm. The matrix of the quartzites comprises of quartz, carbonates and clay minerals. In some sandstones the carbonate content is minor, whereas in others it forms the main cementing material. Fractures and cracks are usually filled with calcite but near zones of movement vein quartz is present.

The siltstones have an identical mineral assemblage to the sandstones and quartzites, but a much finer grain size and fall within the silt category of Pettijohn (Anhaeusser and Button, 1969). They consist of densely packed detrital grains of quartz and feldspar, cemented by clay and carbonate minerals.

The sandstones and siltstones show gradations into impure, and in some cases pure, limestones. The impure limestones consist of variable amounts of detrital quartz and feldspar grains cemented by carbonate. Contorted limestone bands occur in the succession and may represent algal structures.

The term calcareous argillite was adopted by Anhaeusser and Button for the copper bearing sediments in the Witvlei Area. The rocks consist of three phases; silt sized detrital fragments, silt and clay sized fragments of phyllosilicates and carbonate. The detrital phase usually comprises 50% of the rock and is composed mainly of quartz plagioclase and microcline. Graded structures are present in the calcareous argillite together with cross-bedding microfolds and microfaults. The clay fraction of the rock has recrystallized to a mixture of fine grained sericite, chlorite and possibly pyrophyllite. A carbonate cement is nearly always developed and calcite is the dominant mineral.

A study of 65 polished sections of mineralized calcareous argillite (Anhaeusser and Button, 1969) showed that chalcocite, chalcopyrite and bornite are by far the most important copper bearing minerals forming an average of 1.40, 0.51 and 0.50 volume percent respectively. In addition to these minerals covellite, digenite, pyrite, cuprite, malachite and native copper were observed in the sections and chrysocolla and azurite were noted in the samples from trench sections. Most of the samples contained iron oxides and carbonates.

The ore minerals occur as discrete grains, massive sulphide aggregates, pseudomorphs after other minerals and fillings in cracks and veins. Measurement of the grains showed a wide variation from a maximum of 125 microns down to 1 micron, with a median grain size of 4 - 8 microns.

A summary of the analyses of 58 ore specimens from the Pos, Copper Causeway and Malachite Pan areas is shown in Table 6.

Element	Mean Content	Range of values
Copper	1.75%	
Silver	4.28 dwt.	0.74 - 17.36
Zinc	94 ppm.	-
Iron	1.95%	0.95 - 4.49
Cobalt	11 ppm.	0 - 45
Nickel	34 ppm.	15 - 80
Lead	18 ppm.	0 - 80

Table 6. Chemical analyses of 58 ore samples from the Witvlei Area. (Anhaeusser and Button, 1969).

Anhaeusser and Button concluded that only copper and silver are concentrated in the Witvlei ores and that Zn, Fe, Co, Ni and Pb concentrations are similar to the values quoted by Turekian and Wedepohl for an average shale and average carbonate.

Across the southern part of the Witvlei townlands, Okatjirute, is a series of pink, feldspathic quartzites in which grit bands and pebble beds are locally present. The rocks strike NE - SW and dip steeply to the north in the exposures along the southern margin of the Nossob River. This series forms the Tsumis C of the Witvlei Formation and was grouped with the Kamtsas by Seeger and Schalk. This upper stage of the Tsumis is much more extensive to the south of the Witvlei Area and may form the cover to a broad syncline of Tsumis sediments in which the Dordabis - Witvlei belt forms the northern limb.

The base of the Buschmannsklippe Formation, of the Nama System, is represented by a series of reddish brown quartzites, grits and conglomerates which form the prominent NE - SW feature of the Witvlei Berg. The pebbles and boulders in the conglomerate are well rounded and consist mainly of white vein quartz and pink quartzites. The quartzite horizons in the series show evidence of considerable metamorphic recrystallization (Anhaeusser and Button, 1969) with sutured grains interlocking and welded into massive quartzite.

The arenaceous facies is followed by a series of limestones, dolomites and shales which are exposed on the farm Grünental and along the northern side of the Witvlei Berg.

The northern contact of the Buschmannsklippe is largely masked by superficial gravels, sand and calcrete, but there is evidence of a fault contact with the Tsumis B on the farm Grünental (Fig. 3) where shales and dolomites of the Buschmannsklippe are strongly contorted and veined by quartz.

Overburden

In the greater part of the Witvlei Area overburden of sand, gravel and calcrete, ranging in thickness upto tens of metres, masks the bedrock. The percentage of outcrop is small and the main features of exposed bedrock are the ridges of conglomerate forming the Witvlei Berg and the hills of quartzite on Eskadron and to the west of the Pos area.

Figure 4 shows the results of a seismograph survey carried out in order to determine the depth and extent of the overburden throughout the concession. Readings were taken at half kilometre intervals along the roads, farm boundaries and fence lines and the results have been grouped in 5 metre depth intervals for Fig. 4.

The western part of the concession has a relatively shallow cover of overburden whereas in the southern and eastern sections, covering Okatjirute, Okatjirute East and Daheim, overburden in excess of 10 metres is indicated over large areas. The narrow NE trending strip of 0 - 5 m. overburden extending through the eastern region outlines the outcropping ridge of conglomerate of the Witvlei Berg.

To the south of Witvlei, where the overburden exceeds 10 m. and the maximum recorded depth is 30 m., the area is characterised by Kalahari sands. Accumulations of sand are also present along the southern side of the Witvlei Berg where areas of deeper overburden are indicated. Most of

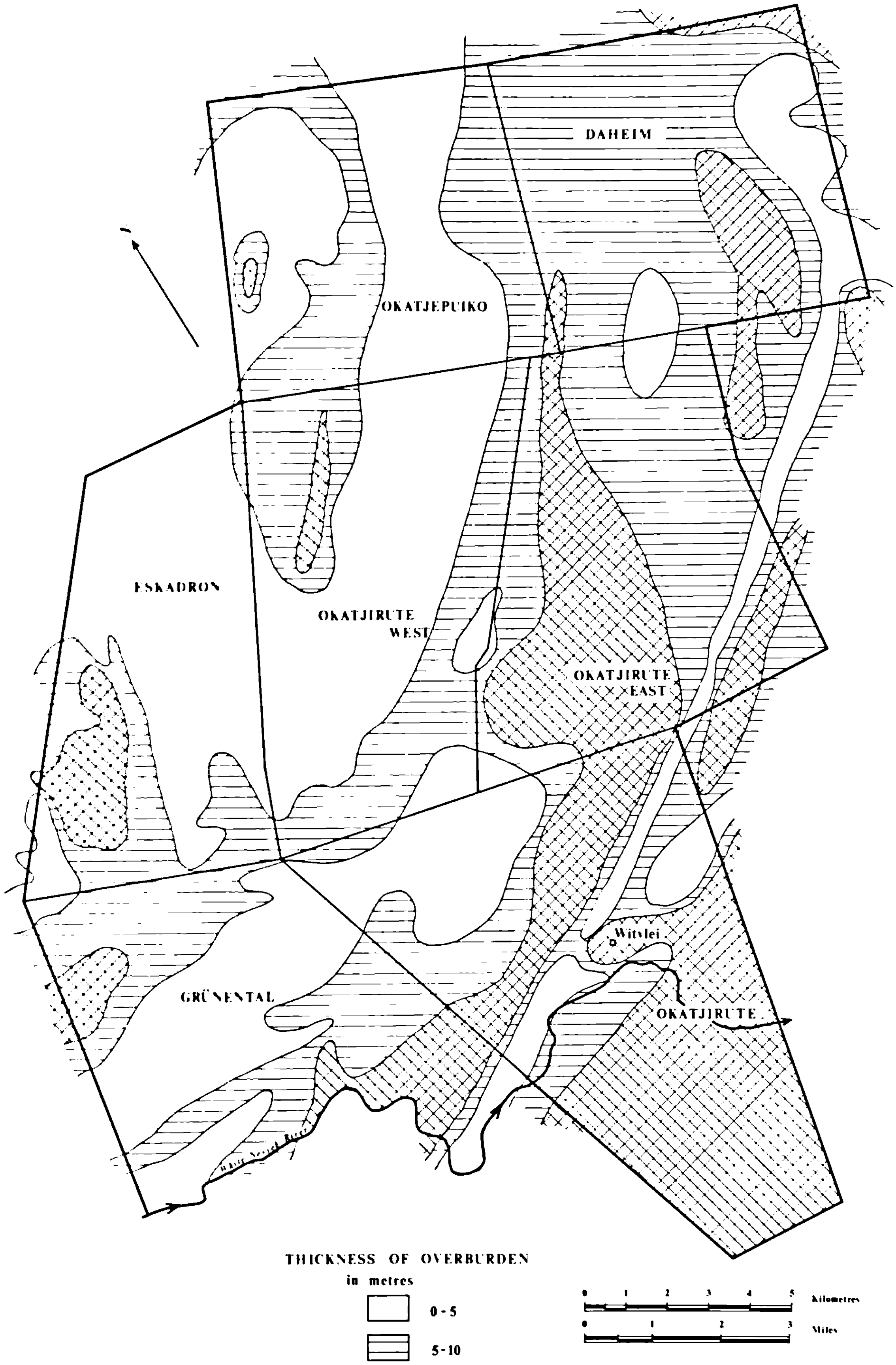


Fig. 4 Thickness of overburden recorded from a seismic survey of the Witvlei Area. (The figure is a simplified version of the seismic map produced by Anglovaal geologists.)

Daheim and the eastern part of Okatjirute East where the overburden is 5 - 10 m. is also characterised by surface Kalahari sands. Throughout this area calcrete ridges, following the NE - SW trend of the bedrock, protrude through the sand cover and may indicate that calcrete is more widespread beneath the sand forming the major part of the overburden.

The deeper overburden of Okatjirute East, over 10 m., is due almost entirely to calcrete as there is little sand or soil cover in this area. Most of the pans and drainage features are floored by calcrete and exposures of 1 - 2 metres of calcrete are common around the edges of the pans (Plate 5). A maximum of 36.5 m. of overburden is recorded on a traverse along the southern boundary fence of Okatjirute East.

Extending northwards from the Witvlei Berg, on Grünental and Okatjirute, the overburden increases rapidly and generally exceeds 10 m. Exposures in road-metal pits in this region show that the overburden consists of surface gravels of rounded quartz and quartzite pebbles resting on calcrete. On the farms Grünental, Eskadron and Okatjirute West there are large areas where the overburden is extremely shallow and consists of less than one metre of sandy soil. In these areas intermittent outcrops of the more resistant quartzites and grits occur. There are however three distinct areas of deeper overburden in the western part of the concession. In northern Okatjirute West and extending into Okatjepuiko the overburden ranges from 5 - 14 m. over an area underlain by the volcanic sequence of the Opdam - Skumok Formation. Calcrete occurs at the surface and forms the margin of several pans in the area. In south-western Eskadron a maximum of 23 m. of overburden is recorded across the synclinal feature. Calcrete ridges follow the structure of the syncline and the depressions between the ridges are filled with sand. The third area of deeper overburden occurs in the northern part of Grünental where calcrete 5 - 12 m. in thickness covers the region bounded by an intra-formational unconformity (Fig. 3).

From the standpoint of exploration for copper the

Plate 5 Exposure of calcrete at the edge of a pan on the farm Okatjirute East. Vegetation around the pan consists of Ziziphus mucronata and Acacia hebeclada shrubs, with Enneapogon brachystachus grass. (Ref. MM/SWA 22/15A.)

Malachite Pan, Copper Causeway and Pos Area occurrences all lie within the areas of relatively shallow overburden. The western extension of the Pos zone, extrapolated by Garskie (Fig. 3), is also an area where the overburden is less than 5 m., whereas to the northeast the projected zone enters an area deeply covered by calcrete and Kalahari sand. The Copper Causeway zone of mineralization is traced along strike to the syncline on Eskadron where the overburden of calcrete and sand varies from 5 - 23 m.

The eastern part of the Witvlei Area, which has the most extensive and thickest cover of overburden, is mainly underlain by rocks of the Tsumis C and Buschmannsklippe Formation and thus not regarded as a potential area for copper mineralization.

Vegetation

The vegetation of the Witvlei Area is dominantly a low tree and shrub savanna with minor areas of shrub savanna and savanna grassland. From a study of air photographs and ground surveys ten distinct vegetation associations are recognised and their extent is outlined in Fig. 5. Marked correlations appear from a study of the distribution of savanna vegetation associations in relation to the thickness and nature of the overburden and the bedrock geology. Lineations in the vegetation clearly define the regional strike, fold structures and fault lines.

An association of Combretum apiculatum and Albizia anthelmintica trees with Grewia flavescens shrubs occurs along the conglomerate ridge of the Witvlei Berg (Plate 6) and on the quartzite hills of Eskadron and the Pos area. The ground vegetation is sparse with annual grasses and herbs appearing during the rainy season. In these areas there is a high percentage of outcrop with little or no soil development or sand cover and the surface is usually strewn with angular rock debris. The air photographs of such areas show marked lineations and distinct banding of the tree and shrub

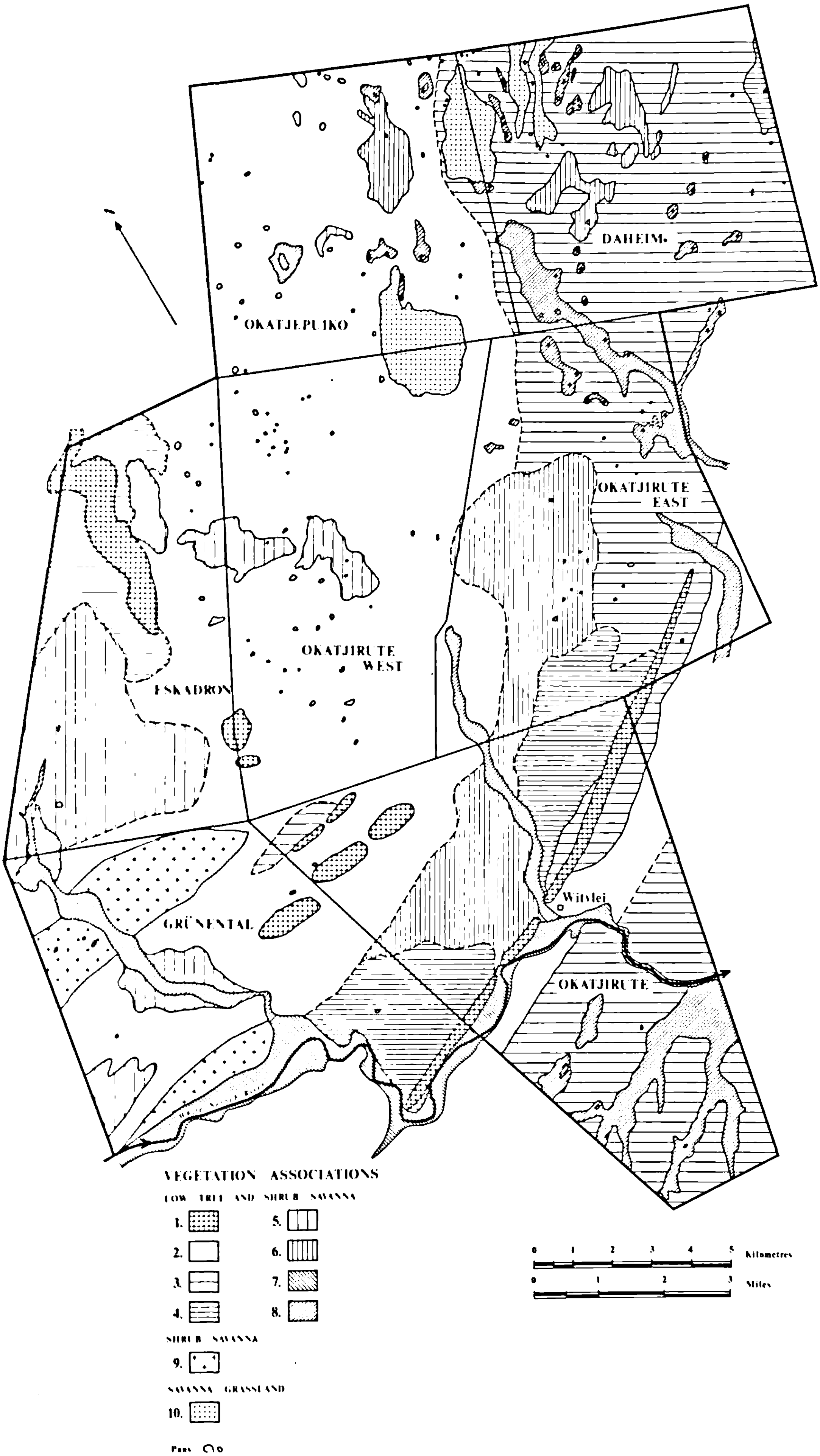


Fig. 5 Vegetation associations of the Witvlei Area. (Key for 1-10 on following pages.)

Key to Fig. 5.

	VEGETATION ASSOCIATIONS	GENERAL HABITAT
1.	Dominated by Combretum apiculatum, Albizia anthelmintica trees and Grewia bicolor, G. flavescens, Commiphora pyracanthoides, Croton gratissimus, Mundulea sericea shrubs.	Near surface bed-rock; elevated ridges and hills.
2.	Characterised by mixed trees and shrubs of Acacia hereroense, A. mellifera, A. hebeclada, Phaeoptilum spinosum, Grewia flava and Tarchonanthus camphoratus with Stipagrostis uniplumis grass.	Near surface bed-rock; undulating terrain.
3.	Dominated by Acacia giraffae and Termimalia sericea trees with Grewia flava, Tarchonanthus camphoratus, Rhus pyroides and Ozoroa paniculosa shrubs and grasses of Stipagrostis uniplumis and Schmidtia pappophoroides.	Deep sand cover.
4.	Characterised by Acacia mellifera and Tarchonanthus camphoratus trees and shrubs with scattered Stipagrostis uniplumis and Aristida congesta grasses.	Sand and gravel accumulations.
5.	Association of Acacia giraffae trees, Acacia mellifera, Catophractes alexandri and Grewia flava shrubs, with Leucosphera bainsii, Aptosimum leuchorrizum herbs and Fingerhuthria africana and Enneapogon brachystachus grasses.	Ridges of calcrete.

Key to Fig. 5 (cont'd.)

6.	Characterised by Boscia albitrunca trees Acacia mellifera, Catophractes alexandri shrubs, with Leuchas pechuellii and Hermannia damarana, Zygophyllum suffruticosum herbs and Enneapogon cenchroides grass.	Extensive surface calcrete.
7.	Dominated by large Acacia karroo trees with mixed shrubs, herbs and grasses.	Banks of White Nossob River.
8.	Association of Acacia karroo, A. Giraffae, A. hebeclada, Ziziphus mucronata and Grewia flava.	Remnant drainage features floored by calcrete.
9.	Characterised by Catophractes alexandri and Grewia flava shrubs with Leucosphera bainsii, Hermannia damarana, Pegolettia pinnatilobata, Pseudogaltonia clavata, Justicia guerkeana herbs and Fingerhuthria africana grass.	Areas of calcrete and shale and limestone outcrop.
10.	Dominated by Eragrostis pallens and Aristida stipitata with scattered trees of Terminalia sericea.	Deep sand cover.

Pans. Many of the pans are covered with Eragrostis curvula and Diandrochloa pusilla grasses and are surrounded by trees and shrubs of Ziziphus mucronata, Diospyros lycioides and Acacia hebeclada.

Plate 6 Combretum apiculatum (foreground) on the southern slope of the Witvlei Berg, and Terminalia sericea, Acacia giraffae and Grewia retinervis growing on sand accumulated at the foot of the slope. (Ref. MM/SWA, 6/31/A)

Plate 7 Catophractes alexandri shrubs growing over calcareous bedrock (foreground) with an association of Acacia mellifera and Albizia anthelmintica on quartzites in the background. (Ref. MM/SWA, 4/2A.)

vegetation. This reflects the contacts between rock types and outlines the broader lithological groups within the sedimentary sequence (Plate 7). The fold structures of the Eskadron quartzite ridge are clearly displayed by the lineations of the tree and shrub layer and lines of denser vegetation crossing the regional structure mark probable faults.

A mixed tree and shrub association of Acacia hereroensis, A. mellifera, A. hebeclada, Grewia flava, Phaeoptilum spinosum and Tarchonanthus camphoratus (Plate 8 and Fig. 5, Assoc. 2) forms a broad north-east trending belt from Grünental through Okatjirute West, Eskadron and Okatjepuiko. The perennial grass Stipagrostis uniplumis is the dominant species of the ground cover but a wide variety of both annual and perennial herbs and grasses occur throughout the region.

The area outlined by this low tree and shrub savanna association has a relatively shallow cover of overburden of sandy soils and is underlain by rocks of the Tsumis A and B Formations and in part by the volcanics of the Opdam - Skumok. Marked lineations in the vegetation are apparent from the air photographs and indicate the regional strike and possible faults, but the local structure is not as clearly revealed by the vegetation as in the areas of elevated outcrops.

To the south of Witvlei and over much of Daheim and Okatjirute East the low tree and shrub savanna is characterised by Acacia giraffae and Terminalia sericea trees with scattered Grewia flava, Tarchonanthus camphoratus, Rhus pyroides and Ozoroa paniculosa shrubs (Plate 9). The most common grass species are the perennials Stipagrostis uniplumis and Schmidtia pappophoroides but many annual grasses and herbs occur after the rains. These areas are characterised by surface Kalahari sands and a similar vegetation association occurs along the slopes of the Witvlei Berg where wind blown sand has accumulated. There are no distinct lineations formed by the tree and shrub vegetation in these areas but a slightly denser vegetation over occasional calcrete ridges in eastern Daheim outlines the regional

Plate 8 Association of Acacia hereroensis, A. mellifera, Grewia flava & Phaeoptilum spinosum trees and shrubs with Stipagrostis uniplumis grass (foreground - vegetation anomaly over mineralization, background - Eskadron quartzite ridge. (Ref. MM/SWA, 10/23.)

Plate 9 Terminalia sericea (left) and Acacia giraffae trees with Stipagrostis uniplumis and Schmidtia papaporoides grasses in an area of deep sand cover. southern Okatjirute. (Ref. MMC/SWA, 32/9.)

Plate 10 Dense growth of Acacia mellifera on gravels accumulated on the northern side of the Witvlei Berg, which forms the horizon. (Ref. MM/SWA, 25/5,6)

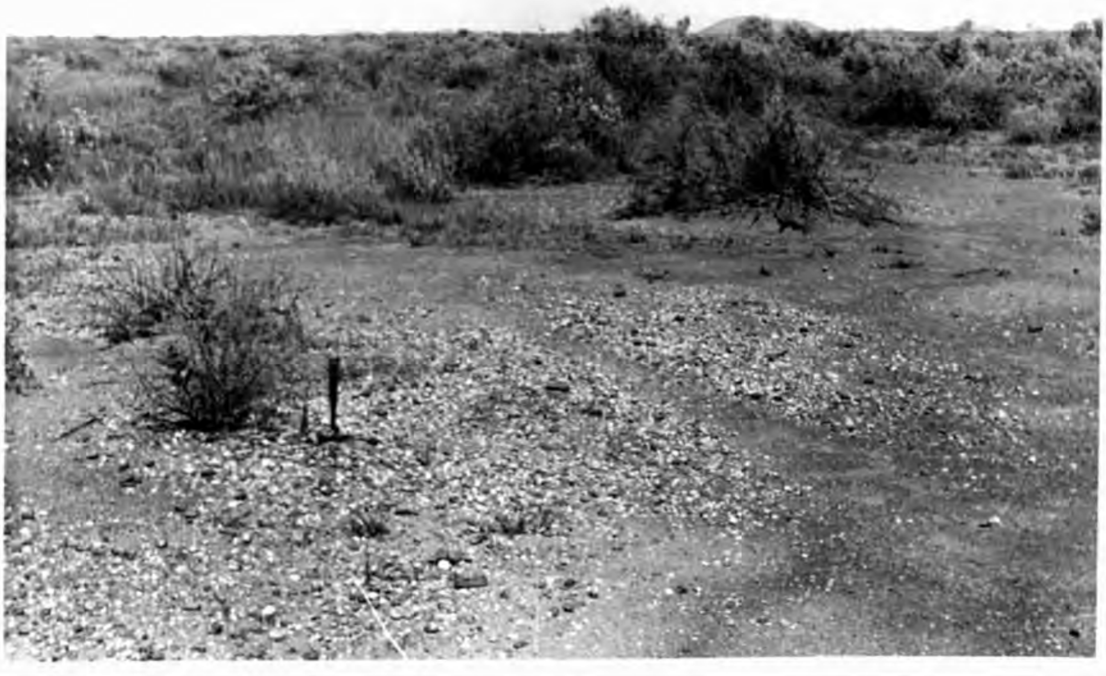


Plate 11 Association of Tarchonanthus camphoratus and Phaeoptilum spinosum growing in sand and gravel, Grünental. Foreground shows surface gravel of rounded quartz and quartzite pebbles. (Ref. MM/SWA, 22/2A.)

strike.

On the northern side of the Witvlei Berg and surrounding the quartzite ridge of Eskadron is an association of dense Acacia mellifera and Tarchonanthus camphoratus (Fig. 5, Assoc. 4 and Plate 10). In these areas the ground vegetation is extremely sparse consisting of a few species of annual herbs and grasses. Large areas of bare ground occur between the shrubs where surface gravels of rounded quartz and quartzite pebbles have accumulated (Plate 11). There are no lineations in the tree and shrub vegetation of these regions to assist in the geological interpretation.

Over the synclinal feature of southern Eskadron a distinct vegetation association is present over a series of calcrete rises and sand filled depressions. Similar areas occur in central Grünental, Eskadron and Okatjirute West. The sand filled depressions have an open vegetation with scattered low shrubs of Grewia flava and a dense grass cover of Stipagrostis uniplumis. The tree and shrub vegetation is much denser over the calcrete rises consisting of Acacia giraffae, Tarchonanthus camphoratus and Catophractes alexandri (Plate 12). The ground vegetation over the calcrete consists of Stipagrostis ciliata, Enneapogon brachystachus and Fingerhuthria africana grasses with a variety of annual and perennial herbs. In the syncline where this vegetation is best developed the overburden varies from 5 - 23 m. but the structure of the syncline is still apparent from the vegetation which emphasises the calcrete rises.

A dense vegetation characterised by Boscia albitrunca trees, large Acacia mellifera and Catophractes alexandri shrubs (Fig. 5, Assoc. 6) is restricted to areas of extensive surface calcrete. This vegetation occurs on Okatjirute East extending south-westwards into Okatjirute, and occurs over smaller areas in northern Eskadron and central Deheim. Occasional lineations are present in the vegetation following slightly elevated calcrete features which probably indicate the regional strike.

Two further low tree and shrub savanna vegetation associations are present in the Witvlei Area and these are confined to the river course of the White Nossob and fossil drainage lines floored by calcrete which mark former tributaries of the Nossob.

Tall *Acacia karroo* trees form the dominant feature of the vegetation along the banks of the White Nossob (Plate 13). The river bed which is 50 - 100 metres wide has a thick sand cover and may support annual grass species in the rainy season. The flood plain of the river which is almost one kilometre wide on Grünental is characterised by shrubs of *Acacia hebeclada*, *Eragrostis porosa* and *Pogonarthria fleckii* annual grasses and the herb *Tribulus zeyheri*.

Acacia karroo, *Acacia giraffae*, *Acacia hebeclada* *Grewia flava* and *Ziziphus mucronata* are the characteristic trees and shrubs of the fossil drainage lines. These features are well defined on the aerial photographs as slight depressions with an open vegetation and surface calcrete. The lily *Pseudogaltonia clavata* and the herb *Leucosphera bainsii* form the dominant ground species along the fossil drainage lines and many annual herbs and grasses occur during the rains.

The shrub savanna vegetation characterised by the association *Grewia flava*, *Phaeoptilum spinosum* and *Catophractes alexandri* shrubs, with *Leucosphera bainsii* and *Hermannia damarana* herbs and the lily *Pseudogaltonia clavata* (Plate 14) is confined to the northern part of Grünental and along the northern margin of the White Nossob River. These areas define the extent of the intra-formational unconformity and rocks of the Buschmannsklippe Formation respectively.

Four distinct areas of grassland dominated by the perennial grasses *Eragrostis pallens* and *Aristida stipitata* (Plate 15) occur on the boundary of Okatjirute West - Okatjepuiko. The grasses form a dense cover about 1 metre high and *Terminalia sericea* trees are scattered throughout the regions. The surface soils consist of coarse to medium grained quartz sands quite distinct from the widespread Kalahari sands.

Throughout the Witvlei Area are seasonal drainage pans which have a different vegetation assemblage to the surrounding regions. The pans in areas of near surface bed-rock are usually grassed over with the species Eragrostis curvula and Diandrochloa pusilla and are surrounded by large shrubs of Ziziphus mucronata, Diospyros lyciodes and Acacia hebeclada. Echinochloa hollubii, a grass species, is often bare for the major part of the year or have a sparse cover of the grasses Enneapogon brachystachus and E. cenchroides. After the rains many annual grasses and herbs form the ground vegetation of the pans. On the edges of pans shrubs of Acacia hebeclada and A. mellifera are often present and the lily Pseudogaltonia clavata and Enneapogon grasses dominate the ground vegetation (Plate 17).

Plate 12 Alternation of Stipagrostis uniplumis grass and scattered shrubs (centre) with denser vegetation of Acacia giraffae, Tarchonanthus camphoratus, Grewia flava and Catophractes alexandri on the calcrete rises, Eskadron syncline. (Ref. MM/SWA, 22/10A.)

Plate 13 Acacia karroo trees with associated shrubs and grasses along the banks of the White Nossob River, 20 km.W. of Witvlei. (Ref. MMC/SWA, 3/6)

Plate 14 Grewia flava, Phaeoptilum spinosum shrubs, Leuchosphaera bainsii, Justicia guerkeana, Hermania damarana herbs and Pseudogaltonia clavata lily, growing over calcrete in the area bounded by an unconformity on north-western Grünental.
(Ref. MM/SWA, 22/5A)

Plate 15 Open grassland of Eragrostis pallens and Aristida stipitata and scattered trees of Terminalia sericea, northern Daheim. (Ref. MM/SWA, 25/11)

Plate 16 Echinochloa holubii grass growing in a pan which is surrounded by Ziziphys mucronata, Diospyros lycioides and Tarchonanthus camphoratus trees and shrubs, on the farm Grünental. (Ref. MM/SWA, 22/3A)

Plate 17 Large pan on Okatjepuiko surrounded by shrubs of Acacia hebeclada and A. mellifera and the lily Pseudogaltonia clavata. The pan is floored by ~~floored by~~ calcrete and outcrops of lava occur around the pan. (Ref. MM/SWA, 25/27,28)

Chapter 5

RECONNAISSANCE IN THE WITVLEI CONCESSION AND THE SELECTION OF AREAS FOR GEOBOTANICAL, BIOGEOCHEMICAL AND GEOCHEMICAL STUDIES

Following the discovery of stratiform copper mineralization at the Okatjirute West Homestead in 1967, the Sigma Mining and Prospecting Company, a subsidiary of Anglovaal South West Africa, applied for and was granted a prospecting licence covering seven farms in the Witvlei area.

The initial geochemical reconnaissance survey was contracted to E.W.B. Miller and Associates and the soil samples collected were analysed by the Anglovaal laboratory at Rand Leases Mine. The geochemical traverse lines were planned at 1 km. intervals to cross the regional strike and use was made of tracks and fence lines on the farms (Fig. 6). Soil samples were collected at 30 metre intervals and from a depth of 15 - 20 cm., and the coarser fraction retained on plastic sieves of approximately 60 - 80 mesh was discarded. The traverse lines were marked in the field at 1 km. intervals with metal plates and also plotted on aerial photographs which were used in the field for location.

Geological information was recorded from outcrops occurring on the traverse lines and copper mineralization was discovered in a series of steeply dipping shales and quartzites on the northern part of Okatjirute, referred to as the Pos Area.

Stream sediment geochemistry and geophysical techniques were considered in the reconnaissance phase but the nature of the terrain and drainage systems, and the lack of contrasting physical properties of the mineralized argillite ruled out the use of these methods.

The geochemical program extended over a 2 - 3 month period during which time the initial geobotanical studies were undertaken by Misses L. Coupland and J. Cudmore on the farm Okasewa, 15 km. west of Witvlei, where copper mineralization was exposed in a pit excavated for road metal. Geobotanical reconnaissance traverses across the regional strike led to the discovery of narrow anomalous zones of the plant species Helichrysum leptolepis (Plate 18) from which the background species were absent. Pits dug within these zones revealed the presence of copper mineralization in argillite bedrock.

Attention was then directed to northern Okatjirute where mineralized outcrops had been discovered on the geochemical traverses. Helichrysum leptolepis was found growing over the outcrops and the mineralized zones could be traced for several hundred metres along strike by the anomalous vegetation. A trench was dug across the strike, through several zones of Helichrysum leptolepis, soil samples were collected for analyses and the dominant plant species were recorded. The results of this work indicated that the zones of mineralized bedrock were clearly defined by peak soil values, in the range 200 - 500 ppm. copper, and by the presence of Helichrysum leptolepis and associated Fimbristylis exilis (Plate 19). The copper levels in the soil also appeared to have a marked effect on the distribution of the grasses and herbs. The most common grass species Stipagrostis uniplumis and Pogonarthria fleckii and the majority of the herb species decrease in abundance where the copper content of the soil exceeds 200 ppm. The grass Aristida congesta and the herb Barleria lanceolata were restricted to the zones of higher copper soil values.

A series of long walking traverses to record the vegetation communities and possible anomalous associations was programmed for the Witvlei Concession. During this phase of reconnaissance several zones of Helichrysum leptolepis were discovered on the farm Okatjirute West in an area subsequently called the Copper Causeway. Helichrysum leptolepis and Fimbristylis exilis were found as a distinct association forming both circular and corridor features from which the trees and shrubs and the normal background vegetation of grasses

Plate 18 Helichrysum leptolepis which occurs in areas of copper mineralization. (Ref. MM/SWA 1/2)

Plate 19 Fimbristylis exilis which occurs in association with Helichrysum leptolepis in areas of copper mineralization. (Ref. MM/SWA 18/39)

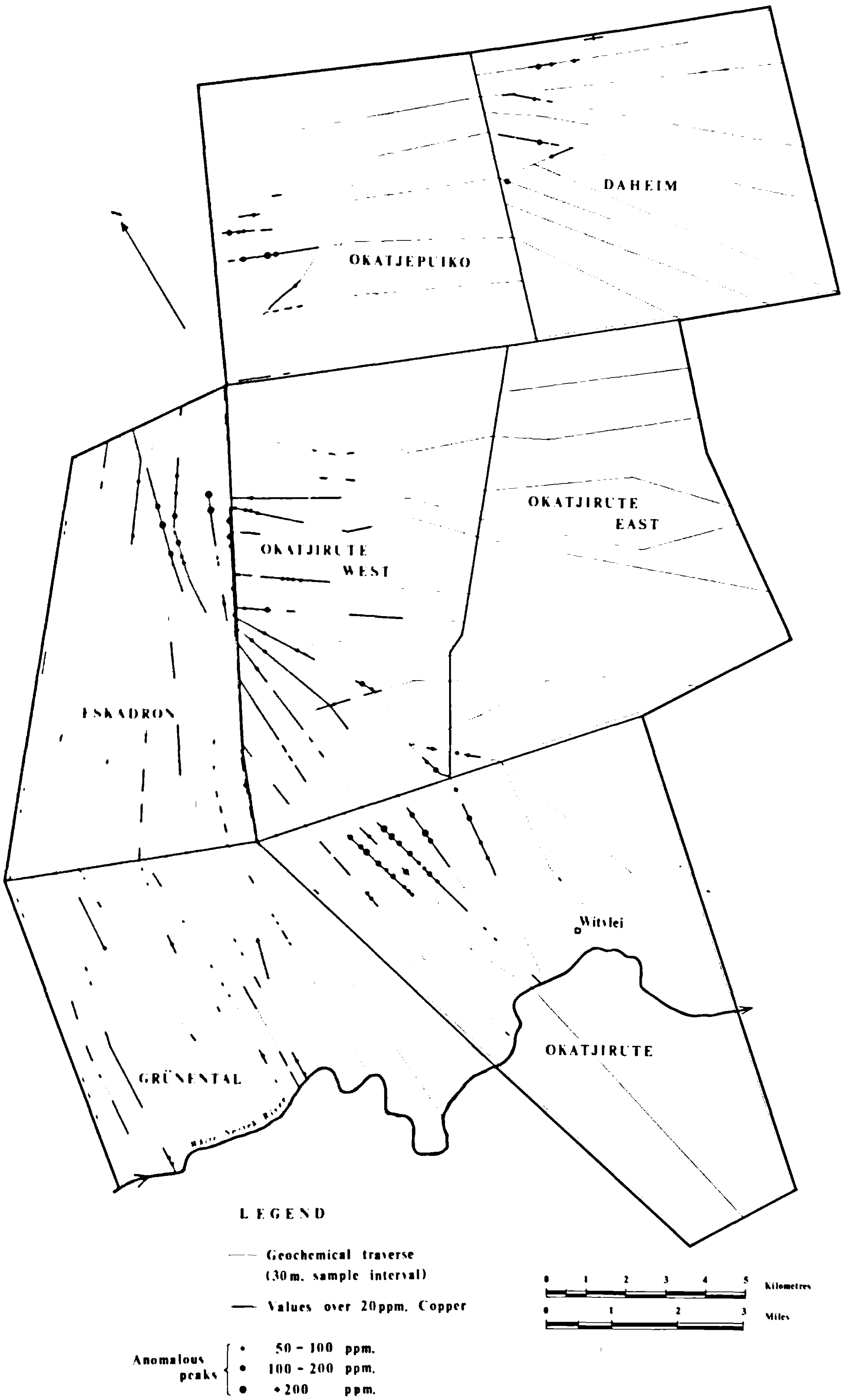


Fig. 6 Copper content of soil samples collected in the Witvlei Area.

and herbs are absent. The peak copper values for the soil samples were from areas of Helichrysum leptolepis and pits in these areas showed mineralized bedrock 20 - 50 cm. below the surface.

As the geochemical results became available from the regional survey of the concession several anomalous areas became apparent. The majority of the samples contain 10 - 20 ppm. copper and 20 ppm. is taken as a convenient background for the area. The sections of the traverse lines where the copper content of the soils exceeds 20 ppm. are shown in Fig. 6 together with the peak values of the anomalies which are graded into three categories.

The most pronounced area of geochemical anomalies is north-western Okatjirute where values exceeding 100 ppm. copper occur within a broad belt extending over two kilometres of strike. Zones of Helichrysum leptolepis and outcrops of mineralized argillite occur within this area.

A concentration of anomalous values with peaks over 200 ppm. copper occurs on the boundary of Okatjirute West and northern Eskadron. This area was investigated in March 1968 and several zones of Helichrysum leptolepis and associated anomalous vegetation were discovered. The zones could be traced for several hundred metres along strike and on one zone outcrops of mineralized argillite were located on the edge of a pan, referred to as the Malachite Pan.

Two further distinct groups of anomalous values occur in western Okatjepuiko and north-western Daheim. Geobotanical reconnaissance in these two areas did not locate any zones of Helichrysum leptolepis or associated anomalous vegetation.

Throughout Okatjirute West, Grünental and eastern Eskadron there are several sporadic high values in the range 50 - 200 ppm. copper and many sections of the traverse lines where the soils contain 20-50 ppm. copper.

Several significant factors are apparent from a comparison of the geochemical results of Fig. 6 with the geology, overburden and vegetation maps of the Witvlei Area of Figs. 3, 4 and 5 respectively.

The main geochemical anomalies occur over rocks of the Tsumis B Formation where the overburden is relatively shallow and the vegetation is characterised by a mixed association of low growing trees and shrubs. The same geological and environmental factors apply for much of Okatjirute West where there are many soil values in the range 20 - 50 ppm. copper and several peak values from 100 - 200 ppm. In western Eskadron and Grünental, also areas of Tsumis B and projected strike extensions of the Copper Causeway and Pos zones of mineralization, very few soil values exceed 50 ppm. copper. However, this region has a considerable cover of overburden especially the synclinal structure of Eskadron where calcrete and sand mask the bedrock.

North-eastwards the Pos zone of mineralization is projected through Okatjirute East, where there is a thick, extensive cover of calcrete, and into Daheim where the overburden consists of both sand and calcrete. The soil samples collected across Okatjirute East all contain less than 20 ppm. copper but in north-western Daheim peak values of upto 120 ppm. are recorded, suggesting that the Pos zone of mineralization does in fact continue north-eastwards but remains undetected on Okatjirute East because of the calcrete overburden.

The high copper soil values of western Okatjepuiko occur in an area of volcanic rocks of the Opdam - Skumok Formation. Geological investigations revealed the presence of malachite in the basaltic lavas exposed around the edges of a large pan and in pits dug across the geochemical anomalies.

The samples collected from the eastern part of the Witvlei Concession, covering most of Daheim, Okatjirute East and the southern part of Okatjirute, all show background copper values. This region is underlain by the Buschmannsklippe and Tsumis C Formations in which copper mineralization was not expected. However, most of this region is covered with extensive overburden of calcrete, sand and gravel which could also account for the lack of geochemical anomalies. There are two areas of higher soil values over the Buschmannsklippe on southern Grünental but they are within fossil drainage channels and most probably represent transported anomalies.

During the early reconnaissance phase of exploration copper mineralization, zones of anomalous vegetation and high copper soil values were recorded in the Pos Area, Copper Causeway and Malachite Pan. These three areas of known mineralization (Fig. 7) were selected for orientation studies in geobotany, biogeochemistry and geochemistry to determine the most effective techniques for locating and defining copper mineralization prior to trenching and drilling stages.

Samples were also collected from these areas for studies in seasonal biogeochemistry and to determine the precision of the laboratory methods for geochemical and biogeochemical analyses (Appendix II A & B).

The above areas are within regions of relatively near surface bedrock where the vegetation is a low tree and shrub savanna characterised by the species Acacia hereroensis, A. mellifera, A. hebeclada, Grewia flava, Phaeoptilum spinosum and Tarchonanthus camphoratus (Figs. 4 and 5). The results of the orientation studies should be applicable to large sections of the Witvlei Area where similar environmental conditions exist.

The mineralized zones as projected on Fig. 3 also pass into areas of deep sand cover and surface calcrete where the species composition of the tree and shrub vegetation and the ground cover varies significantly from the areas proposed for orientation studies. Thus, ideally additional orientation work should be carried out in areas of deep sand cover and calcrete. Unfortunately, this phase could not be carried out satisfactorily as copper mineralization of potential ore grade was never discovered in a sand or calcrete environment throughout the exploration program.

Initially, biogeochemistry was thought to be the most favourable technique for exploration in these areas of exten-

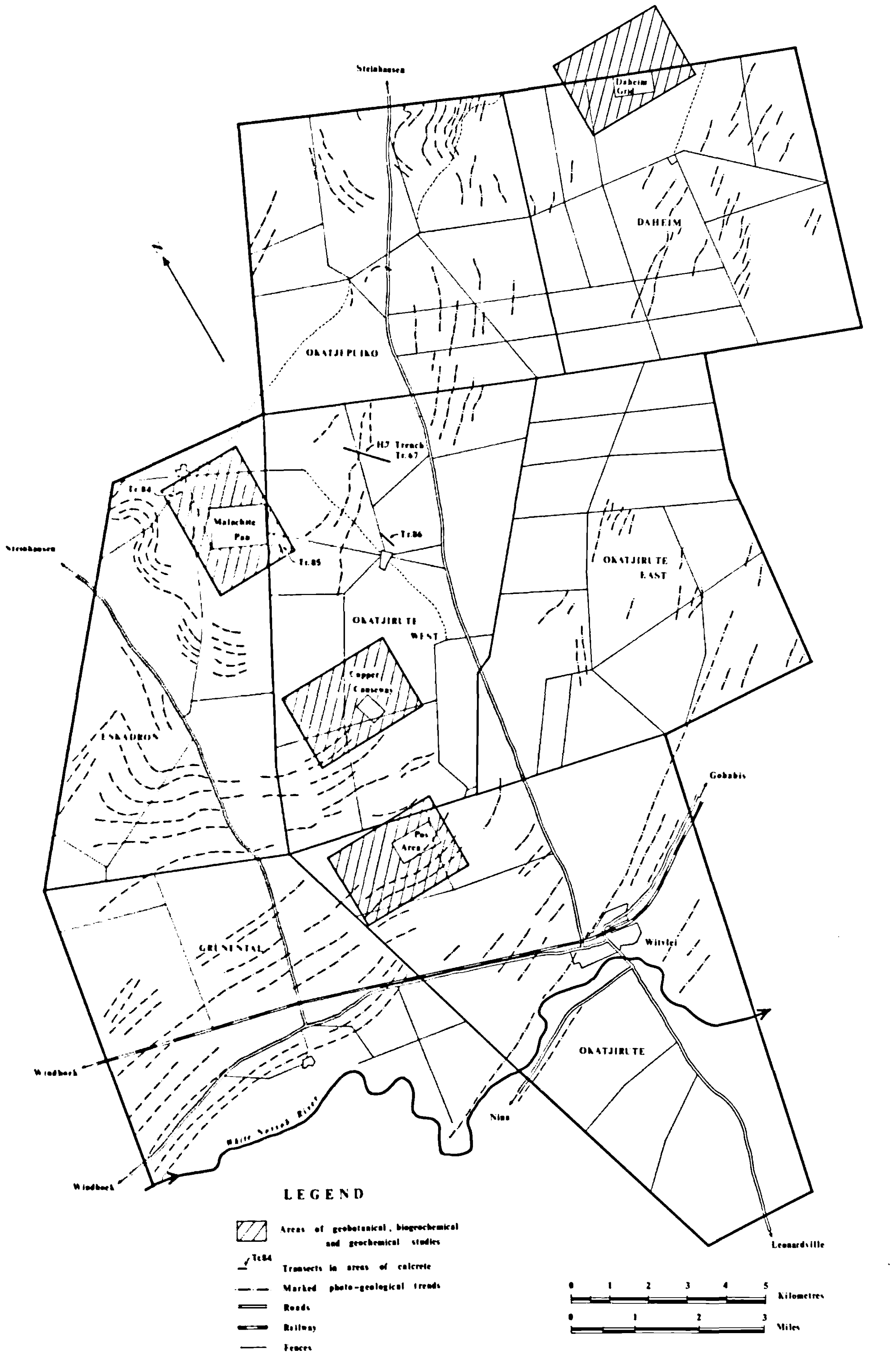


Fig. 7 Areas within the Witvlei Concession selected for geobotanical, biogeochemical and geochemical studies.

sive overburden, as the deep-rooted tree and shrub species should give a better reflection of the bedrock geochemistry than the surface soils. However, preliminary studies of the rooting habits of the common trees and shrubs (Appendix I) and the species distribution indicates that biogeochemistry may not be as widely applicable as anticipated.

In the sand covered areas of the Witvlei Concession Acacia giraffae is the only common deep-rooted species (Table 7). Of the other commonly occurring species in this environment Terminalia sericea and Acacia mellifera have shallow lateral roots and Grewia flava and Tarchonanthus camphoratus have a branching root system observed to depths of about one metre. In regions of calcrete the two most commonly occurring species Catophractes alexandri and Acacia mellifera have shallow lateral root systems but Acacia hebeclada and Boscia albitrunca have more deeply penetrating tap roots.

Grewia flava, Tarchonanthus camphoratus and Acacia mellifera are the only species fairly common in all three environments.

Regional exploration was continued in the Witvlei Area by the Anglovaal geological staff and based mainly on the photogeological interpretation and reconnaissance geochemistry. A phase of exploration trenches, excavated by mechanical digger, was planned for the region to cross the projected strike extensions of the Pos and Copper Causeway zones of mineralization. To the west of the Pos Area, within Okatjirute, several narrow horizons of mineralized argillite were exposed by the trenching but further westwards on Grünental only quartzites and shales were revealed. Trenches in Okatjirute East and Daheim failed to locate mineralization and in many sections, because of the deep sand cover or calcrete, did not even expose

SPECIES	RELATIVE ABUNDANCE			ROOT SYSTEM	
	Near Surface bedrock	Sand covered	Surface calcrete	Habit	Depth
A.giraffae	o*	a	o	branching	deep
A.hereroensis	a	o	r	lateral	shallow
A.hebeclada	a	o	a	tap	intermed.
A.mellifera	a	f	a	lateral	shallow
B.albitrunca	f	r	f	tap	deep
C.alexandri	o	vr	va	lateral	shallow
G.flava	va	a	f	branching	intermed.
P.spinosum	a	r	o	tap	deep
R.pyroides	f	f	r	branching	shallow
T.camphoratus	a	f	f	branching	intermed.
T.sericea	vr	a	vr	lateral	shallow

* va - very abundant, a - abundant, f - frequent, o - occasional, r - rare, vr - very rare.

Table 7. Relative abundance and root systems of the more common tree and shrub species, in various environments, within the Witvlei Concession.

the bedrock. A subsequent phase of exploration by wagon drilling across the geochemical highs indicated a zone of copper mineralization, several metres in thickness, on the northern boundary of Daheim. A trench over the drill section exposed mineralized shale beneath 1.5 metres of sand and gravel and this initiated the geochemical and biogeochemical surveys of the Daheim Grid (Fig. 7).

The regional exploration trench H. 7 in northern Okatjirute West crosses the projected strike extension of the Copper Causeway. A narrow zone of mineralized limestone and several horizons of weakly mineralized shales were exposed in the trench beneath sand and gravel overburden. Geochemical and biogeochemical samples were collected along a transect parallel to the trench to see if the mineralization could be detected by surface exploration.

From a geological standpoint and from photo-geological interpretation the syncline of Eskadron was thought to be a potential area for copper mineralization. A more detailed geochemical survey using a closer line spacing and sample interval did not produce any anomalies and the regional trenching program was abandoned in this area because of the thick calcrete overburden. A final phase of exploration by wagon drilling across the structure of the syncline also failed to indicate copper mineralization. This region had been selected for biogeochemical surveys because of the thick cover of overburden but after negative results were obtained from drilling the biogeochemical work was not undertaken.

As stated above copper mineralization was never located beneath thick surface calcrete but geological mapping in the Malachite Pan and Okatjirute West Homestead areas outlined narrow zones of mineralized argillite forming intermittent outcrops in areas of surface calcrete and along calcrete rises. Three transects 84 - 86 (Fig. 7) were located in these areas for geobotanical studies and for the collection of geochemical and biogeochemical samples.

Chapter 6

GEOBOTANICAL, BIOGEOCHEMICAL AND GEOCHEMICAL INVESTIGATIONS IN AREAS OF NEAR SURFACE BEDROCK.

A. THE POS AREA

Introduction

The regional structure of the Pos Area is clearly shown by the E - W lineations in the tree and shrub vegetation (Fig. 8). Across the southern part of the area is a line of three hills rising 20 - 30 metres above the general surface. The vegetation on the hills is dominated by Albizia anthelmintica, Combretum apiculatum, Commiphora pyracanthoides, Grewia flavescens and Grewia bicolor and the presence of Catophractes alexandri over the more calcareous sequences in the bedrock gives a banded effect to the vegetation. A dense growth of Tarchonanthus camphoratus defines the drainage lines, cutting across the E - W strike, where sand has accumulated (Fig. 8).

The vegetation for the remainder of the area is dominated by Acacia mellifera with associated Grewia flava, Tarchonanthus camphoratus and Catophractes alexandri shrubs, and Stipagrostis uniplumis grass forms the major part of the ground cover. Throughout most of this region there is a cover of sand which increases in thickness from the base of the hills towards the stream courses.

The presence of copper mineralization in the Pos Area was indicated in the early stages of exploration by both geochemistry and geobotany. The geochemical reconnaissance survey (Fig. 6) showed significant copper anomalies of over 200 ppm. on most of the traverse lines passing through the area and the geobotanical transects revealed several zones of anomalous vegetation characterised by Helichrysum leptolepis and Fimbristylis exilis.

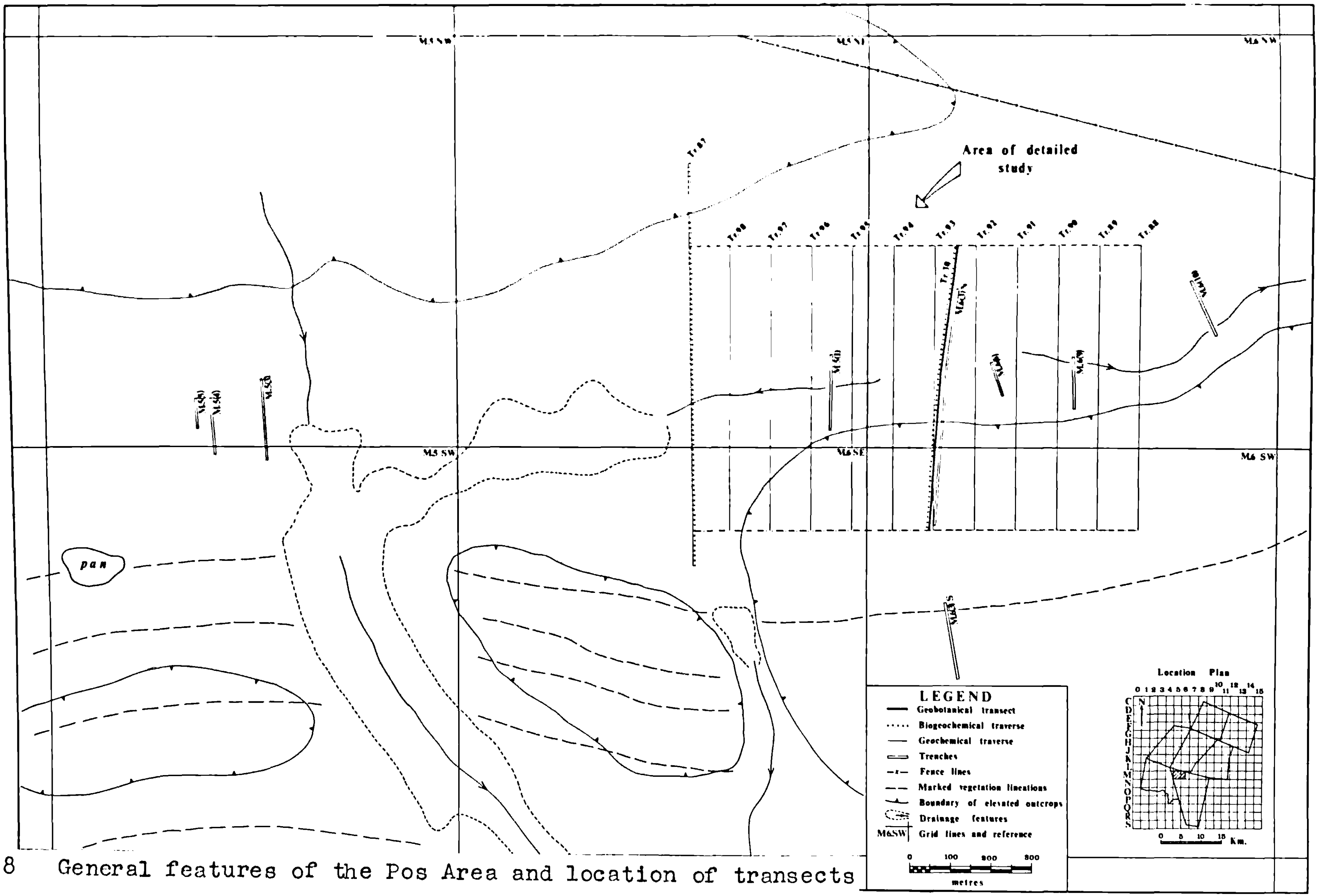


Fig. 8 General features of the Pos Area and location of transects

In order to establish the relationship between the distribution of vegetation with respect to copper mineralization the tree and shrub and ground species were recorded along Transect 30 parallel to the trench section M.6(3)N. Soil samples and plant samples were also collected along the transect for geochemical analyses, to determine the most favourable tree or shrub species for biogeochemical prospecting in this environment.

Transect 30.

The strata exposed in the trench section M.6.(3)N. (Fig. 9) dip steeply to the south and the succession consists of an alternation of quartzites and shales with occasional bands of limestone and mineralized argillite. There are no conglomerate horizons in the section but conglomerate outcrops occur to the north-east of the Transect. The quartzites are generally fine grained and well sorted and display both graded bedding and cross bedding structures. The limestone at 290 m.S shows contorted banding which may represent algal structures and several of the limestones contain pyrite.

Copper mineralization is generally confined to the argillites although some of the green shales contain upto 0.20% copper. Stringers of malachite, parallel to the bedding, and disseminated sulphides are present in the exposed argillite sections. The main zone of mineralization is from 200 - 270 m.S where there are eight horizons of mineralized argillite varying in copper content from 0.36 - 2.02%. Most of the argillites are less than 1 m. in thickness. Mineralization is also present in narrow bands of argillite at 39, 443, 495 and 553 m.S.

Along most of the transect there is a covering of sand which does not exceed 50 cm. in depth. As shown in the soil profiles (Fig. 9) some of the more resistant quartzites form outcrops and towards the southern end of the transect, on the slope of the hill, there is an average of about 30% outcrop.

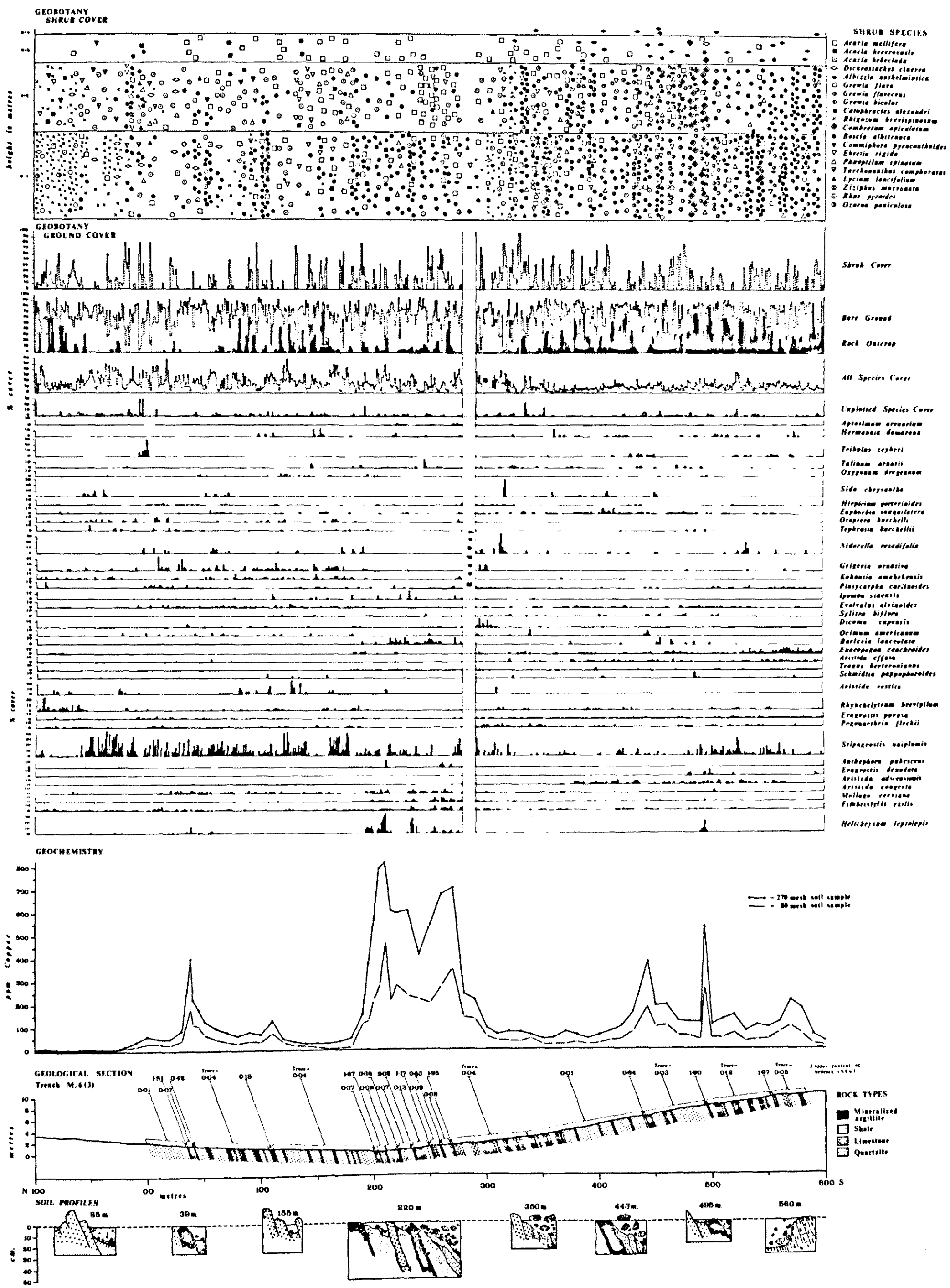


Fig. 9 Transect 30, Pos Area, showing the relationship between the distribution of plant species, soil geochemistry, geology and soil profiles.

The mineralized argillites appear to be fairly resistant to weathering forming outcrops in several places (Plate 20) or masked by a very thin covering of sand. The shales and limestones are more deeply weathered and do not form outcrops.

The surface soils over the various rock types are very similar in composition and the results of sieve analyses are shown in Fig. 10. The greater proportion of the soils consist of fine and medium grained sand which forms between 60 and 80% and the silt and clay fraction for all the samples is very small forming only 3 - 6% of the total. The gravel, consisting of angular and sub-angular quartz and quartzite, is the most variable fraction and forms from 1% in the sample from 100 m.N to a maximum of 29% in the sample taken over the mineralization at 496 m.S. The soils at 100 m.N and 00 m. are very well sorted, containing over 50% fine sand grade and may represent an accumulation of wind blown sand. Towards the southern end of the transect on the slope of the hill the soils show a wider range in particle size and contain a greater proportion of the coarser fractions.

The majority of the soils sampled along the transect show an acid reaction, with a pH variation between 5.3 and 6.7 (Table 8). The soil directly over mineralization at 209 m. has a pH of 6.2. The two samples which give an alkaline reaction, with pH readings of 8.2 and 9.0, are from 565 and 570 m. where there is limestone bedrock and calcrete in the soil profiles.

Soil samples for geochemical analyses were collected from a depth of 15 - 20 cm. and sieved to -80 and -270 mesh. The highest copper values for both mesh fractions occur directly over the horizons of mineralized argillite. The main geochemical anomally extends from 200 - 280 m.S where the -80 mesh samples contain more than 200 ppm. copper and peak values exceed 400 ppm. (Fig. 9). The soils over the individual narrow zones of mineralized argillite at 39, 443 and 496 m. have a high copper content and a minor peak is indicated at 120 m.S where a shale containing 0.18% copper is exposed in the trench section. The samples from 20 - 100 m.N, with both the -80 and -270 mesh fractions containing less than 10 ppm. copper, show that the background copper level in the soils is very low.

Plate 20 Outcrop of mineralized argillite at 210m.S on Transect 30, Pos Area. Plants of Helichrysum leptolepis occur along the strike of the outcrop.
(Ref. MM/SWA 4/3A)

Distance M.	pH of Soil	ppm.Copper -80 mesh	Soil Colour Dry	Wet
100N.	5.5	5	5YR.5/6	5YR.4/4
50N.	5.9	5	4/6	3/4
0	6.0	30	4/4	3/4
38.S	5.6	185	4/6	4/4
50	5.6	150	5/6	4/4
100	5.6	35	4/6	4/4
150	5.3	10	5/6	4/4
200	5.5	260	5/6	4/4
209	6.2	470	5/6	4/6
250	6.3	202	5/6	4/4
300	5.9	57	5/6	4/4
350	6.3	22	5/6	4/4
400	6.0	26	5/6	3/4
443	5.8	185	5/6	4/4
496	5.6	271	5/6	3/4
500	5.7	50	5/6	3/4
550	5.3	45	5/6	3/4
565	8.2	-	5/6	4/4
570	9.0	102	6/4	5/4
600.S	6.7	18	5/6	3/4

Table 8 pH, copper content and colour of bulk soil soil samples from Transect 30, Pos Area.

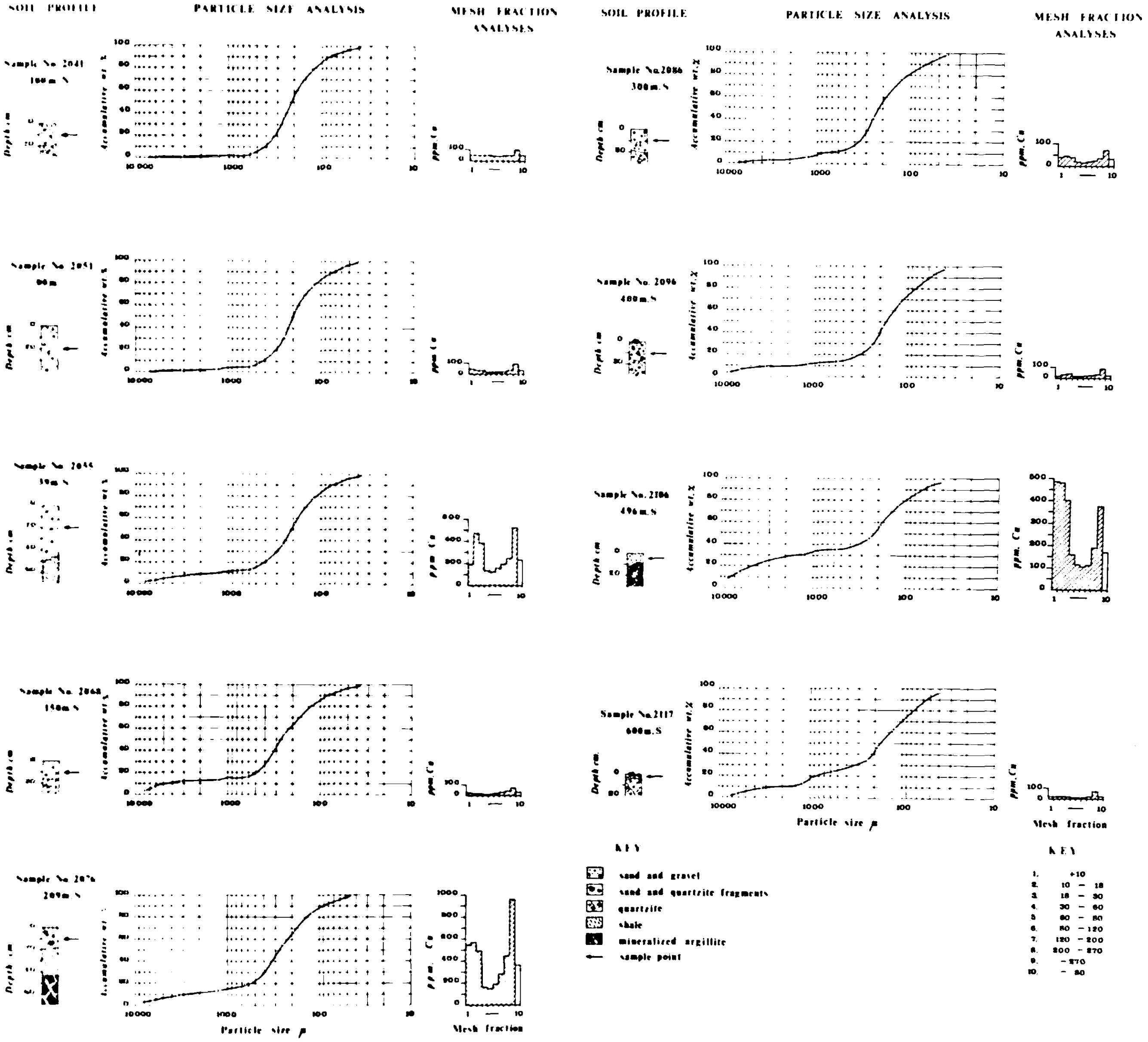


Fig. 10 Particle size analysis and mesh fraction analyses for bulk soil samples collected on Transect 30, Pcs Area.

The mesh fractions obtained from the sieving were analysed for copper content and the results are shown in Fig. 10. The soils collected over quartzite bedrock have a relatively low copper content in all mesh fractions with the maximum value for the -270 mesh. The samples 2055, 2067 and 2106 from the soil profiles over mineralized argillites show a similar trend in the copper content of the various mesh fractions. The coarser fractions from +10 to -30 mesh, which cover the ranges of coarse sand, very coarse sand and gravel, have high copper contents in the range 4-500 ppm. for the three samples. The -270 mesh fraction, of very fine sand, silt and clay, also contain over 400 ppm. copper and a maximum of 950 ppm. for sample 2076. The four mesh fractions from 30 - 200 mesh, which consist mainly of fine and medium sand, have much lower copper levels of between 150 and 200 ppm.

Geobotany

The trees and shrubs form a fairly dense cover along the transect and are mainly less than 2 m. in height. *Acacia mellifera* shrubs from 2 - 3 m. high occur throughout the area and large *Albizia anthelmintica* trees from 2 - 4 m. are present on the hillside towards the southern end of the transect.

On the slope of the hill from 350 - 600 m.S there is a distinct vegetation association formed by *Albizia anthelmintica* and *Combretum apiculatum* trees with *Grewia bicolor*, *G. flavescens*, *Dichrostachys cinerea* and *Commiphora pyracanthoides* shrubs. This association is common on the elevated ridges in the Pos Area.

Along the remainder of the transect the most common shrub species are *Acacia mellifera*, *Catophractes alexandri* *Grewia flava* with frequent occurrences of *Tarchonanthus camphoratus*, *Phaeoptilum spinosum* and *Boscia albitrunca*. The species *A. hebeclada*, *A. hereroensis*, *Ozoroa paniculosa*, *Rhus pyroides* and *Ziziphus mucronata* have a very scattered distribution on the transect and form only a minor part of the vegetation.

The vegetation banding observed on the air photographs of this area is reflected in the tree and shrub recording (Fig. 9) which indicates changes in the density and species composition across strike. In some narrow sections, 0 - 40 m.N, 20 - 40, 60 - 80 and 120 - 140 m.S shrubs are almost absent and a greater area of the ground surface is exposed. Rhigosum brevispinosum shows a marked concentration from 40 - 100 m.N and 300 - 330 m.S and with the absence of other species in these areas forms a contrasting tonal strip along strike. Catophractes alexandri also shows a concentration on some parts of the transect especially from 540 - 600 m.S where there is a wide zone of limestone which gives rise to calcareous soils. A third species Combretum apiculatum, which occurs between 480 and 500 m.S on the hillside, produces a pronounced banding effect.

Directly over the mineralized argillites shrubs are absent. This is not revealed in the shrub cover diagram as the shrubs are recorded in 10 m. quadrats and the open corridors in the shrub vegetation are only 1 - 4 m. wide. Across the main zones of mineralization, from 200 - 270 m.S where the soils have a high copper content, Acacia mellifera is the dominant species forming large shrubs 1 - 3 m. in height. Catophractes alexandri and Grewia flava are also fairly common in this area but the variety of shrub species is more limited.

Throughout the area there is a much greater proportion of bare ground than area covered by vegetation. The plant species form an average cover of 25% and rarely exceed 50%. Over the southern end of the transect on the hillside, the cover is generally less than 20% because of the increase of outcrop and the very shallow soils.

A total of 56 grass and herb species were recorded on transect 30 and the distribution of 32 species is shown in Fig. 9. The remaining species (Table 9) have only a scattered occurrence and are grouped together on the diagram as unplotted species.

A distinct vegetation association, dominated by Helichrysum leptolepis, is present over the zones of mineralized argillite. The grass species Aristida congesta and Anthephora pubescens with Fimbristylis exilis, Mollugo cerviana and the woody herb Barleria lanceolata occur with Helichrysum leptolepis but these species are also present in other parts of the transect.

Helichrysum leptolepis occurs over all the zones of mineralized argillite exposed in the trench section and although it is not recorded on the transect at 443 and 553 m.S it occurs on the strike extension of these mineralized zones. From 205 - 209 m.S, over a section of argillites and shales which average 1.67% copper, Helichrysum leptolepis covers 20 - 30% of the ground surface (Plate 21). Fimbristylis exilis is associated with Helichrysum leptolepis on all the zones of mineralization forming upto 5% cover but it also occurs in the more sandy areas scattered among Stipagrostis

1	Acrotome inflata	13	Fockea angustifolia
2	Alternanthera pungens	14	Heliotropium ovalifolium
3	Aptosimum depressum	15	Hirpicium gorterioides
4	Aptosimum leucorrhizum	16	Limeum viscosum
5	Celosia linearis	17	Monechma nepta
6	Cenchrus ciliaris	18	Nelsia quadrangula
7	Chascanum pinnatifidum	19	Neorautanenia amboensis
8	Commelina benghalensis	20	Portulaca grandiflora
9	Crotalaria argyraea	21	Pseudogaltonia clavata
10	Crotalaria spartioides	22	Pupalia lappacea
11	Cucumis africanus	23	Sida chrysantha
12	Cyphocarpa angustifolia	24	Solanum rautanenii

Table 9. Grass and herb species also occurring on Transect 30 and grouped as unplotted species cover in Fig. 9

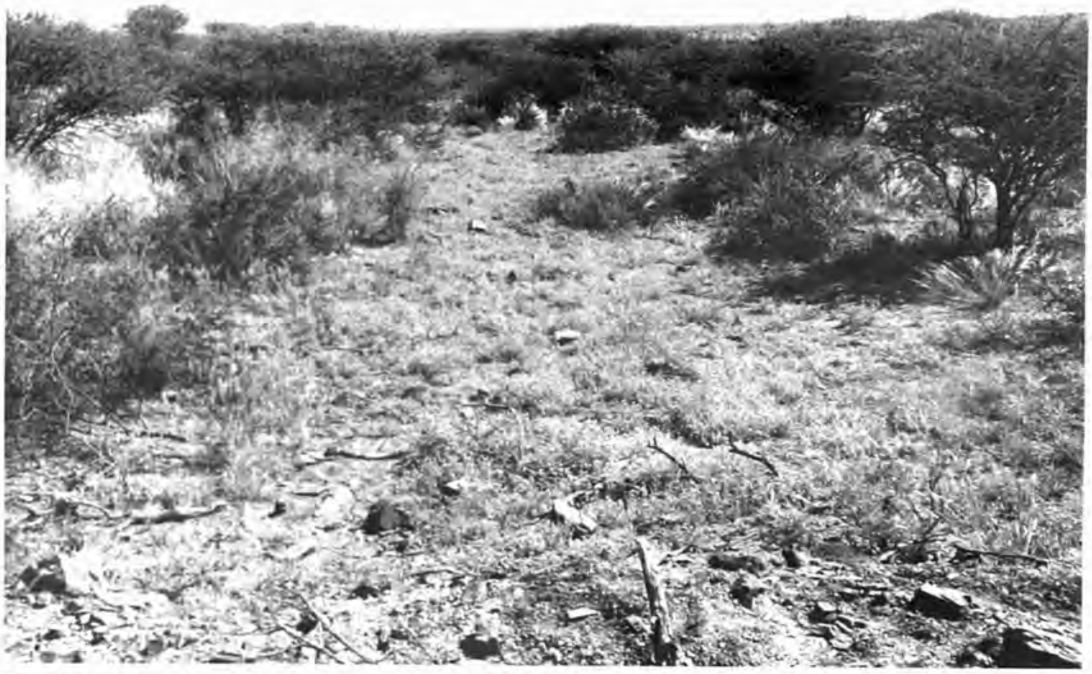


Plate 21 View westwards along the vegetation anomaly following the main zone of mineralization from 205 - 210m.S on Transect 30, Pos Area. The ground vegetation consists of an association of the species Helichrysum leptolepis, Fimbristylis exilis and Aristida congesta. Shrubs of Acacia hebeclada and Acacia mellifera occur along the margins of the anomalous zone. (Ref. MMC/SWA 38/27)

uniplumis grass. Mollugo cerviana and Aristida congesta are generally confined to the main section of mineralization and geochemical anomaly from 200 - 270 m.S and Aristida congesta also occurs around the mineralization at 39 m.S. Anthephora pubescens is not a common grass species in the area and only occurs directly over mineralization at three localities on the transect. Barleria lanceolata (Plate 22) is mainly confined to the central zone of copper mineralization, with scattered occurrences on the hillside. It does not grow over the argillite with Helichrysum leptolepis but along the margins of the areas under the larger shrubs.

The most common grass species in the area is Stipagrostis uniplumis which shows a greater density from 50m.N to 170 m.S where the sand cover is deeper. It cuts out sharply on either side of the mineralization (Plate 21) and is also less frequent on the hillside. The grasses Aristida adscensionis and A. effusa are confined to the hill on the southern part of the transect and Enneapogon cenchroides is also common in this region especially from 540 - 600 m.S where limestone and calcrete occur. The annual species Eragrostis porosa and Pogonarthria fleckii occur throughout the transect forming upto 5% cover but are absent between 200 and 270 m.S where the copper content of the soil is high. Rhyncheletrum brevipilum and Aristida vestita which are fairly common on the transect are also absent from this zone.

The majority of the herbs do not occur across the main area of mineralization where the copper content of the soils is high and none are present in the Helichrysum leptolepis zones. Talinum arnotii, Platycarpha carlinoides, Ipomoea sinensis and Aptosimum arenarium occur between 200 and 270 m.S but do not show any marked concentration. The association Otoptera burchellii, Geigeria ornativa, Kohautia omahekensis occurs in the area of thicker sand cover with Stipagrostis uniplumis grass, and these species are absent from the rocky hillside.

Plate 22 The woody herb Barleria lanceolata which occurs within the mineralized section of Transect 30.
(Ref. MM/SWA 7/2)

Biogeochemistry

The geobotanical recording shows a total of 20 tree and shrub species along the transect and samples of 16 species were collected for analyses. The copper content for these samples is plotted in Fig. 11. Grewia flava, Acacia mellifera Catophractes alexandri, Tarchonanthus camphoratus, Phaeoptilum spinosum and Boscia albitrunca could be sampled along most of the transect and a direct comparison of copper values of background samples and samples from the mineralized zone can be made. Of the other 10 species several are confined to the slope on the southern end of the transect and Barleria lanceolata is confined to the main mineralized zone.

No comparative data was gained from the samples of Rhigosum brevispinosum, Dichrostachys cinerea, Commiphora pyracanthoides and Ziziphus mucronata as all the samples are from low copper areas and the two samples of Combretum apiculatum are from the same location. The Barleria lanceolata samples, which were all collected from sites of high copper soil content do not show any great variation in their copper content, with the ranges being 11 - 16 ppm. (Dry weight)* for the leaves and 4 - 9 ppm. for the twigs.

The samples of Acacia hereroensis from 211 m.S adjacent to mineralization have a much higher copper content in both the leaves and the twigs than the remaining eight samples on the transect. This sample contains 20 ppm. leaves and 15 ppm. twigs compared to less than 7 ppm. and 6 ppm. respectively for the remaining samples.

The samples of Albizia anthelmintica from 495 and 496 m.S, near to copper mineralization show a marked increase in the copper content of the leaves, with values twice those of the other five samples. The twig samples, however, all have similar copper values of about 4 ppm.

Five samples of Ehretia rigida were collected on the transect including one from background at 90 m.N and one from the main area of mineralization from 215 m.S. The sample from

* All copper content values quoted for plant samples refer to dry weight.

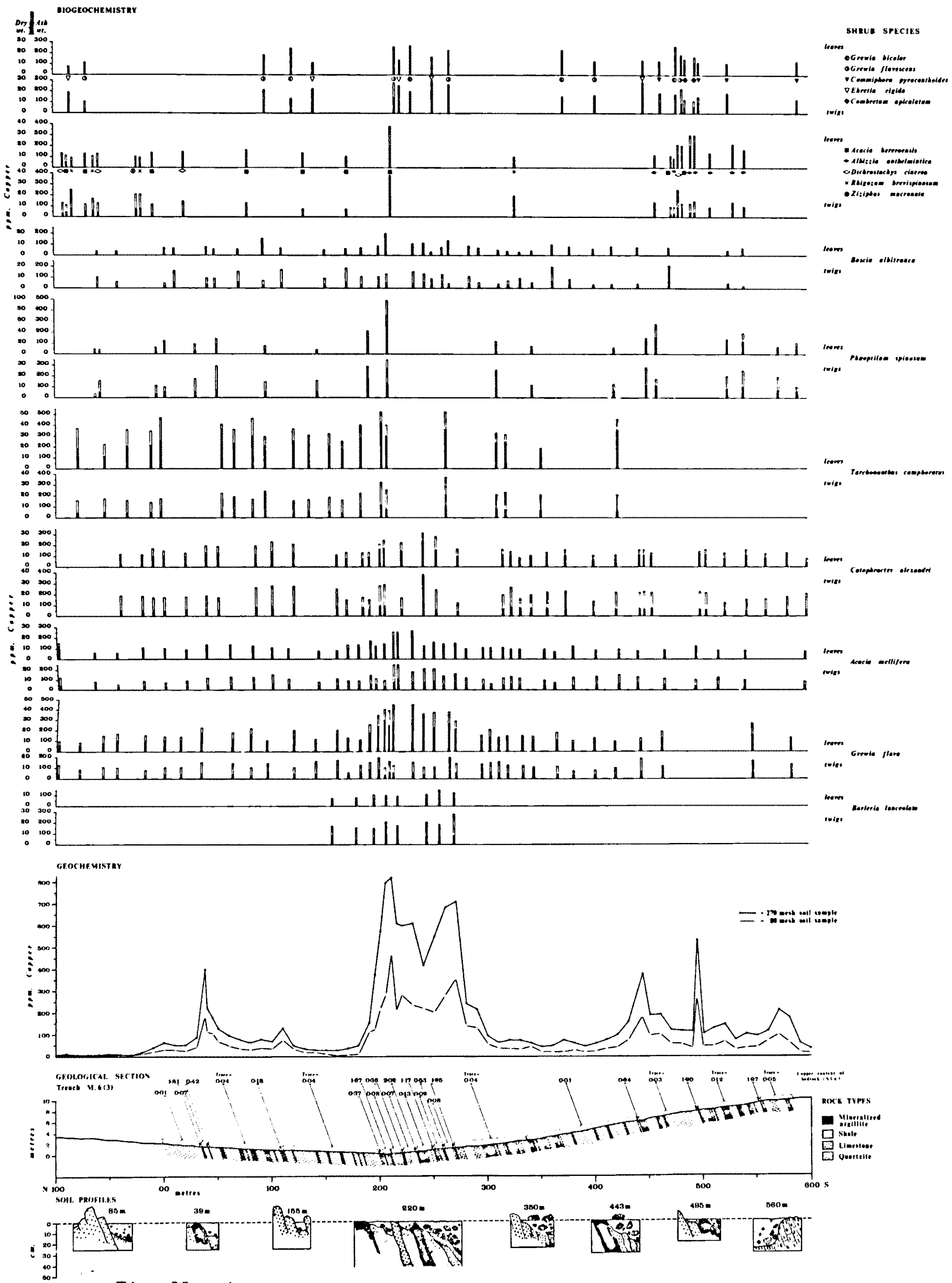


Fig. 11 A comparison of the copper content of tree and shrub species with soil geochemistry and geology for Transect 30, Pos Area.

the mineralized zone contained 19.4 ppm. leaves and 11.8 ppm. twigs compared with 8.6 and 7.0 ppm. copper for the sample from background. The remaining three samples have intermediate copper values.

The samples of <u>Grewia flavescens</u> show a wide variation in the copper content of both the leaves and the twigs. The background samples from 70 m.N and 400 m.S have less than 10 ppm. copper in the leaves compared with 24.9 ppm. from the sample at 215 m.S near mineralization. The twigs from this site also show a two-fold increase in the copper content compared to the samples from background.

The four <u>Grewia bicolor</u> samples from varying sites of copper content of the soils show little variation in the copper values for the leaves and twigs, with ranges of 17 - 20 ppm. and 6 - 10 ppm. respectively.

The six most common species in the area were sampled at 10 - 20 m. intervals along the transect and the results of the analyses are shown on individual lines on Fig. 11. A direct comparison of the copper content of the plant, both leaves and twigs, and the soil from the same location is shown in graphical form in Fig. 12.

<u>Grewia flava</u>

The leaf samples show a marked increase in copper content across the main mineralized zone from 190 - 270 m.S. The values in this region vary from 17.7 - 29.4 ppm. copper which is 2 - 3 times the background level of 9.8 ppm. calculated for 21 samples (Table 10). The only other sample on the transect which has a high copper content, 18.0 ppm., occurs at 39 m.S where a horizon of mineralized argillite is present. The species distribution is poor towards the southern end of the transect from 4 - 600 m. and hence the effect of the three narrow zones of mineralization on the copper content of the leaves cannot be determined.

The twigs show a variation in copper content from 2.7 - 8.7 ppm. with the higher values occurring across the main

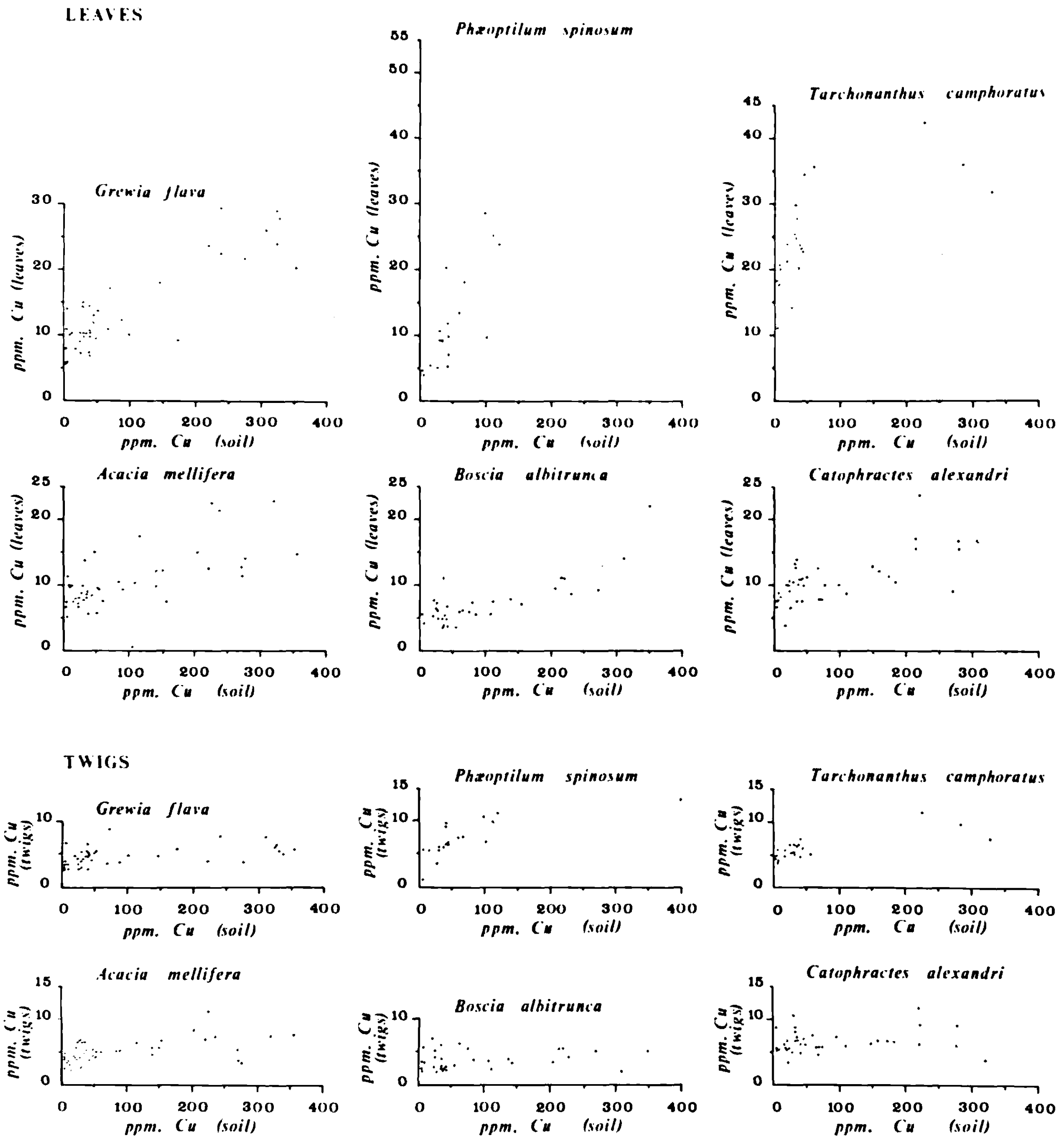


Fig. 12 The relationship between the copper content of shrub samples, leaves and twigs, and the copper content of the soil (-80 mesh).

Shrub species	Nº of Samples	ppm. Copper	
		Leaves	Twigs
Grewia flava	21	9.8	4.1
Acacia mellifera	18	8.5	4.2
Catophractes alexandri	12	8.2	5.7
Tarchonanthus camphoratus	10	20.5	5.1
Phaeoptilum spinosum	8	7.0	5.0
Boscia albitrunca	13	5.4	3.5

Table 10. Mean copper content of the shrub samples, leaves and twigs, from the background sections of Transect 30, Pos Area.

mineralized section. However, there is no clear division between anomalous and background samples as shown in the leaves.

There appears to be a fairly linear relationship between the copper content of the leaves and the corresponding soil value for that collection site (Fig. 12). In the areas of low copper soil content, less than 50 ppm., the leaves show a concentration of values around 10 ppm. There are very few samples in the intermediate range but where soil values are in excess of 200 ppm. the leaf values range from 20 - 30 ppm. forming a distinct anomalous group.

The scatter diagram for the twigs of Grewia flava indicates that there is a slight increase in the copper content with the increasing soil values but the trend is not as clearly defined as for the leaves.

Acacia mellifera

The leaf samples from the main mineralized zone have a range of copper values between 12.0 and 22.7 ppm., appreciably higher than the mean value of 8.7 ppm. for the background samples. Two high values of 15.0 and 13.8 ppm. from 39 and 61 m.S, outside the main area of copper mineralization, reflect the narrow horizon of mineralized argillite at 39 m.S.

Samples were also taken near the mineralization on the southern part of the transect at 440 and 494 m.S where the leaves contain 7.3 and 11.4 ppm. copper; values which do not indicate mineralization.

The copper content of the twigs from the main mineralized section varies from 5.5 - 11.2 ppm., with one low value of 3.3 ppm. from 204 m.S. The mean copper content for the background samples is 4.2 ppm. The samples near to the minor zones of mineralization at 39 m.S and towards the southern end of the transect do not show any appreciable increase in the copper values above the background level.

Fig. 12 shows that the background leaf samples contain less than 10 ppm. with a gradual increase to 15 - 25 ppm. for the samples from areas of higher copper levels in the soil. The twig samples corresponding to the background soils show a range of 3 - 6 ppm. copper with a slight increase in the samples from areas where the soils contain over 200 ppm. copper.

<u>Catophractes alexandri</u>

The plotted values on the histogram for the leaves do not clearly define the main mineralized zone, but the five samples from 200 - 252 m.S ranging in values from 14.5 - 23.7 ppm. copper are the highest values on the transect and considerably higher than the mean background of 8.2 ppm. At 120 m.S near to a weakly mineralized shale the leaves contain 13.8 ppm. copper which is slightly in excess of the sample from 39 m.S, directly over a mineralized argillite. The samples taken adjacent to the narrow bands of argillite towards the southern end of the transect contain 11.3 and 12.2 ppm. copper; similar values to some of the background samples.

In the twig samples the only significant value is from 240 m.S, where the sample contains 11.7 ppm. copper, the maximum value for the transect. Other samples from the mineralized area contain from 6 - 9 ppm. copper and there are several samples from the background areas with up to 8 ppm.

The leaf samples show a slight increase in copper with the increasing content in the soils (Fig. 12) but, the twig samples do not show any trend with the variation of copper in the soils. The values range from 3 - 11 ppm. in both background and anomalous soils.

Tarchonanthus camphoratus

The distribution of this species is fairly limited on the transect. There are very few occurrences in the main mineralized zone and it is practically absent from the hillside on the southern end of the line. The three samples from the mineralized area contain from 29.6 - 42.3 ppm. copper with the maximum value at 201 m.S. Other values considerably higher than the mean background of 20.5 ppm. occur at 53 and 420 m.S. These sites are 15 - 20 m. from a zone of mineralization but occur within the geochemical anomaly caused by the zone.

The twig samples from the main mineralized zone vary in copper content from 7.5 - 11.4 ppm. and those from the remainder of the transect from 3.3 - 7.5 ppm.

The leaf samples from the sites of less than 50 ppm. copper in the soils (Fig. 12) show a very wide range in copper content from 11 - 30 ppm., whereas the samples with corresponding soil values from 50 - 350 ppm. only show a further increase from 30 - 42 ppm. In the twig samples two distinct groups are present. The samples from the background areas contain from 3 - 7 ppm. copper and the second group, where the soils range from 250 - 350 ppm., the twigs contain from 8 - 12 ppm. copper.

Phaeoptilum spinosum

This species also has a more scattered distribution on the transect and only one sample occurs in the main area of mineralization. The leaves of this sample from 208 m.S contain 54.5 ppm. copper compared to the mean background value of 7.0 ppm. Other values several times the background are recorded for the samples at 190, 50 and 450 m.S. The first sample containing 25.2 ppm. is from the edge of the main mineralized area and the sample at 50 m., with a value of 18.8 ppm. is within the area of the geochemical anomaly formed by the mineralized argillite at 39 m.S. The higher copper content of the leaf samples from 450 m.S may be due to the narrow band of argillite at 443 m. containing 0.64% copper.

The maximum value for the twigs is also from the sample at 208 m.S and along the transect the higher twig values correspond with the high leaf values. The diagrams of Fig. 12 show that there is an apparent linear relationship between the copper content of the soil and plant for both leaves and twigs. However, there is only one sample from an area of very high copper content of the soil and no intermediate values.

Boscia albitrunca

Within the main mineralized zone the leaf values vary from 8.6 - 21.9 ppm. copper with the highest value from a sample adjacent to a zone of mineralized argillite at 207 m.S. The mean background value for the species is 5.4 ppm. One higher value of 11.0 ppm. at 93 m.S is unrelated to mineralization, whereas the samples from 41 and 440 m.S, very close to copper-bearing argillite, show no increase in copper content above the background level.

The twig samples do not show any marked increases in copper across the mineralized sections.

The scatter diagrams (Fig. 12) indicate that there is a gradual increase in the copper content of the leaves with the increasing copper values of the soil but, the twigs have a fairly constant copper content throughout the range of soil values.

Summary of the results for Transect 30 and follow-up work in The Pos Area.

The zones of copper mineralization are most clearly defined by the anomalous vegetation association and the soil geochemistry.

Helichrysum leptolepis occurs over all the zones of mineralization and Fimbristylis exilis, Mollugo cerviana and Aristida congesta are commonly associated. The absence of herb species and the common background grasses Stipagrostis uniplumis, Pogonarthria fleckii, Eragrostis porosa and Rhyn-

chelytrum brevipilum and the open corridors of the tree and shrub vegetation are also characteristic of the zones of mineralization.

Peak copper soil values of 200 - 500 ppm. for the -80 mesh occur over all the more significant zones of copper mineralization but, there is a very limited lateral spread of copper in the soils.

The leaves of _Phaeoptilum spinosum_ and _Tarchonanthus camphoratus_ produce the most spectacular biogeochemical anomalies but the use of these species in exploration in this region is limited because of their sparse distribution. _Grewia flava_ leaves also show clearly anomalous values in the range 20 - 30 ppm. copper over the main zone of mineralization and would be a more suitable species for biogeochemical prospecting because of its common occurrence and wide distribution.

To outline the strike extensions of mineralization exposed in trench M.6(3) a follow-up stage of geobotanical observations and geochemical sampling was undertaken. A grid was marked out extending over an area 1100 by 700 metres with the traverse lines 87 - 98 spaced at 100 metre intervals (Fig. 8). Soil samples were collected at 10 m. intervals from a depth of 15 cm. and the results of analyses of the -80 mesh fraction are shown in the copper isopleth map of Fig. 13.

The main features of the results are two parallel zones of +200 ppm. copper extending over strike lengths of 800 and 500 metres. The northern zone outlines the strike extension of the main mineralized horizon in trench M.6(3).N from 205 - 210 m.S. From the geochemical results the mineralization would appear continuous to the eastern margin of the survey area but die out 200 - 300 metres west of the trench. The southern zone of +200 ppm. copper has a limited extension to both the east and west following the mineralized argillite exposed at 270 m.S in the trench.

A further strong anomaly occurs around 800W/160S where soil values exceed 300 ppm. copper. This shows the westward strike extension of the narrow zone of mineralized argillite at 39 m.S in trench M.6(3)N.

On the southern section of the geochemical grid from 500 - 700 m.S (Fig. 13), covering the slope of the quartzite hill, narrow E - W zones of 100 - 200 ppm. copper follow the strike of the bedrock. Three zones are apparent and they correspond to the horizons of mineralized argillite and shale exposed in the trench at 443, 495 and 560 m.S.

The zones of copper mineralization shown in trench M.6(3)N and three further trenches M.5(1), M.6(6) and M.6(9) excavated during geological exploration, are more easily followed along strike by the presence of Helichrysum leptolepis and associated anomalous vegetation. The main zone of mineralization in trench M.6(3)N from 205 - 210 m.S can be followed eastwards for 200 metres by the continuous corridor of Helichrysum leptolepis and directly correlates with a mineralized zone in trench M.6(6). Westwards the Helichrysum leptolepis zone (Plate 21) is continuous for over 200 metres and then the mineralization can be traced to trench M.5(1) and beyond by scattered occurrences of Helichrysum leptolepis.

The narrow mineralized argillite at 39 m.S in trench M.6(3)N can be followed westwards by an almost continuous anomalous vegetation association to 800W/150S where there is an absence of shrubs over an area 40 by 20 metres and a dense ground cover of Helichrysum leptolepis. The strong geochemical anomaly exceeding 300 ppm. copper of Fig. 13 corresponds to this area.

The three narrow zones of mineralization towards the southern end on the trench M.6(3)N at 443, 495 and 560 m.S can be traced along strike both east and west for several hundred metres on the vegetation characteristics (Fig. 14). The wider zone of mineralized argillite and shales at 443m.S, containing 0.6% copper, is continuous for 800 metres and can be followed along strike by the narrow corridor apparent from the absence of shrubs, common herbs and grasses and the scattered occurrence of Helichrysum leptolepis and Fimbristylis exilis (Plate 23).

A comparison of the trench sections of Fig. 14 clearly

Plate 23 Mineralized horizon of argillite and shales clearly defined by the absence of shrubs, background grasses and herbs. Helichrysum leptolepis and Fimbristylis exilis are scattered along the anomalous zone which can be followed continuously for 800 metres. View westwards in the southern section of the Pos Area. (Ref. MM/SWA, 14/16A)

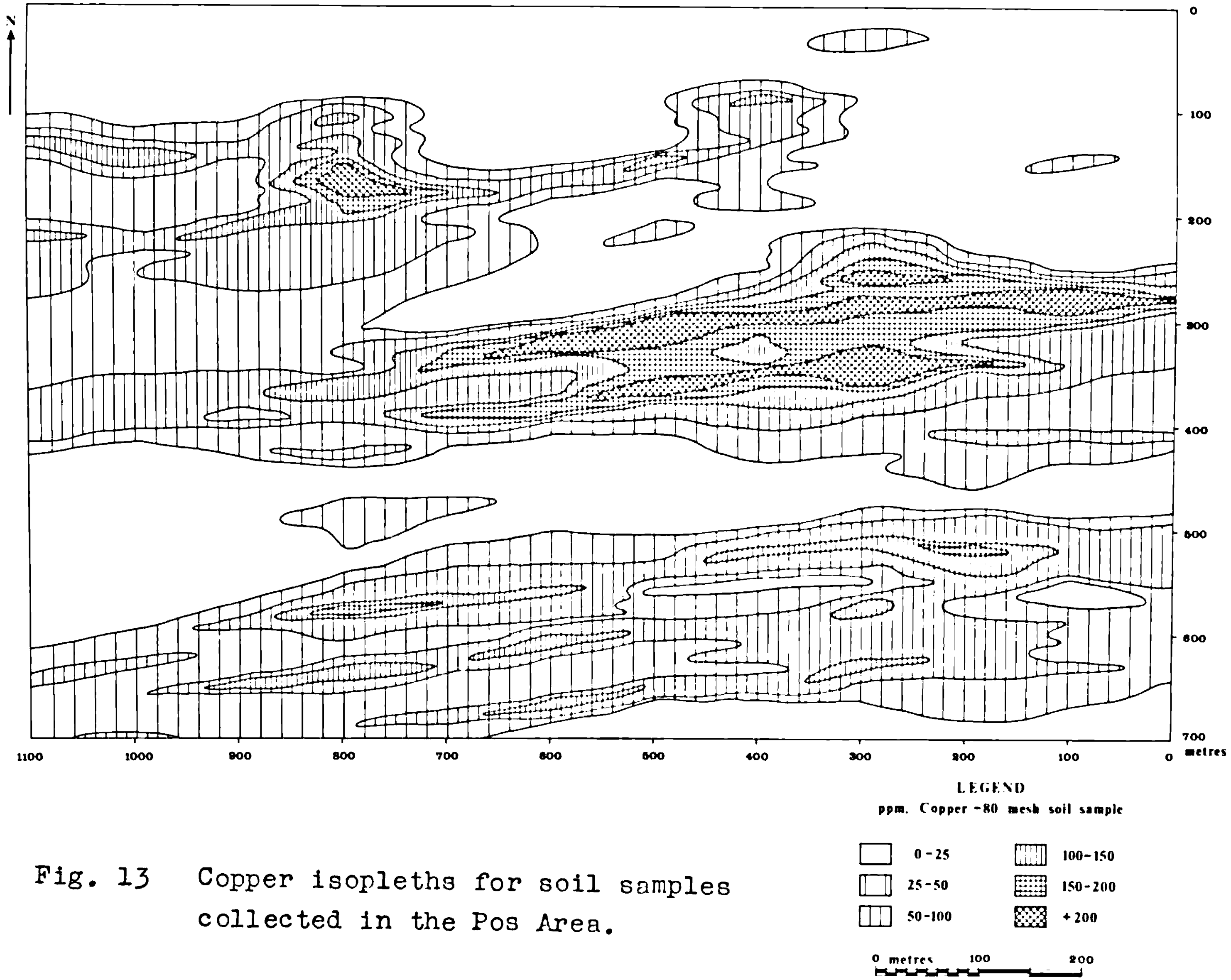
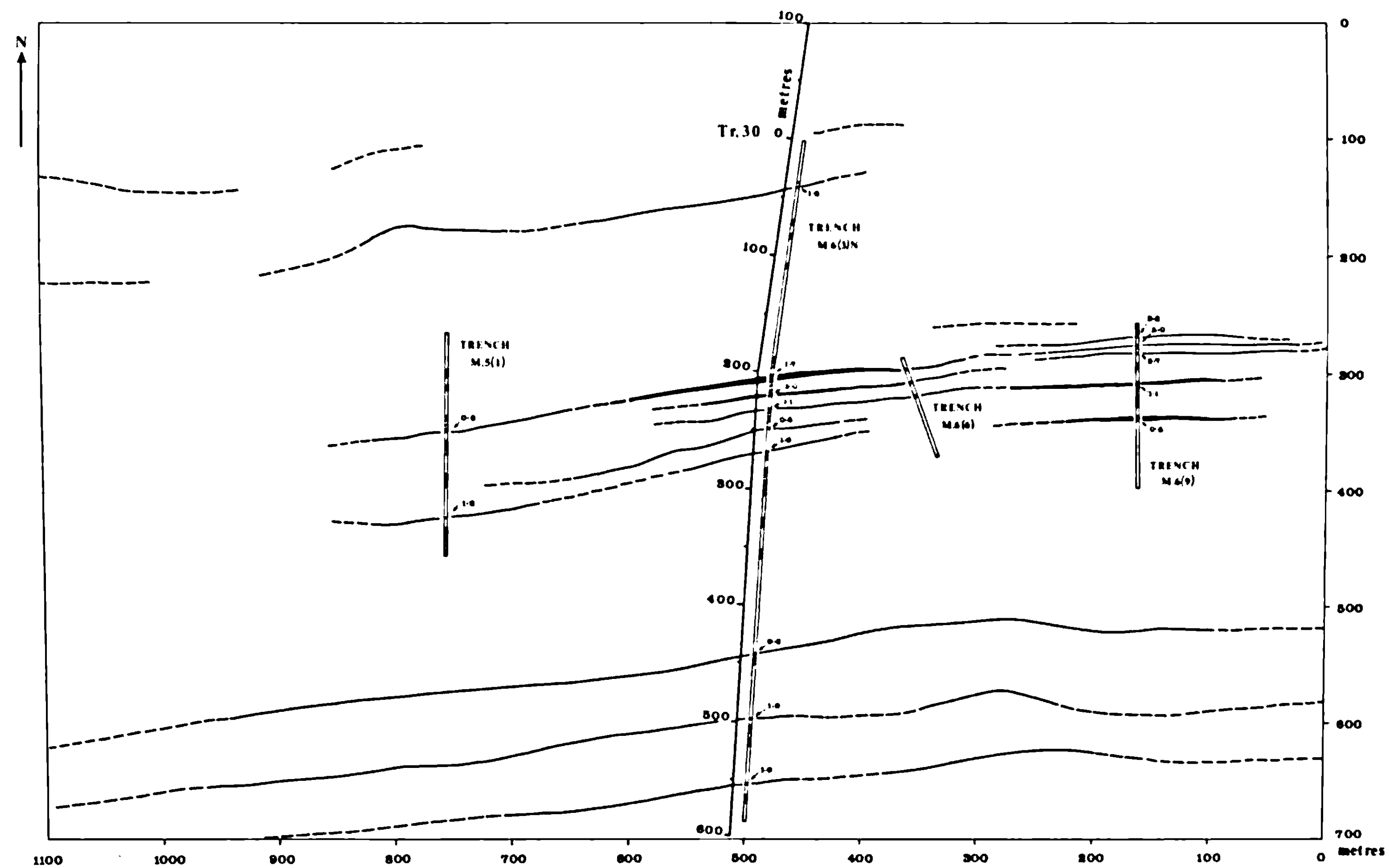


Fig. 13 Copper isopleths for soil samples collected in the Pos Area.



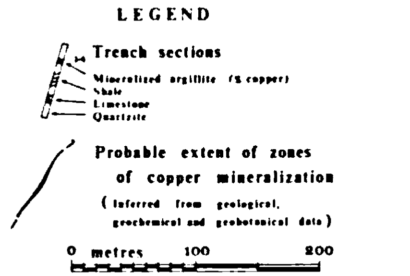


Fig. 14 Extent of copper mineralization in the Pos Area as indicated from trench sections, geochemical and geobotanical data.

indicates that the mineralized argillites are not consistent in either grade or thickness when traced along strike. The 6 metre zone grading 1.7% copper in trench M.6(3)N extends for probably only 400 m. thinning rapidly along strike and is correlated with a zone of less than 1 metre of 0.6% copper in trench M.5(1).

The geobotanical observations and geochemical results indicate that the mineralization does not extend very far westwards beyond trench M.5(1). However, the sand cover increases towards the west, both in the drainage feature from 350 - 430 m.S and along the base of the hills, and could mask mineralization. To investigate the possibility of mineralization beneath the sand cover and as a follow-up to the initial biogeochemical studies of Transect 30, plant samples were collected along the western boundary of the geochemical grid on Tr. 87 (Fig. 8). The transect extended 200m. north and 100m. south beyond the geochemical grid and leaf samples of <u>Grewia flava</u> were collected at approximately 10 m. intervals. The results of analyses and copper content of the soils (-80 mesh) are shown in Fig. 15.

The geochemical profile indicates a broad zone of values over 50 ppm. copper from 110 - 420 m.S, and three distinct peak values from 90 - 130 ppm. at 130, 220 and 260 m.S. A further zone of higher values from 370 - 410 m.S coincides with the drainage feature. All the soil values for the northern section of the transect from 200N - 100S are less than 10 ppm. copper and values for the southern section are all less than 50 ppm.

The copper content of the leaf samples varies from 8.9 - 33.8 ppm. with a mean value of 14.4 ppm. for those samples collected in the background section of the transect from 200N - 100S. The standard deviation for this group of 30 samples is 2.7 and the value for probably anomalous (Hawkes and Webb, 1962) samples 22.5 ppm. copper. The location and copper content of the 15 probably anomalous samples are shown in Table 11.

Location m.S	ppm. copper
30	23.0
127	26.4
171	26.4
190	33.8
199	22.7
222	23.8
241	24.7
251	27.7
278	27.3
299	23.6
331	25.8
342	23.2
430	22.9
590	23.1
623	22.6

Table 11. Location and copper content of probably anomalous samples of Grewia flava leaves collected on Transect 87, Pos Area.

All but four of the probably anomalous biogeochemical samples occur between 130 - 350 m.S (Fig. 15) falling within the broader geochemical anomaly from 110 - 420 m.S. However, of the peak biogeochemical values from 127, 171, 190, 251, 278 and 331 m.S only one sample coincides with a geochemical peak. The maximum value recorded for the leaves of Grewia flava of 33.8 ppm. copper from 190m., is from an area where the soils contain less than 50 ppm.

No probably anomalous leaf samples occur in the section 370 - 420 m.S, the drainage feature, and this suggests that the higher geochemical values are the result of sheet wash from the main mineralized zone higher upslope (Fig. 13).

The two leaf samples from 20 and 30 m.S, an area of background from the geochemistry, have an extremely high copper content of 22.4 and 23.0 ppm. respectively and may indicate

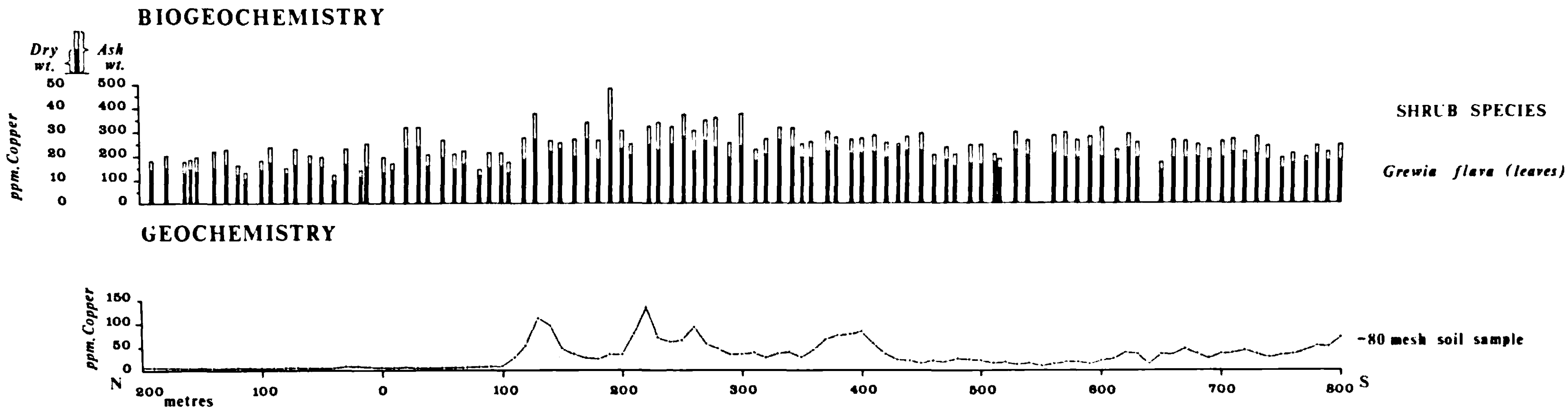


Fig. 15 A comparison of biogeochemical and geochemical data for Transect 87, Pos Area.

copper mineralization in depth, beneath the sand cover.

The probably anomalous samples from 590 and 620 m.S occur in the approximate region of a zone of mineralization projected from geobotanical and geochemical studies (Fig. 14).

The strong biogeochemical anomalies between 120 - 350 m.S, and the non-coincidence of biogeochemical and geochemical peak values warrants further investigation, to determine whether copper mineralization is present in this section and if so which of the two exploration methods gives a better definition of the mineralization.

B. The Copper Causeway Area

Introduction

The surrounding region of the Copper Causeway is one of level to undulating terrain with shallow sandy soils. Outcrops of quartzites and grits occur throughout the region and become more prominent towards the west, where individual horizons form continuous outcrops for several hundred metres. The regional strike, as shown by vegetation lineations on aerial photographs, swings from E - W to NE - SW (Fig. 16).

The low tree and shrub savanna of this region is characterised by the species Grewia flava, Phaeoptilum spinosum, Acacia hereroensis, A. mellifera, A. hebeclada and Tarchonanthus camphoratus. Stipagrostis uniplumis, a perennial grass, dominates the ground vegetation but, a great variety of annual and perennial grasses and herbs occur throughout the area. The drainage pans have a dense cover of the grass Eragrostis curvula with large shrubs of Ziziphus mucronata and Acacia hebeclada around the margins. Fossil drainage features leading into and linking the pans are apparent from the denser shrub cover of Tarchonanthus camphoratus.

The initial geobotanical reconnaissance of the Copper Causeway outlined several distinct areas of anomalous vegetation characterised by Helichrysum leptolepis and Fimbristy-

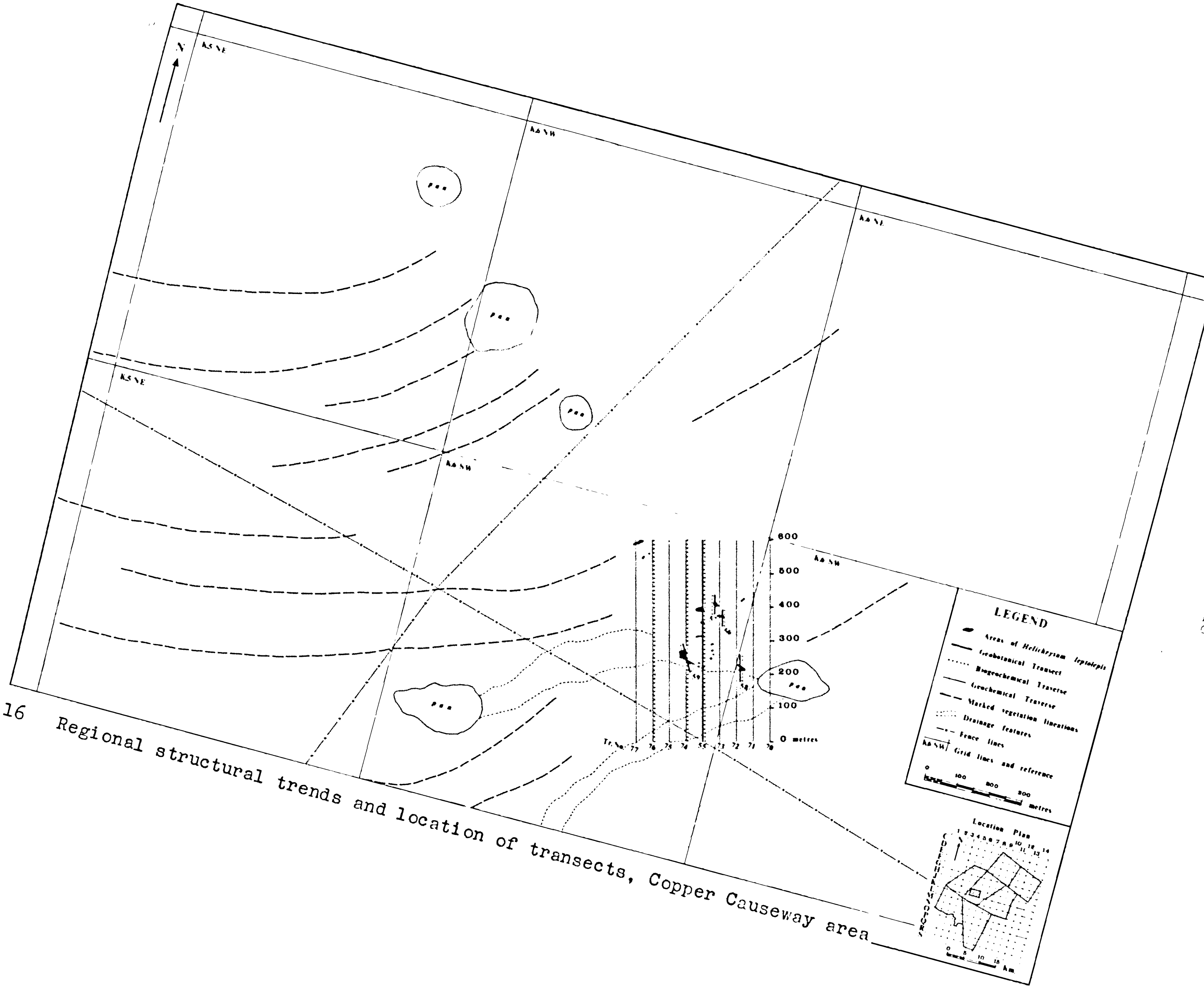


Fig. 16 Regional structural trends and location of transects, Copper Causeway area

lis exilis (Plate 24). A trench section located to cross several of the Helichrysum leptolepis areas and the regional strike revealed mineralized argillite beneath each anomalous vegetation zone.

In order to study the distribution of plant species with respect to copper mineralization and the copper content of the soils geobotanical transects were recorded across the area. The principal transect 55 crosses several anomalous vegetaion zones and extends well into the background vegetation (Fig. 16), and transects 56 - 59 each cross one distinct area of Helichrysum leptolepis.

Plant samples were collected along the transects to investigate the relative uptake of copper by the various species in background and anomalous areas and to determine the most favourable species for biogeochemical prospecting.

The distribution of the anomalous vegetation was mapped and a geochemical survey carried out in the area to determine the extent of mineralization and aid the geological interpretation.

Transect 55

The geobotanical transect is parallel to the trench K.6.(1), and 10 metres to the east, so that a direct comparison can be made between the vegetation and the bedrock. The geological section of the trench, soil profiles, geochemical and geobotanical data are shown in Fig. 17.

There is generally between 10 - 90 cm. of soil cover along the transect and outcrop only occurs in a few localities. It is apparent from the soil profiles and trench sections that the mineralized argillites are more resistant to weathering than the quartzites and shales, as their suboutcrops are much closer to surface. There are no distinct soil horizons formed but subdivisions can be made on the nature and percentage of gravel in the soil. A layer of angular to subangular gravel of quartz and quartzite is usually present resting on the bedrock and the surface material is composed

Plate 24 View eastwards across the main geobotanical anomaly of the Copper Causeway. The foreground, void of shrubs and grasses, has a dense cover of Helichrysum leptolepis and associated Fimbristylis exilis. The perennial grass Stipagrostis uniplumis, with the shrubs Acacia hereroensis, Acacia mellifera and Acacia hebeclada, occur in the background. (Ref. MMC/SWA 12/28A-32A)

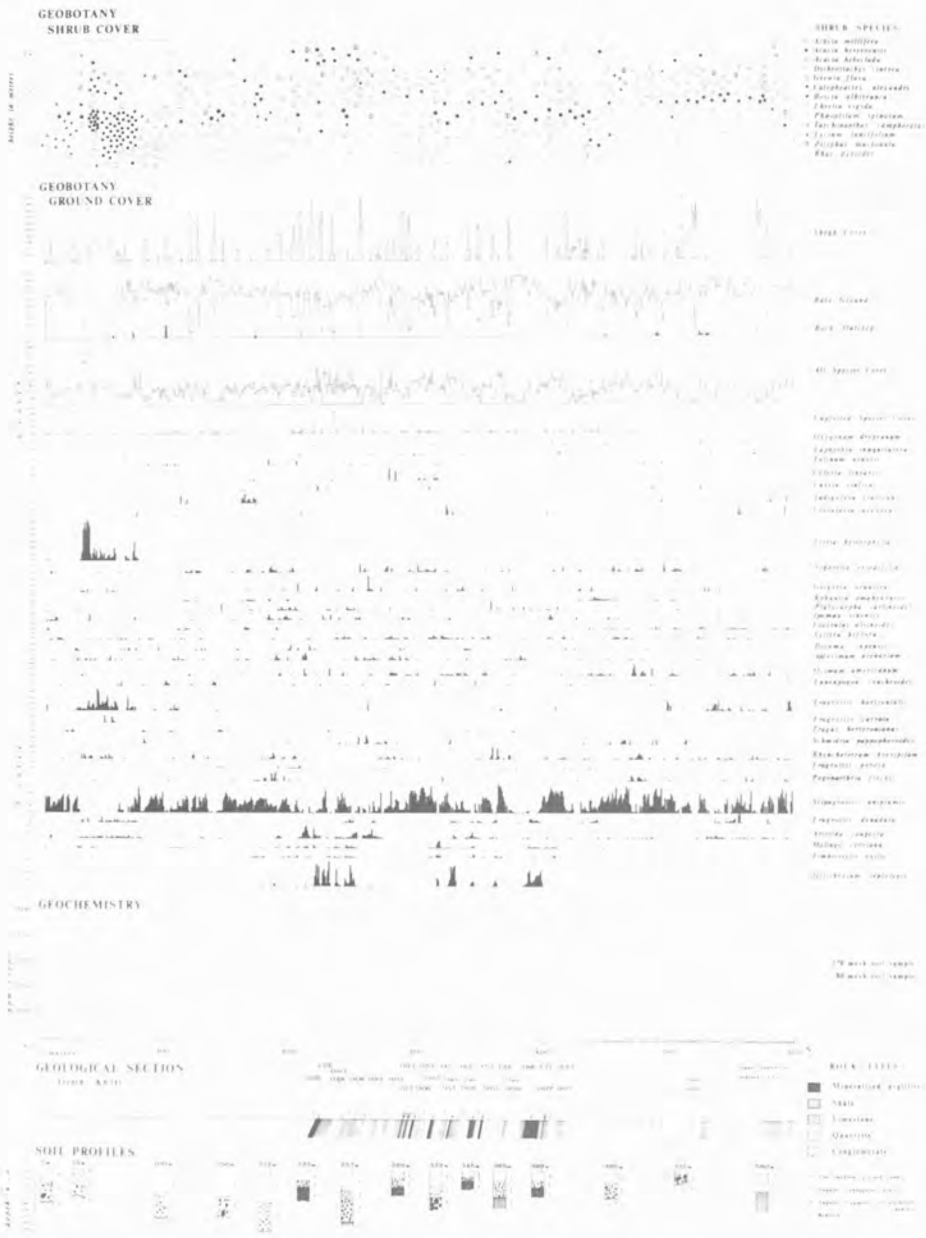


Fig. 17 Transect 55, Copper Causeway area, showing the relationship between the distribution of plant species, soil geochemistry, geology and soil profiles.

of medium to fine sand with small quantities of gravel and other size fractions.

The mesh fraction analyses of bulk samples (Fig. 18) shows that the gravel content of the surface layer varies from 4 - 31% and the coarse and very coarse sand from 11 - 23%. The major part of the soil is medium and fine sand forming 46 - 65% and the very fine sand forms 9 - 28% of the sample. The silt and clay fractions are small and form only 4 - 8% of the total. The surface material is poorly sorted and there does not appear to be any significant changes in the composition over varying bedrock types.

The rocks exposed in the trench section comprise a sedimentary sequence of shales, quartzites, conglomerates and limestones and show rapid alternations of lithological units. In some sections fine grained argillites are followed by conglomerate bands containing rounded pebbles upto 3 cm. in diameter. Many of the argillaceous rocks are calcareous and one broad zone of limestone is present in the sequence from 240 - 255 m. In the section from 220 - 420 m., where the mineralization occurs, the proportion of fine grained rocks increases. The copper mineralization is in the argillites and ten distinct zones are present which vary in copper content from 0.33 - 3.71%. Several shale and quartzite horizons within the main area of mineralization contain small amounts of copper, whereas the rocks sampled between 410 - 600 m. have only trace values.

Soil samples, sieved to -80 and -270 mesh, were collected at 10 metre intervals along the transect and a corresponding zone of anomalous copper content was revealed in each mesh fraction. The -80 mesh samples from background have 5 - 20 ppm. copper whereas those samples in the mineralized zone all contained over 150 ppm., with peak values in the range 200 - 400 ppm. The peak values of copper coincide with bands of mineralized argillite in all cases. The background copper content of the -270 mesh samples varies from 10 - 50 ppm. and the peak values of samples over mineralization exceed 500 ppm. The graph of the -270 mesh copper values closely fol-

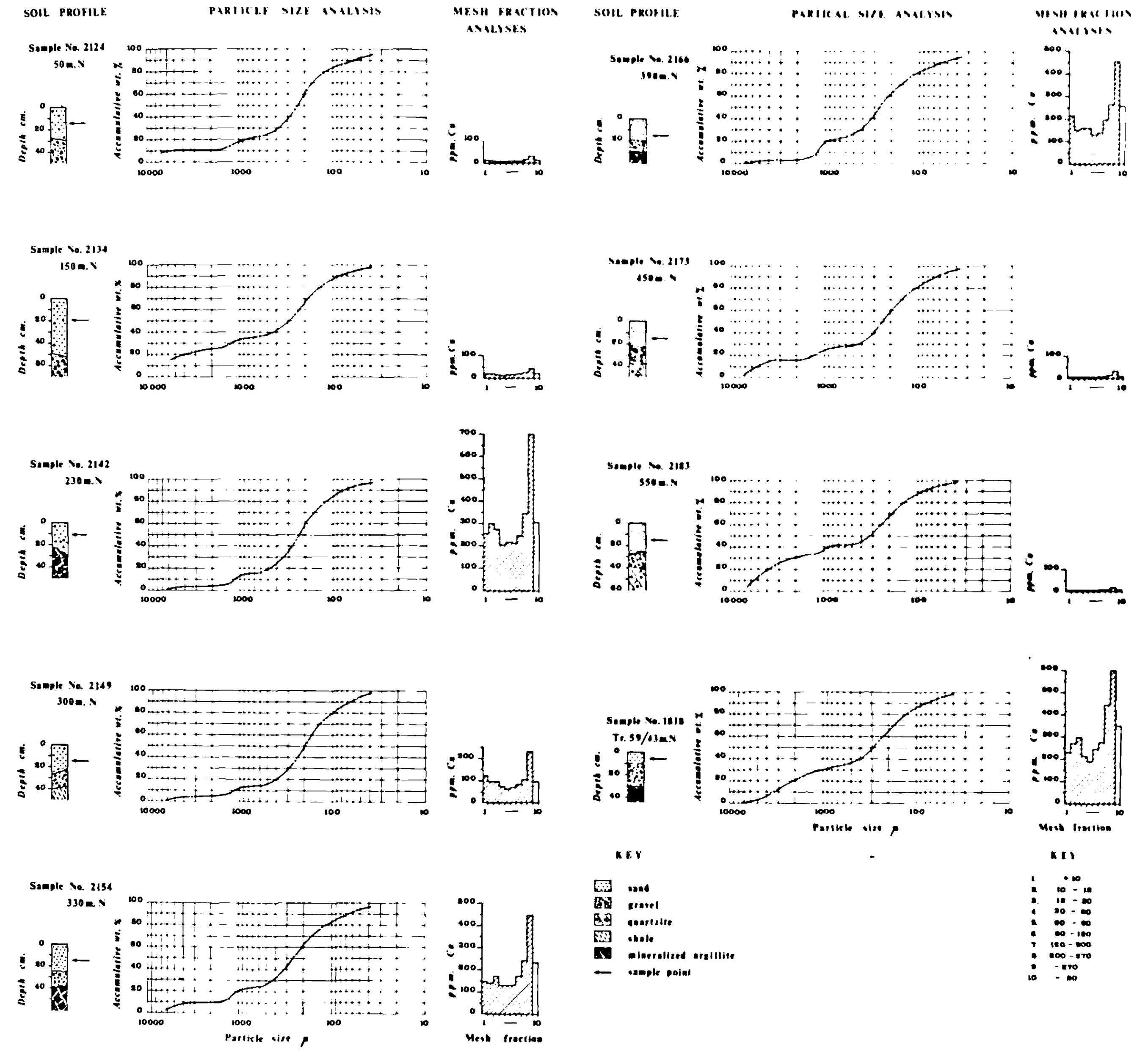


Fig. 18 Particle size analysis and mesh fraction analyses for copper, of bulk soil samples from Transect 55 (8 samples) and Transect 59 (1 sample) Copper Causeway.

lows the -80 mesh graph and the values are approximately twice the -80 mesh values.

The size fractions sieved from the bulk soil samples were also analysed for copper and the results shown in Fig. 18. The four samples from 50, 150, 450 and 550 m., outside the mineralized zone, have very low copper values in all size fractions, attaining a maximum of 50 ppm. in the -270 mesh. The remaining samples from 230 - 390 m., within the mineralized zone, indicate that all mesh fractions have a high copper content several times the background. The lower copper values are from the 30 - 120 mesh range and there is a marked increase in the finer fractions upto a maximum in the -270 mesh.

The pH was measured on the bulk soil samples collected along the transect and the values range from 5.1 - 6.4 (Table 12). There does not appear to be any direct relation between the pH of the soil and the underlying rock type or the copper content of the soil. The soils over the mineralized argillites show almost the complete range of pH from 5.1 - 6.3.

Geobotany

The species of grasses, herbs and forbs form an average ground cover of 20 - 30% and only occasionally form more than 50%. The bare ground consists of areas of sandy soil as outcrop only forms a minor part of the surface.

Helichrysum leptolepis is confined to the section where the soils are high in copper content and has its greatest concentration directly over the zones of mineralized argillite. In these areas it forms from 20 - 40% of the ground cover and few other species occur in the vicinity. Fimbristylis exilis is also confined to the zone of high copper val-

Distance m. N	pH of Soil	ppm. Copper	Soil Colour	
			Dry	Wet
5	5.7	7	5YR.5/4	5YR.4/4
50	5.7	10	4/4	4/3
100	6.4	22	4/6	4/4
150	6.0	23	5/6	4/4
200	6.3	70	5/4	4/4
230	6.3	272	5/6	4/4
250	6.0	210	5/4	4/4
300	5.9	102	5/6	4/4
317	5.6	232	5/6	3/4
330	5.6	260	5/4	4/4
350	5.2	255	5/6	4/4
361	5.6	445	5/6	4/4
390	5.1	200	5/6	4/4
400	6.0	135	5/6	4/4
450	5.9	5	4/6	4/4
500	5.8	7	5/6	4/4
550	5.3	10	4/6	3/4
600	5.4	5	5/6	4/4

Table 12. pH, copper content and colour of bulk soil samples from Transect 55, Copper Causeway.

ues, forming upto 5% cover in places. However, it does not show any marked increase directly over mineralized bedrock.

The species Mollugo cerviana, Aristida congesta and Eragrostis denudata occur throughout the transect but show a greater concentration in the areas of copper mineralization. Aristida congesta forms 20% of the ground cover from 200 - 250 m. and Eragrostis denudata is associated with the areas of Helichrysum leptolepis between 300 and 400 m. However, these two grass species generally occur peripheral to Helichrysum leptolepis and the copper mineralization.

Stipagrostis uniplumis, the main perennial grass species of the area, forms an average cover of 10 - 30% but is absent from all the areas of Helichrysum leptolepis where the copper content of the soil is high. It is also absent from 30 - 70 m. on the transect where a distinct vegetation association occurs along a fossil drainage feature. In this zone the grass species are Eragrostis horizontalis, Rhyncheletrum brevipilum, Aristida congesta and Eragrostis denudata and the creeping legume Listia heterophylla is also present forming upto 80% ground cover. This distinct association is possibly due to the very thin cover of soil, only about 5 cm., which rests on a coarse angular gravel of quartzite and forms a limiting factor for the rooting systems. The association Eragrostis horizontalis, E. denudata and Aristida congesta also occurs from 500 - 600 m. where there is gravel close to surface, but Stipagrostis uniplumis is also present in scattered clumps. The other grass species recorded on the transect are not very common. Pogonarthria fleckii occurs mainly in the background areas whereas the other species occur throughout the transect with the exception of the areas of Helichrysum leptolepis.

The majority of the herbs and forbs are present throughout the transect including the section from 200 - 400m. where there are higher copper values for the soils. However, these species with the exception of Cassia italica and Ocimum americanum do not occur in association with Helichrysum leptolepis over the mineralized argillites. Dichoma capensis, Evolvulus alsinoides, Kohautia omahekensis and Indigofera *flavicans* only occur in the background areas of low copper concentration. Individual species rarely form more than 10% of the ground cover along the transect.

Seventeen further herb species and six grass species listed in Table 13 also occur in minor percentages on the transect and are grouped as unplotted species on Fig. 17.

1. *Anthephora pubescens*	13. *Cyphocarpa angustifolia*
2. *Aristida adscensionis*	14. *Hermannia damarana*
3. *Aristida effusa*	15. *Hirpicium gorterioides*
4. *Brachiaria nigropedata*	16. *Indigophera heterotricha*
5. *Cenchrus ciliaris*	17. *Limeum viscosum*
6. *Eragrostis superba*	18. *Otoptera burchelli*
7. *Acrotome inflata*	19. *Platycarpha carlinoides*
8. *Aptosimum leucorrizum*	20. *Portulaca grandiflora*
9. *Asparagus africanus*	21. *Pupalia lappacea*
10. *Blepharis leentertziae*	22. *Sida chrysantha*
11. *Chascanum pinnatifidum*	23. *Tribulus zeyheri*
12. *Commelina benghalensis*	

Table 13. Grass species (1-6) and herbs (7-23) also occurring on Transect 55 and grouped as Unplotted Species in Fig. 17.

Across the area the tree and shrub cover is very open with approximately one species per ten square metres. The majority are from 50 cm. to 2 m. in height and the most common species are *Grewia flava*, *Acacia hebeclada*, *A. hereroensis*, *A. mellifera* and *Phaeoptilum spinosum*. *Catophractes alexandri* shrubs form a marked concentration from 40 - 80 m. but the species is not common in this region. All species of trees and shrubs are absent from the zones of mineralization. This is not apparent in the shrub cover diagram of Fig. 17 as the species were recorded in 10 m. quadrats and some of the zones of mineralization are only 1 - 2 m. wide. The species composition does not show any marked changes across the mineralized section from 200 - 400 m. but there is a slight concentration of tall *Acacia hereroensis* from 200 - 250 m.

Biogeochemistry

The most commonly occurring shrubs and grasses were sampled at 10 to 20 m. intervals along the transect and the less common species wherever present. The ash weight and dry weight copper values for all samples are shown in Fig. 19, and a graphical plot of the copper content of the plant with the copper content of the soil is shown in Fig. 20.

The samples of Stipagrostis uniplumis show a marked increase in copper content between 200 - 400 m. on the transect. In this zone the copper content varies from 7 - 20 ppm. dry weight, whereas the mean value for the background samples is 3.1 ppm. The samples with the highest copper content of 20.8 and 18.6 ppm. occur at 230 and 362 m. respectively and border zones of Helichrysum leptolepis over copper mineralization. The graphical plot of plant and soil copper values (Fig. 20) indicates that the S. uniplumis samples from the background areas all contain less than 5 ppm. There is a linear relationship through the intermediate values to a maximum of 20 ppm. copper in the grass where the soil values reach 250 - 300 ppm.

Fewer samples of the grass species Aristida congesta could be collected because of its more scattered distribution in the area but a comparison of samples from background and near to mineralization can be made. The samples from background have a very low mean copper content of 1.6 ppm. and the values increase in the mineralized section of the transect to a maximum of 6.2 ppm. at 385 m., which is over copper mineralization. The graphical plot indicates two groups of samples. The background samples contain 1 - 2 ppm. and those from the higher copper sites 4 - 6 ppm. The copper content of Aristida congesta is extremely low even where it is associated with Helichrysum leptolepis over mineralization.

The leaf samples of Grewia flava show an increase in copper across the mineralized zone from 200 - 400 m. In this section the leaves contain more than 20 ppm. compared to the mean background value of 14.6 ppm. The highest values in the range 25 - 31 ppm., from the locations 230, 320, 345 and 398m.,

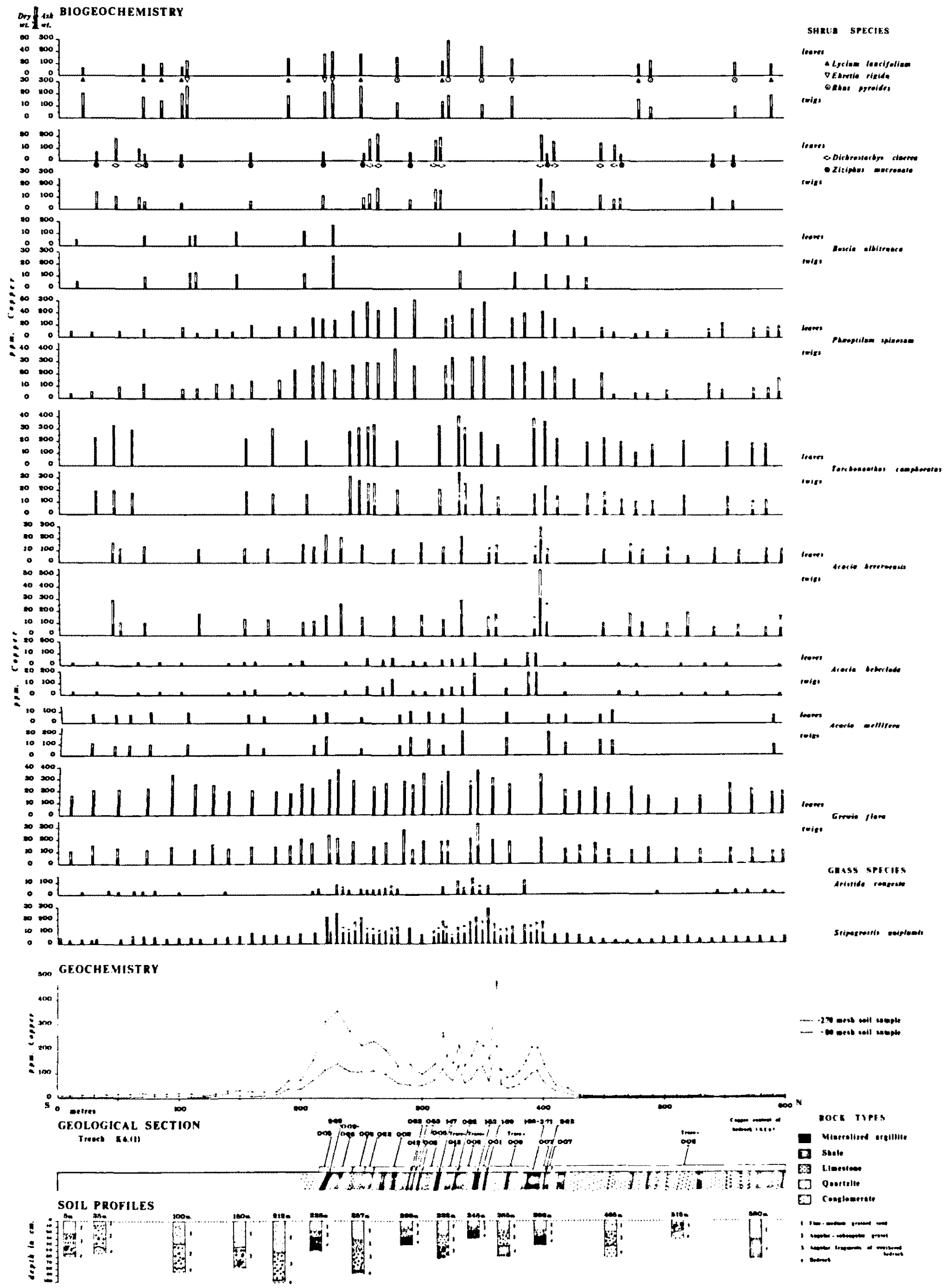


Fig. 19 Transect 55, Copper Causeway showing the relationship between biogeochemistry, soil geochemistry and geology.

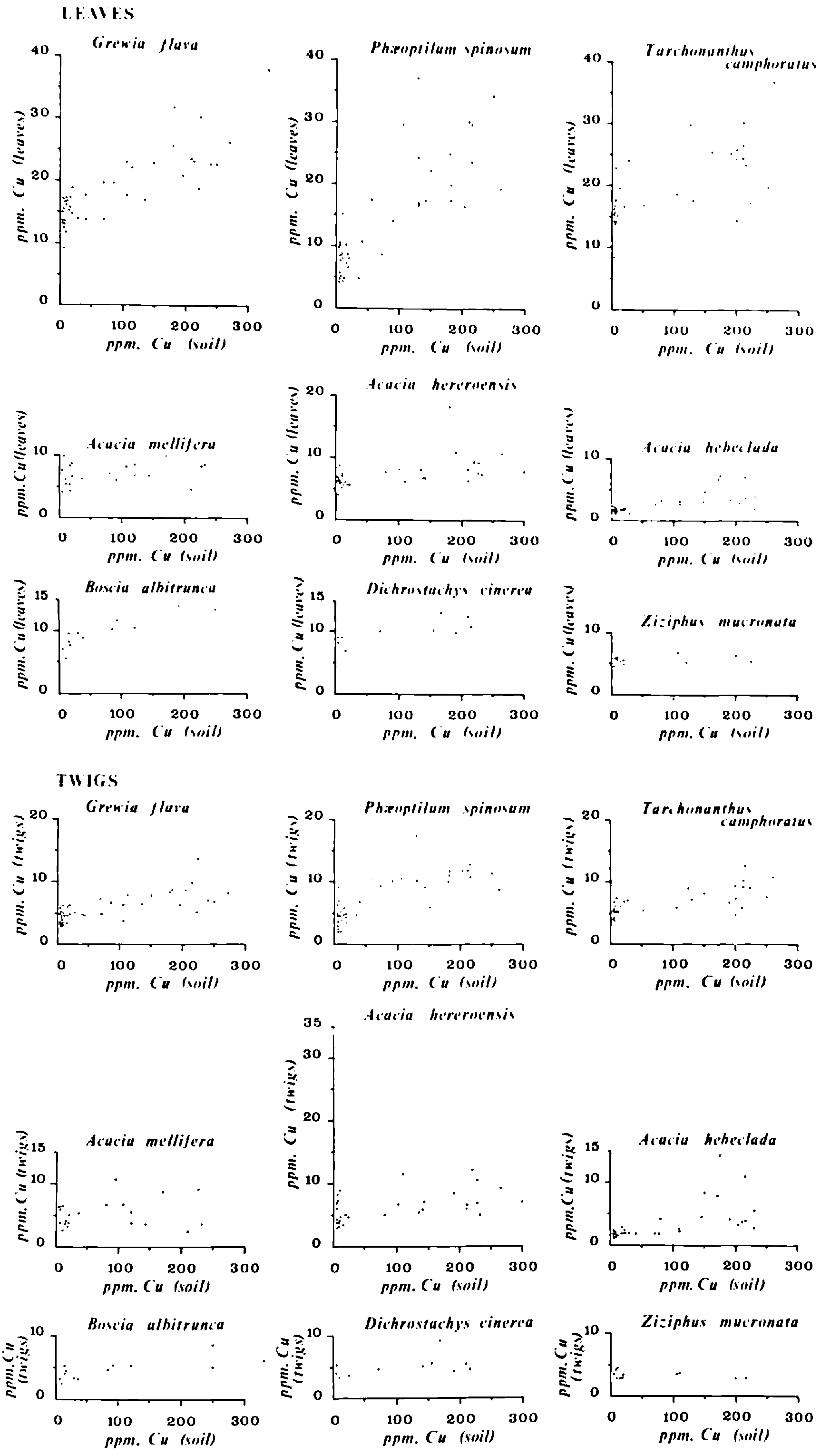


Fig. 20 The relationship between the copper content of plant species, leaves and twigs and the copper content of the soil (-80 mesh).

are all adjacent to horizons of mineralized argillite. The maximum copper content of the twigs of 13.6 ppm. is from the sample at 345 m. and the samples from the mineralized section generally exceed 8 ppm., compared to 4.7 ppm. for the mean background value for the twigs. Figure 20 shows a linear relationship from background samples containing 12 - 17 ppm. to the anomalous leaf samples in the range 20 - 30 ppm., where the soils contain more than 100 ppm. The twigs have 3 - 7 ppm. copper from sites where the copper content of the soil is low, increasing to 7 - 10 ppm. where the soils exceed 200 ppm. copper.

Acacia mellifera leaves show a very small range of copper values, 4.1 - 10.5 ppm., and the higher values do not correspond with the areas of mineralization. The peak value of 10.5 ppm. is for the sample from 458 m. over barren quartzite. The twig samples have a similar range of values to the leaves, 2.5 - 10.8 ppm., and only two samples from the mineralized section exceed the background value. The graphical plot shows that the leaves from both high and low copper sites have the same range of values of 5 - 10 ppm. Similarly the twigs do not show any marked variation in copper content with the increasing values in the soils.

The samples of *Acacia hebeclada* have extremely low background levels of 1.7 and 1.9 ppm. copper for the leaves and twigs respectively. All the values above 2.5 ppm. are from samples in the mineralized section from 200 - 400 m. The highest leaf values of 6 - 7 ppm. copper, about four times the mean background, occur at 390 m. adjacent to mineralization. The twig samples from this location are also 4 - 5 times the background value. The graphical plot (Fig. 20) shows a cluster, for leaf samples, around 2 ppm. for the background areas, and the higher values of 5 ppm. are all from sites of 200 - 300 ppm. copper in the soil. A similar distribution is shown for the twig samples which contain 1 - 3 ppm. for the background soils and over 5 ppm. with soils containing more than 150 ppm. copper.

The highest copper values for the leaves of *Acacia hereroensis* are from samples adjacent to mineralization; 10.7

ppm. at 232 m., 10.8 ppm. at 332 m. and 18.2 ppm. at 397 m. However, the other samples from the mineralized section from 200 - 400 m. do not show any appreciable increase in copper content above the mean background value of 6.7 ppm. The twig sample from 397 m. contains 34.0 ppm. copper, which is twice the content of the leaves and six times the mean background for twigs on the transect. The samples from 397 m. (9 m.W) and 393 m. (3 m.E) have greatly different copper contents although these samples are only 12 m. apart and both adjacent to mineralization. In the graphical plot the leaf samples from background contain 5 - 7 ppm. copper and show increasing values as the copper content of the soil increases. The twigs of Acacia hereroensis have a wider variation of copper for the background samples, 3 - 9 ppm., but, do not show any marked increase with the high soil values.

The leaves of Tarchonanthus camphoratus have a very high copper content compared to the other species with a mean background value of 16.4 ppm. The samples with the highest values are adjacent to mineralization; 30 ppm. from 395 m. and 36 ppm. from 330 m., and most of the samples between 200 - 400 m. contain more than 25 ppm. copper. The twigs contain considerably less copper than the leaves and the mean background value for the transect is 5.6 ppm. The higher values for the twigs, greater than 9 ppm., do not all occur near to mineralization and do not correspond with the maximum values recorded for the leaves. The soil - leaf copper graph for Tarchonanthus camphoratus indicates that the background samples contain 14 - 17 ppm. and there is a general increase to 25 ppm. when the soils contain 200 ppm. copper. The twigs from background vary from 4 - 8 ppm. and the maximum values correspond to the soils containing 200 - 300 ppm. copper.

The leaf samples of Phaeoptilum spinosum collected between 200 - 400 m. contain from 17.4 - 37.1 ppm. copper which is considerably higher than the mean background of 7.6 ppm. for the transect. The twig samples are also much higher in copper content across the mineralized section, ranging from 9 - 12 ppm. compared with the mean background of 4.5 ppm.

The leaf samples corresponding with low soil values contain from 4 - 11 ppm. (Fig. 20) and are in the range 15 - 30 ppm. when the soils have more than 150 ppm. copper. Similarly the twigs show a general increase from 3 - 7 ppm. with background soils to greater than 10 ppm. where the soil contains 200 - 300 ppm. copper.

Only twelve samples of Boscia albitrunca were collected on the transect and the mean background value for the leaves is 8.0 ppm. copper. The maximum leaf value is 13.4 ppm. from 226 m., which is near copper mineralization, and the twig sample from the same location shows the maximum content for the species of 8.3 ppm. The mean background value for the twigs is 3.9 ppm. Both the leaves and the twigs show slight increases in copper content with increasing values in the soil (Fig. 20).

Eleven samples of Ziziphus mucronata taken from various sites along the transect show very low copper values and also a very small range; 4.9 - 6.6 ppm. for the leaves and 2.7 - 4.4 ppm. for the twigs. The graphical plot shows no detectable increase in the plant content of copper with increasing copper in the soils.

The highest values from the ten samples of Dichrostachys cinerea occur in the leaf and twig samples from 398 m., near to copper mineralization. These values are 13.1 and 9.1 ppm. compared with a mean background of 7.0 and 3.5 ppm. for the leaves and twigs respectively. The leaf samples in the section 200 - 400 m. have greater than 10 ppm. copper, showing a slight increase over the background samples. The twigs however, do not show any increase with increasing copper in the soil.

Rhus pyroides samples were collected from five sites along the transect. The leaf samples near to mineralization contain 17 - 25 ppm. copper compared to 8 - 12 ppm. for the samples from background. The twig samples from the mineralized section of the transect also contain more copper than those from background but the difference in values is not so great. The range in values for the twigs is 4 - 9 ppm.

Three samples of Ehretia rigida from 220, 226 and

375 m., within the mineralized section, have a copper content of the leaves between 15 - 24 ppm. compared to 10 ppm. for the sample from background at 103 m. The twigs do not show any great variation in copper content in the four samples with the range 9.8 - 11.5 ppm.

The six leaf samples of Lycium lancifolium from background sites contain from 12 - 16 ppm. copper whereas the three samples from the mineralized section have 24 - 32 ppm. The range of values for the twigs is 7 - 11 ppm. copper with the higher values from samples near to mineralization.

Transects 56, 57, 58 and 59

The ground vegetation was also recorded across four distinct zones of Helichrysum leptolepis along the transects 56 - 59, which vary in length from 50 - 80 m. The location of these transects is shown in Fig. 16. No outcrops occur on the transects but, the soil profiles (Fig. 21) indicate that only a thin cover of sand and gravel mask the mineralized argillites (Plates 25 and 26). Over the quartzites the soil cover is usually 80 cm. - 1 m. and consists of angular to sub-angular gravel of quartz and quartzite resting on blocks of weathered bedrock. The surface soil is medium to fine sand with small quantities of gravel, silt and clay. Particle size analyses for sample 1818, taken from a 10 cm. depth on Transect 59, (Fig. 18) indicates that the soil contains 21% gravel, more than 50% medium and fine grained sand and only 4% silt and clay combined.

The geological sections for Transects 56 and 57 are taken from trench K.6.(2) which is about 5 m. from the transect lines. Short trenches, extending just beyond the zones of Helichrysum leptolepis, were opened to reveal the bedrock on transects 58 and 59. The trench section of Transect 59 crosses the corridor feature (Plate 25) and the edge of the main pan of the Copper Causeway (Plate 24) where Helichrysum leptolepis is the dominant plant species. Mineralized argillite occurs in the trench below the corridor of Helichrysum

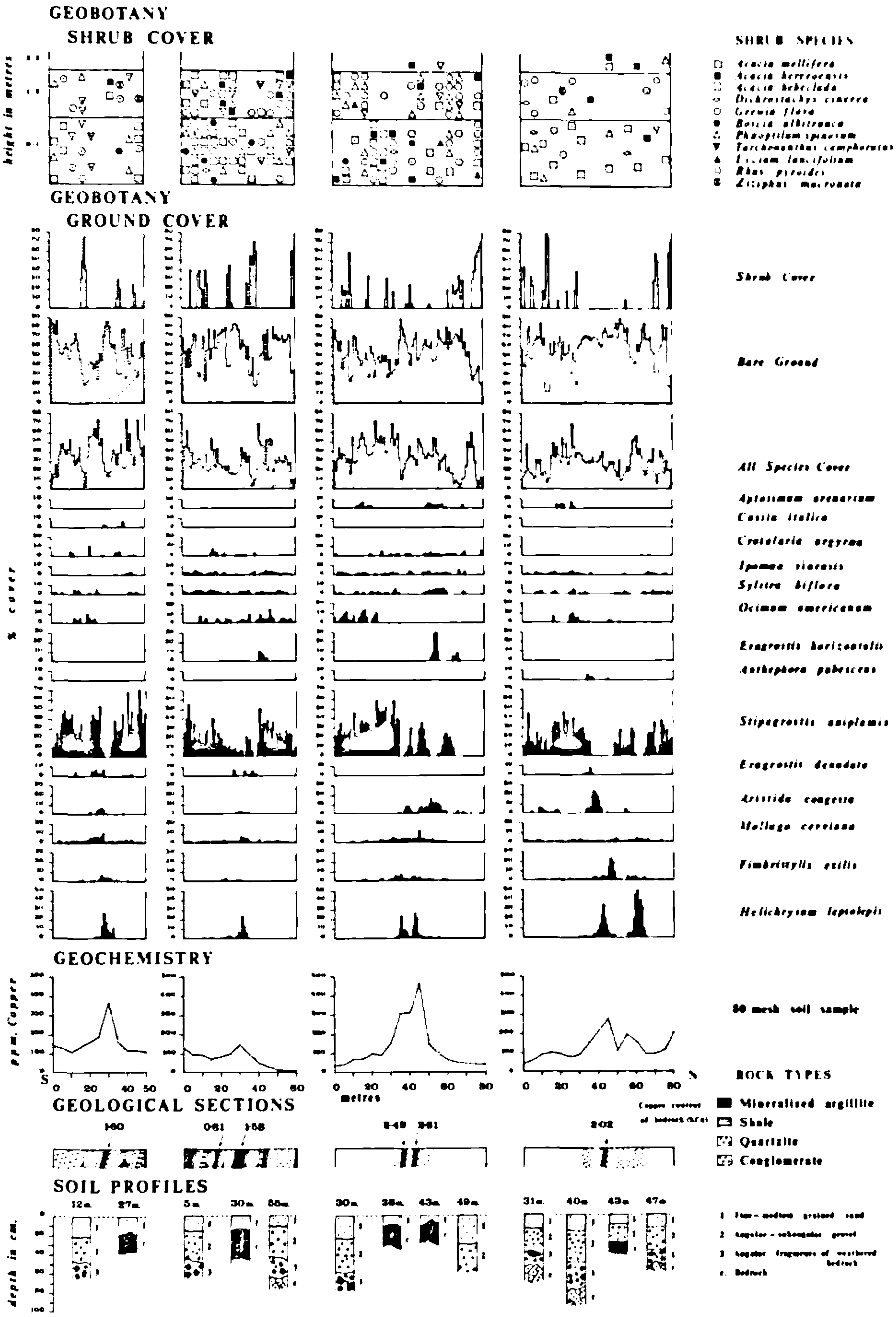


Fig. 21 Transects 56, 57, 58 and 59, within the Copper Causeway area, showing the relationship between the distribution of plant species, soil geochemistry, geology and soil profiles.

leptolepis (Plate 25) but quartzite is present on the edge of the pan.

Geobotany

The transects do not extend into the regional background, but the geochemical peaks for copper of the -80 mesh soil fraction coincide with the mineralized argillite exposed in the trenches. Helichrysum leptolepis has its maximum occurrence in these areas forming up to 25% of the ground cover on three of the transects and 50% on Transect 59.

Fimbristylis exilis, Aristida congesta and Eragrostis denudata are associated with Helichrysum leptolepis over the mineralization (Fig 21) and Anthephora pubescens borders the copper zone on Transect 59. Mollugo cerviana occurs throughout the transect but shows a slight increase in density over the mineralization on Transects 56 - 58. The most common grass species of the background areas is Stipagrostis uniplumis which forms 20 - 40% cover in most places. This species cuts out completely directly over the mineralized argillite. The remaining species plotted on Fig. 21 and recorded in Table 14 are absent from the zones of copper mineralization, with the exception of Cassia italica which occurs with Helichrysum leptolepis at approximately 30 m.N on Transect 56. Ocimum americanum is adjacent to mineralization on all transects and Aptosimum arenarium occurs on each side of the mineralized zone on Transect 56.

The species composition of the shrub cover is very similar along the transects, consisting mainly of Grewia flava, Acacia hebeclada, A. mellifera, A. hereroensis, Phaeoptilum spinosum and Tarchonanthus camphoratus, but there is a wide variation in the shrub density.

Plate 25 View south-eastwards along the corridor of Helichrysum leptolepis intersected by Transect 59, Copper Causeway. Fimbristylis exilis, Mollugo cerviana, Aristida congesta and Eragrostis denudata also occur within the corridor and Anthephora pubescens along the margins. Mineralized argillite is exposed in the trench section directly below the zone of Helichrysum leptolepis. (Ref. MM/SWA 25/51,52.)

Plate 26 View northwards along the trench section of Transect 58, Copper Causeway. The two zones of mineralized argillite form more resistant horizons than the quartzites.
(Ref. MM/SWA 25/29,30)

1.	*Enneapogon cenchroides*	11.	*Dichoma capensis*
2.	*Eragrostis horizontalis*	12.	*Evolvulus alsinoides*
3.	*Eragrostis porosa*	13.	*Euphorbia inaequilaterans*
4.	*Eragrostis superba*	14.	*Geigeria ornativa*
5.	*Rhynchelytrum brevipilum*	15.	*Hirpicium gorterioides*
6.	*Schmidtia pappophoroides*	16.	*Kohautia omahekensis*
7.	*Acrotome inflata*	17.	*Platycarpha carlinoides*
8.	*Celosia linearis*	18.	*Portulaca grandiflora*
9.	*Cenchrus ciliaris*	19.	*Talinum arnotii*
10.	*Chascanum pinnatifidum*	20.	*Vernonia fastigiata*

Table 14. Grasses (1 - 6) and herbs (7 - 20) also occurring on Transects 56 - 59, Copper Causeway, and not plotted on Fig. 21.

Biogeochemistry

Plant samples were collected along the transects, but as the transects only go a short distance on either side of the mineralization the majority of the samples have an anomalous copper content. The analytical results for these samples are shown in Tables IV. 22 - 26 (Appendix).

The samples of *Stipagrostis uniplumis* generally show increasing copper content with increasing copper in the soils. The grass samples, from areas where 200 ppm. and greater is recorded for the soils, vary in copper content from 13.5 - 30.3 ppm.

The *Grewia flava* samples show a wide variation in copper content of the leaves and twigs; 10.2 - 39.7 ppm. and 3.9 - 12.6 ppm. respectively. The maximum values for the leaves from Transects 57 and 58 are from shrubs growing adjacent to known mineralization and the five samples from 49 - 79 m. on Transect 59 which border an area of *Helichrysum leptolepis*. The copper content of the twigs of these samples is also correspondingly high.

The mean copper content of Phaeoptilum spinosum leaves from background on Transect 55 is 7.6 ppm. The majority of the samples from Transects 57 - 59 contain several times this background level with peak values in the range 32 - 40 ppm. and 110 ppm. The high values in the plants correspond to sites where the copper content of the soil is also high. The twig samples of Phaeoptilum spinosum from these transects have 2 - 5 times the copper content of the background samples collected from Transect 55.

Six of the Acacia hereroensis leaf samples have a copper content considerably higher than the mean background for the area of 6.7 ppm., calculated for Transect 55. The copper content of the twigs of these six samples; Tr. 57, 30 m., Tr. 58, 41 m. and Tr 59, 58 m., 68 m. and 80 m.; are also the highest values recorded. The samples of Acacia hereroensis from 35 and 48 m. on Tr 58 and 45 m. on Tr 59, from sites where the surface soil has a high copper content, have only background levels of copper in the leaves and twigs. The shrub samples at 68 m. on Tr. 59 has the highest level of copper in the leaves (30.3 ppm.) and twigs (16.3 ppm.) but the surface soil is not extremely high in copper.

Six other shrub species were sampled on Transects 57 - 59 and the results of analyses closely follow the trends indicated from Transect 55 for these species. The leaves of Acacia mellifera from 4 and 30 m. on Transect 57 have the highest copper values for the species, the latter site being nearer to mineralized argillite. Three leaf samples of Lycium lancifolium have an extremely high copper content ranging from 26.0 - 34.8 ppm., compared to the background range of 12 - 16 ppm. for Transect 55. The highest values recorded for the leaves of Rhus pyroides and Tarchonanthus camphoratus are from shrubs growing in areas where the soil is also high in copper.

Transects 74 and 76

Additional samples of Stipagrostis uniplumis and Grewia flava leaves were collected along Transects 74 and 76 at approximately 10 m. intervals. On Transect 74, from 0 - 150 m. and 470 - 600 m., where the surface soils contain very little copper the grass samples have less than 4 ppm. copper (Fig. 22). Between 210 - 300 m. Stipagrostis uniplumis contains more than 6 ppm., four samples exceed 10 ppm. and the maximum value recorded is 14.8 ppm. copper from 270 m. Two further samples exceed 6 ppm., from 420 and 430., and the soils for all these locations have more than 100 ppm. copper in the -80 mesh fraction.

The majority of the grass samples from Transect 76 contain less than 4 ppm. copper. The samples from 60 and 70 m. are slightly above the background level for copper and those from 350, 440, 560 and 570 m. exceed 6 ppm. The soil values for the second group of locations are in the range 40 - 90 ppm. copper but at 60 and 70 m. values of 10 ppm. are recorded.

The leaf samples of Grewia flava show a wide range in copper content from 9.2 - 27.8 ppm. (Fig. 22) The highest values in the range 21 - 28 ppm. are from samples at 305, 508, 555, 565 and 575 m. The copper content of the corresponding soil samples varies from 40 - 70 ppm.

Summary of the results of the geobotanical transects.

The zones of copper mineralization exposed by the trenches on Transects 55 - 59 are clearly defined by a characteristic anomalous vegetation and a high copper content of the soils. The broader area of mineralization is reflected by biogeochemical highs in the leaves and twigs of several plant species.

The background vegetation for the area consisting of a wide variety of low trees and shrubs, grasses and herbs, cuts out on either side of the mineralized zone. The vegetation over

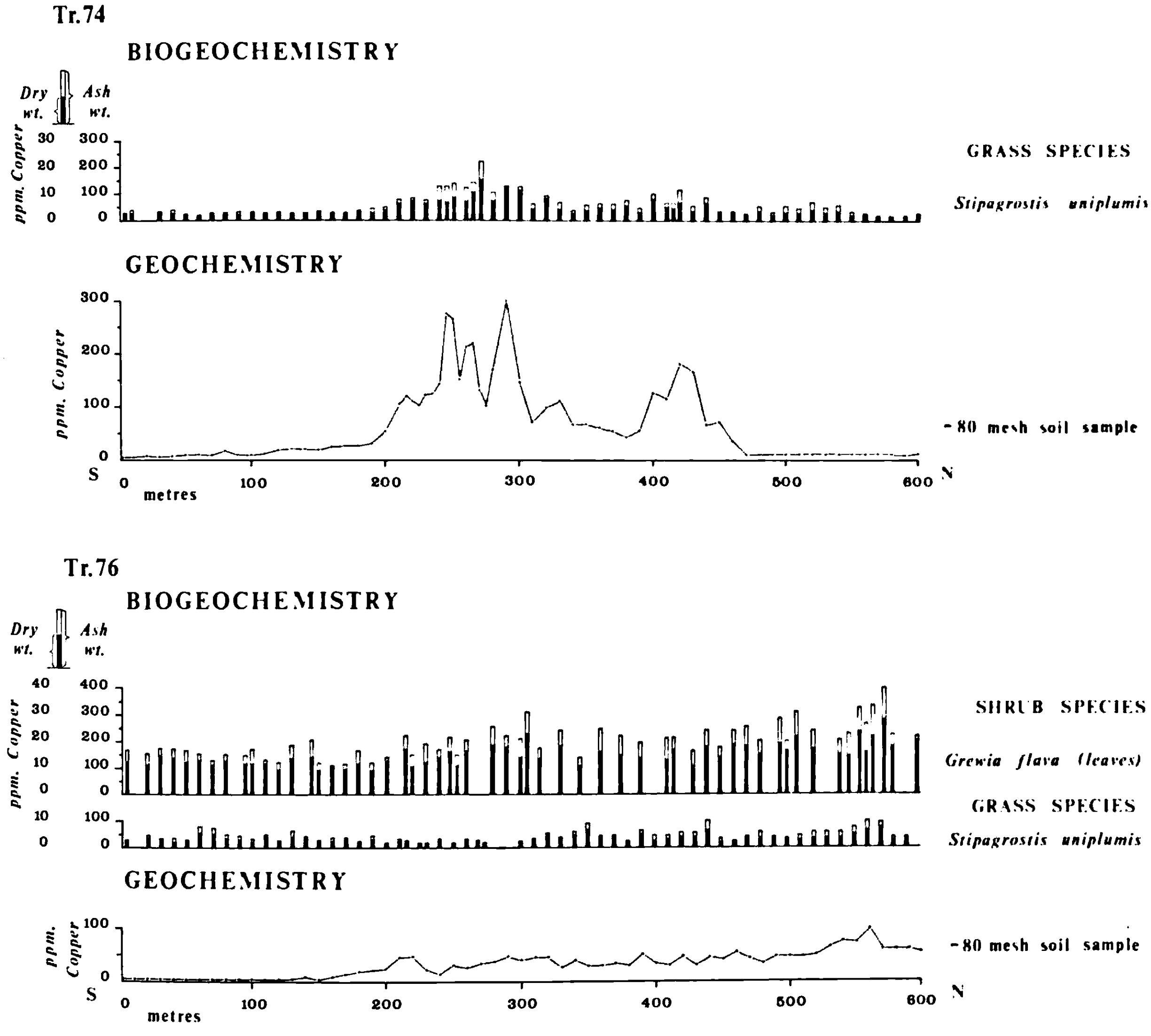


Fig. 22 Transects 74 and 76, Copper Causeway area, showing the relationship between biogeochemistry and geochemistry for the grass species <u>Stipagrostis uniplumis</u> and the shrub species <u>Grewia flava</u>.

mineralization consists of Helichrysum leptolepis and Fimbristylis exilis with scattered occurrences of Mollugo cerviana, Aristida congesta and Eragrostis denudata.

The soils over the zones of mineralization show peak copper values in the range 200 - 400 ppm. for the -80 mesh and all samples in the mineralized section from 200 - 400 m.N Tr. 55 exceed 100 ppm. compared to less than 10 ppm. for the background section of the transect. The -270 mesh copper values are approximately twice the -80 mesh value in all cases.

The biogeochemical studies show that several species have contrasting copper values for leaf and twig samples collected in the mineralized areas and the background sections of the transects. A clearer division between anomalous and background values, with more consistent results, is shown by the leaf samples of Grewia flava, Phaeoptilum spinosum and Tarchonanthus camphoratus.

Geobotanical mapping and interpretation of the copper mineralization

Transect 55 was used as a base line for the mapping and a 50 m. grid was surveyed over an area of 600 x 400 m. Within this region the principal vegetation associations were determined and their extent outlined, (Fig. 23).

Many distinct areas of Helichrysum leptolepis occur in the central section, but collectively do not follow any specific pattern or structural trend. The larger areas are pan-shaped 10 - 15 m. across and one has a tail-like extension for 40 m. to the southeast (Plate 24). Three areas are isolated from the main group; at 220 m.N/120 m.E intersected by Transect 58, 430 m.N/130 m.E and 550 m.N/180 m.E in the extreme northwest corner. Fimbristylis exilis is associated with Helichrysum leptolepis in all these areas and Mollugo cerviana may be present. Shrubs, grasses and other herb species do not usually occur in this association.

In several locations areas of Helichrysum leptolepis are surrounded by, and linked by zones of Aristida congesta and scattered occurrences of Helichrysum leptolepis. The

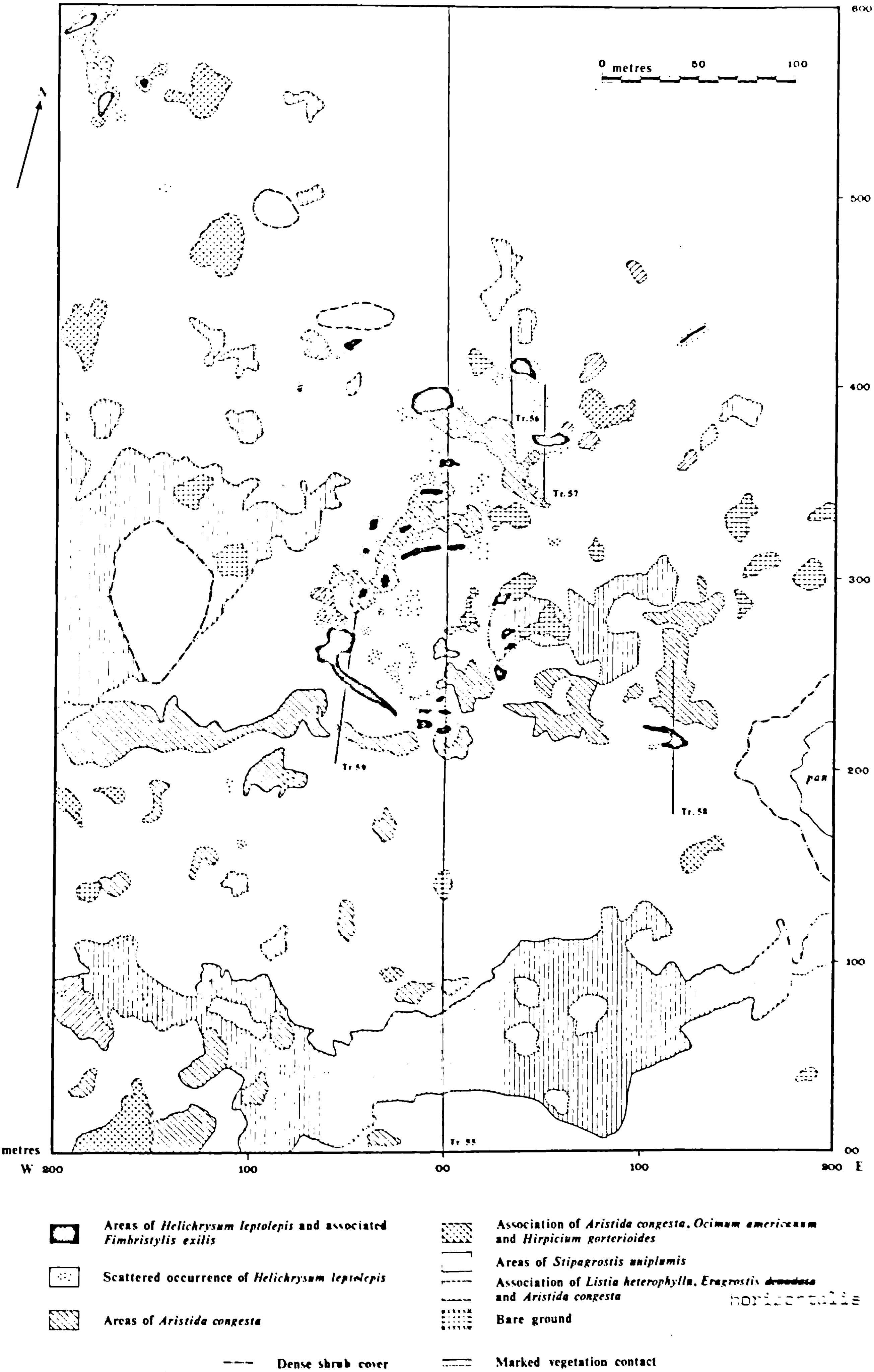


Fig. 23 The distribution of vegetation associations in Copper Causeway area.

grasses Erogrostis denudata, Anthephora pubescens and the herbs Ocimum americanum, Cassia italica and Crotalaria argyrea may also be present within these areas.

The major part of the mapping area has a uniform cover of the perennial grass Stipagrostis uniplumis. The grasses Rhyncheletrum brevipilum, Schmidtia pappophoroides, Eragrostis porosa and Pogonarthria fleckii are also fairly common interspersed among clumps of Stipagrostis uniplumis. The annual and perennial herbs, and additional grass species listed for Transect 55 occur in this association and together form the background vegetation of the area. Scattered Helichrysum leptolepis occurs among Stipagrostis uniplumis in the central region.

The shrub cover, consisting mainly of Grewia flava, Phaeoptilum spinosum, Acacia hebeclada, A. mellifera, A. hereroensis and Tarchonanthus camphoratus, is very open where Stipagrostis uniplumis is the dominant ground species. The majority of the shrubs are 1 - 2 m. in height with occasional large Acacia mellifera (3 - 4 m.) scattered through the area.

The association of Listia heterophylla, a creeping legume, and the grasses Eragrostis horizontalis and Aristida congesta form an extensive E - W zone in the southern section of the grid and outline a fossil drainage feature, which links two pans. The grasses Eragrostis denudata, Rhyncheletrum brevipilum, and herbs Platycarpha carlinoides, Aptosimum arenarium and Geigeria ornativa also predominate in this feature. The shrubs tend to occur in groups with tall Tarchonanthus camphoratus surrounded by Acacia hebeclada and Acacia mellifera.

A similar vegetation association with Eragrostis horizontalis the dominant species, occurs along the western margin of the area from 220 - 380 m.N around an area of denser shrub cover of Tarchonanthus camphoratus and Acacia hereroensis. This feature is also on a fossil drainage line linking two pans (Fig. 16) and from the air photograph appears to extend into the pan on the eastern border of the vegetation map. The feature crosses the main mineralized area and the extensive zones of Aristida congesta, trending E - W between 200 - 300 m.N, may be a reflection of the drainage line.

An isopleth map of the copper content of the soils was prepared for the area of the vegetation map. Samples were collected at 10 m. intervals along traverses spaced at 50 m. and parallel to Transect 55. The areas of high soil values, +150 ppm. in the -80 mesh fraction, include all the areas of Helichrysum leptolepis and associated Fimbristylis exilis (Fig. 24). However, the zones of high soil values do not extend significantly beyond the anomalous vegetation. In the region around 220 m.N/120 m.E the E - W spread of high values is caused by the drainage into the pan. There are no apparent east or west extensions, to the central zone of geochemical highs, along the direction of the regional strike.

The vegetation and soil geochemistry indicate that the surface expression of the mineralization is confined to the central section of the mapping area and no significant strike extensions occur.

Very few outcrops occur in the area and the geology observed was limited to the trench sections and the information available from wagon drilling (Fig. 25). The rocks in trenches K.6(1) and K.6(2) strike east - west and dip steeply to the south yet although these trenches are only 50 m. apart no distinct correlation of the sedimentary sequence could be made. Several short trenches and wagon drill sections were completed but the exposed mineralization in the trenches could not be extended with any degree of certainty. Several features suggest tight isoclinal folding which could explain the drilling and trenching results. In the western wall of the trench K.6(1), within the broad mineralized section from 390 - 400 m., the nose of a westerly plunging fold was observed. Ten metres beyond the trench to the west, on a strike extension of the mineralized argillite, quartzite was exposed by trenching; to the east, two narrow zones of mineralized argillite were located from wagon drilling. This

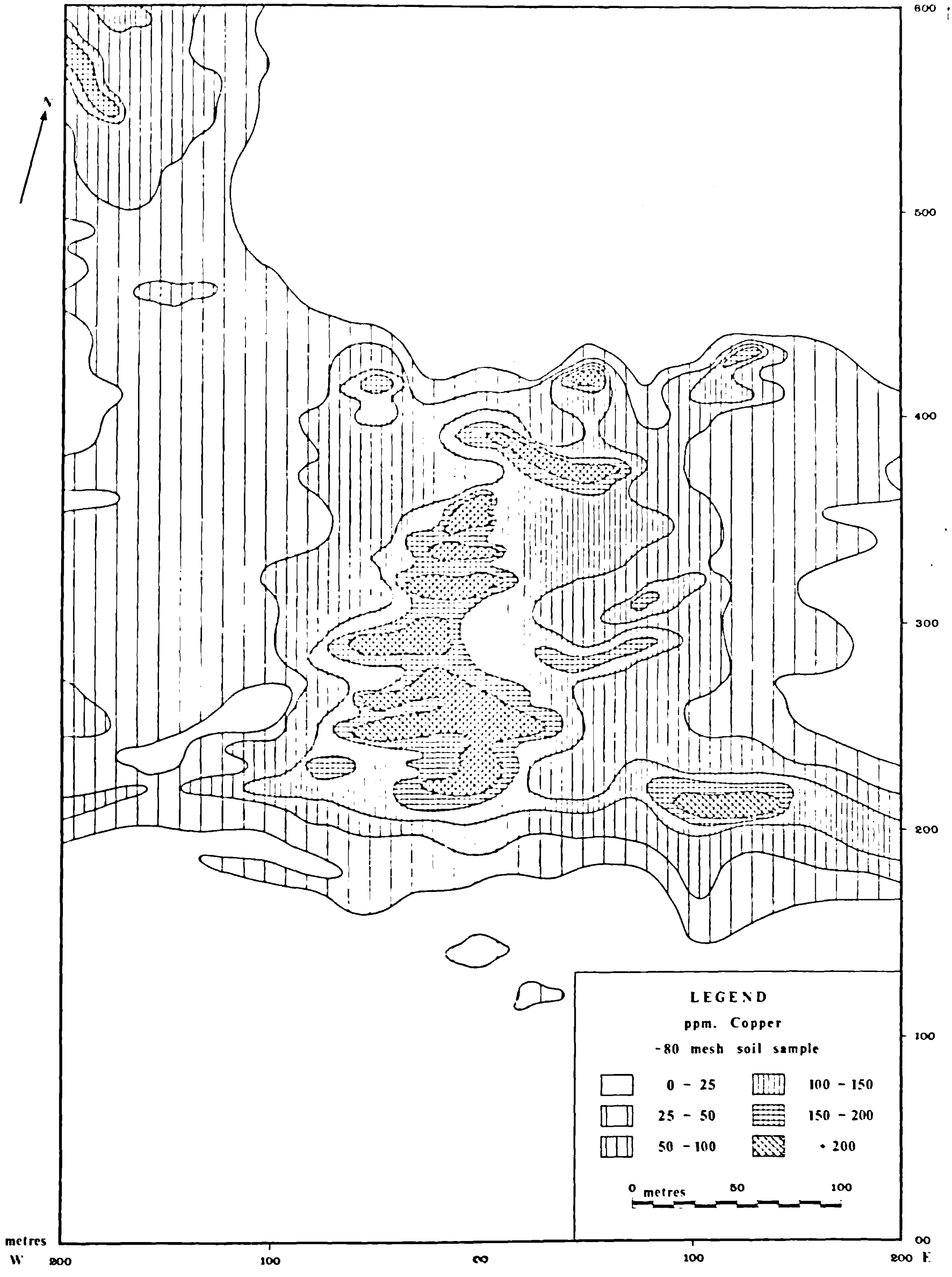


Fig. 24 The distribution of copper in the soils, Copper Causeway area. (-80 mesh fraction; 15cm. depth.)

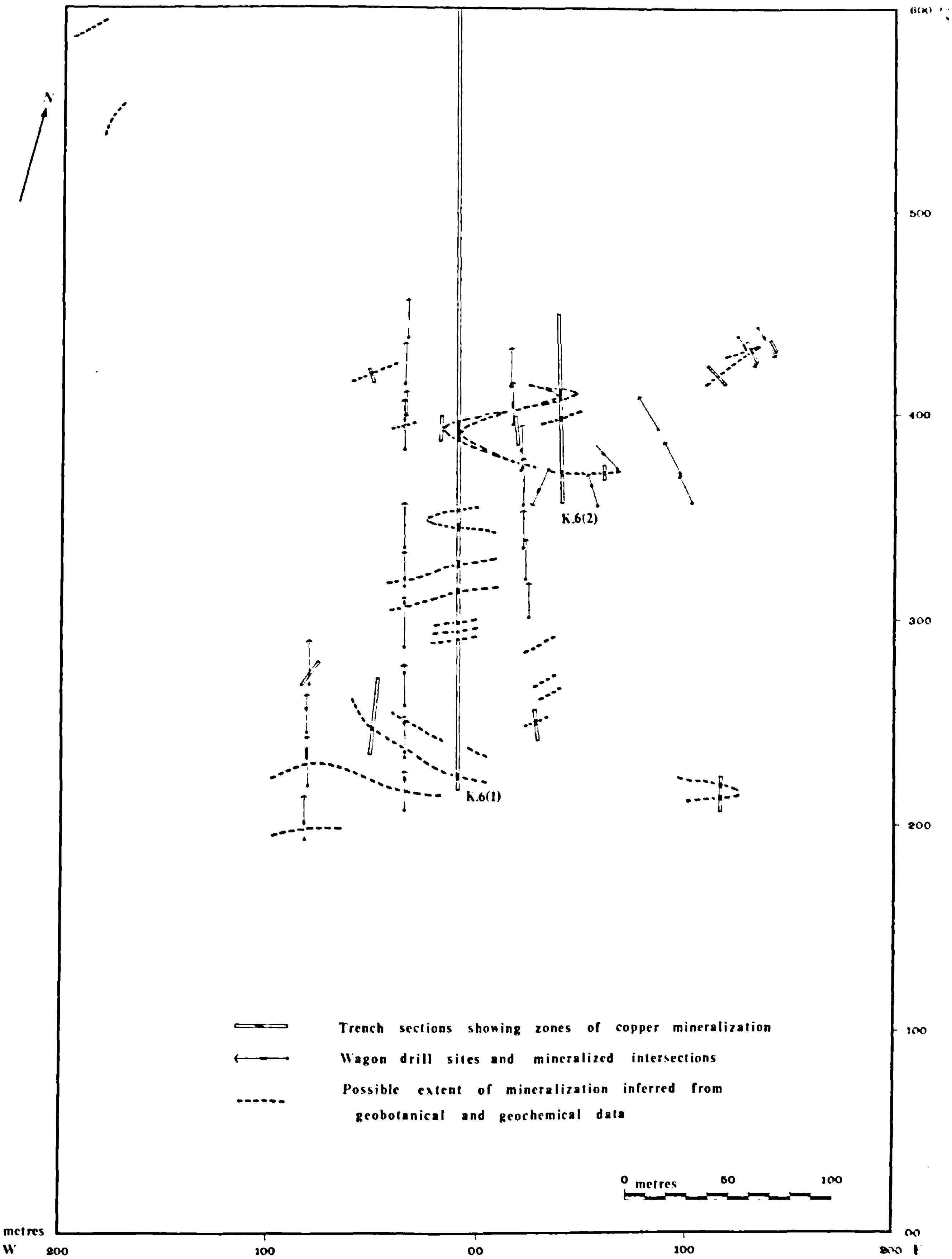


Fig. 25 Interpretation of the extent of copper mineralization at the Copper Causeway from geological, geobotanical and geochemical data.

suggests that the broad mineralized zone of 10 metres is the duplication and thickening of one horizon by folding. Strike trenches along anomalous vegetation zones crossing Transect 58 (220 m.N/120 m.E), show that two horizons of mineralized argillite exposed in the trench section come together in a fold structure which is outlined by an area of Helichrysum leptolepis.

C. THE MALACHITE PAN AREA

Introduction

Attention was first directed towards north-eastern Eskadron as geochemical anomalies were apparent from the regional reconnaissance survey (Fig. 6). All five traverse lines in this area show anomalous values, with many soil samples containing more than 200 ppm. copper. The region was visited in March 1968 in order to locate the anomalies in the field and to assess the potential of geobotanical surveys in the follow-up phase.

Several large areas of Helichrysum leptolepis were discovered and certain zones could be followed continuously for several hundred metres. Tracing the Helichrysum leptolepis zones led to the discovery of outcrops of mineralized argillite, with malachite staining, around the edges of a pan (Plate 27).

An initial programme of soil geochemistry and geobotanical mapping was planned to outline possible zones of mineralization for trenching and drilling phases. Geological information was also recorded from outcrops and the exposed bedrock in trenches, as additional sections were completed.

The regional strike, indicated from lineations in the vegetation on air photographs and the initial ground reconnaissance, is northwest - southeast. A base line following this trend was located along the fence line extending from the Okatjirute West - Eskadron boundary (Fig. 26). A 100 metre grid was surveyed from the baseline for 1 kilometre to the northeast. The traverse lines 33 - 47 were used for geochemical sampling and the grid stations for geobotanical and geological mapping by plane table.

In addition to the geobotanical mapping the vegetation distribution was recorded along Transect 48 which crosses several zones of Helichrysum leptolepis, and Transects 49, 52, 53 and 54 which each intersect one main zone of anomalous vegetation. Plant samples for analyses were collected along these transects. Additional recording transects could not be completed later in the programme as trenching and drilling had greatly destroyed the natural vegetation. However, detailed biogeochemical studies were undertaken in 1970 along Transects 35, 38, 42 and 45 when more information about the mineralization had been gathered.

Geobotanical Mapping

In the initial phase of geobotanical mapping all the areas of Helichrysum leptolepis and associated zones of anomalous vegetation were located (Fig. 27). Subsequent work outlined other vegetation associations within the Malachite Pan grid. Mapping was carried out by plane table from the 100 m. grid stations using a scale of 1:1000.

In the areas of Helichrysum leptolepis and the associated species Fimbristylis exilis, Aristida congesta and Eragrostis denudata, trees and shrubs are absent. The central parts of the zones are often barren of all vegetation (Plate 28), including Helichrysum leptolepis. The associated species Fimbristylis exilis, E. denudata and A. congesta may be scattered throughout the area or restricted to the margin of the zone. Herbs and forbs are generally absent in this association but Vellozia humilis occurs over the bare central areas of the Helichrysum leptolepis zones around 900/250 m.NE.

Many of the Helichrysum leptolepis areas are surrounded by a characteristic association of the grass species Eragrostis denudata, Aristida congesta and Anthephora pubescens.

Plate 27 View eastwards across the Malachite Pan. The vegetation in the foreground comprises Helichrysum leptolepis, Aristida congesta, Mollugo cervianа and Fimbristylis exilis. Around the pan Listia heterophylla, Vahlia capensis and Diandrochloa pusilla are the dominant ground species. Transect 48 is located across this area, following the line of the hammer. Outcrops of mineralized argillite occur on the edges of the pan. (Ref. MMC/SWA 17/3)

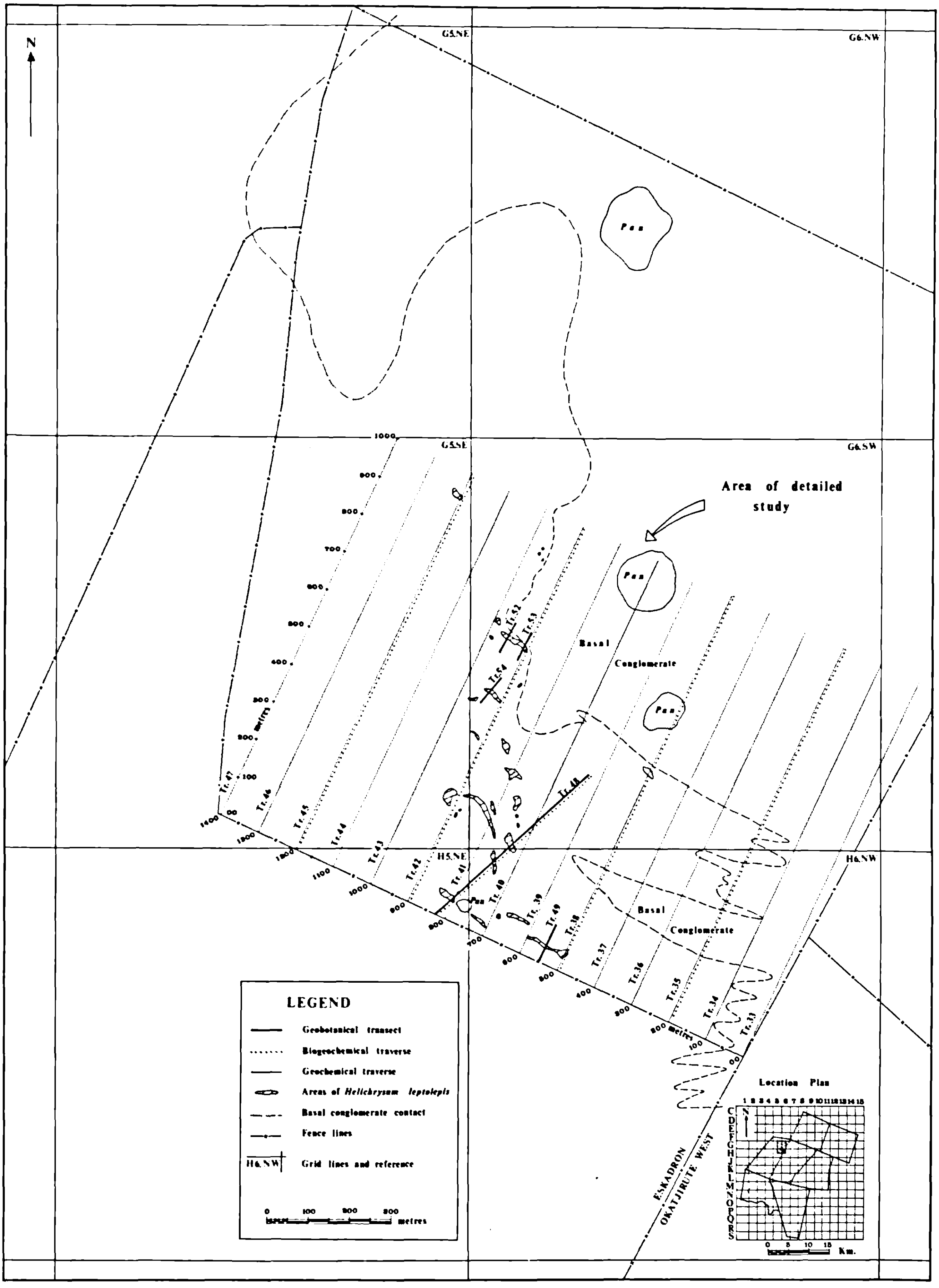


Fig. 26 Location of geobotanical, biogeochemical and geochemical transects at the Malachite Pan Area, on the farm Eskadron.

Scattered groups of Helichrysum leptolepis may be present among the grasses but with the exception of Platycarpha carlinoides and Geigeria ornative herb species are usually absent from these areas. Groups of tall Acacia hereroensis shrubs with Grewia flava and Rhus pyroides often occur within the area of the grass species and border the zones of Helichrysum leptolepis.

Several of the Helichrysum leptolepis zones can be traced continuously for upto 100 metres and individual areas may cover 200 - 300 square metres. All the principal areas of anomalous vegetation occur within a N - S belt approximately 400 metres wide (Fig. 27) and two general trend directions are apparent in the vegetation. Several of the larger areas of Helichrysum leptolepis and associated anomalous vegetation are aligned N - S, parallel to the elongation of the belt. Other narrower zones follow a NW - SE trend which is parallel to the regional strike.

The vegetation for the remainder of the area is extremely varied and the only specific vegetation associations occur over areas of calcrete and the drainage pans.

An association of Ocimum americanum, Nidorella resedifolia, and the grasses Enneapogon brachystachus and Fingerhuthria africana occurs over the calcrete ridge, in the southwestern section of the area, and in the areas around 550/350, 500/450 and 880/80 m.NE, where calcrete is also present at the surface. The species Seddera suffruiticosa, Helinus spartioides and Cleome angustifolia are also common species over the calcrete ridge and the grass Aristida vestita forms a significant part of the ground cover in the area around 550/350 m.NE. The dominant shrub species in these areas are Acacia mellifera, Grewia flava and Tarchonanthus camphoratus and lineations in the shrub cover are apparent on the aerial photographs and indicate the regional strike.

The two large drainage pans in the northern part of the area have a dense uniform cover of the grass species Eragrostis curvula and in the areas surrounding the pans the ground vegetation is characterised by an association of Aristida adscensionis, Aristida congesta, Vahlia capensis, Listia

Plate 28 View eastwards from 850m.NW/450m.NE. Malachite Pan grid showing:-

1. Bare area caused by toxic soil conditions;
2. Association of Helichrysum leptolepis and Fimbristylis exilis forming geobotanical anomaly;
3. Association of the grass species Aristida congesta, Eragrostis denudata and Anthephora pubescens surrounding the Helichrysum leptolepis zone;
4. Large shrubs of Acacia hereroensis and surrounding Rhus pyroides bordering the anomalous ground vegetation. (Ref. MMC/SWA 17/6)

Plate 29 (a) <u>Aristida congesta</u> (Ref. MM/SWA 11/7) (b) <u>Eragrostis denudata</u> (Ref. MM/SWA 11/6) (c) <u>Anthephora pubescens</u> (Ref. MM/SWA 11/8)

The three grass species occur in association with <u>Helichrysum leptolepis</u> in areas of copper mineralization.

heterophylla and Tribulus zeyheri. Tall thickets of Ziziphus mucronata, Diospyros lyciodes and Acacia hebeclada shrubs occur on the margins of the pans.

Areas of dense shrub cover also occur in the western margin of the region where large Acacia mellifera 3 - 4 m. in height and Tarchonanthus camphoratus are the main shrub species. The ground vegetation is very sparse in these areas and consists largely of the grasses Cymbopogon contortus, Cymbopogon plurinoides, Aristida adscensionis and Aristida congesta and the low growing herbs Platycarpha carlinoides and Vellozia humilis.

The background vegetation of the Malachite Pan area (Fig. 27, unshaded areas) consists of a fairly dense cover of mixed grass species with scattered herbs and forbs. Eragrostis denudata, Anthephora pubescens and Schmidtia pappophoroides are the most common grasses with Aristida congesta, Stipagrostis uniplumis, Cymbopogon contortus and Eragrostis superba often present in minor proportions. Ocimum americanum, Sylitra biflora, Dichoma capensis, Talinum arnotii and Ipomoea sinensis are the more common herb species occurring with the vegetation. In several areas dense Stipagrostis uniplumis occurs to the exclusion of most of the other grasses and herbs, and forms extensive areas on each side of the calcrete ridge and in the eastern part of the grid.

The tree and shrub vegetation for the major part of the area is generally open and dominated by the species Acacia hereroensis, Grewia flava and Phaeoptilum spinosum. The shrubs are mainly 1 - 3 metres in height but taller Acacia mellifera shrubs, Boscia albitrunca and Acacia giraffae trees, are scattered throughout the area.

Geochemical Survey

Soil samples, from a depth of 15 - 20 cm., were collected at 15 m. intervals along the Transects 33 - 47 (Fig. 26). Additional samples were collected from 0 - 500 m. NE on lines 550, 650, 750, and 825 and from 0 - 1000 m. on line 950 to provide more detailed information within the anomalous areas. The results of analyses of the -80 mesh fraction of the soil samples are shown by the isopleth map of Fig. 28.

The samples from the northeast section, which represent the background for the map area, are in the range 10 - 30 ppm. copper and the peak values from the anomalous sections range from 450 - 960 ppm. The general trend of the geochemical highs is NE - SW following the regional strike but, the main areas of +200 ppm. copper form a north - south zone 300-400 m. wide.

Several correlations between the geochemical data and the geobotanical mapping are apparent from a comparison of Figs. 27 and 28 by the use of overlays (Back pocket).

1. The geochemical anomaly maxima coincide with the areas of Helichrysum leptolepis and associated species.
2. The soil values generally exceed 200 ppm. copper in The areas of the anomalous vegetation association of Eragrostis denudata, Aristida congesta and Anthephora pubescens.
3. An area of background soil values in the range 10 - 20 ppm. copper is coincident with the area of Ocimum americanum and associated species over the calcrete ridge. Low soil values also occur around 550/350 NE; and area characterised by similar vegetation and calcrete.
4. The N - S zone 300 - 400 m. wide and the NW/SE trend is clearly defined by both the high soil values and the areas of anomalous vegetation.

Geological mapping

The surface geology and sections exposed in the trenches were mapped from the 100 metre grid by plane tabling. The outcrops are mainly restricted to reddish quartzites which exhibit graded bedding, cross-bedding, ripple marks and contain occasional heavy mineral layers and grit bands. Individual horizons can be traced for several hundred metres along a NW - SE direction, denoting the regional strike and the beds dip to the southwest at angles between 35 - 70 degrees. Several

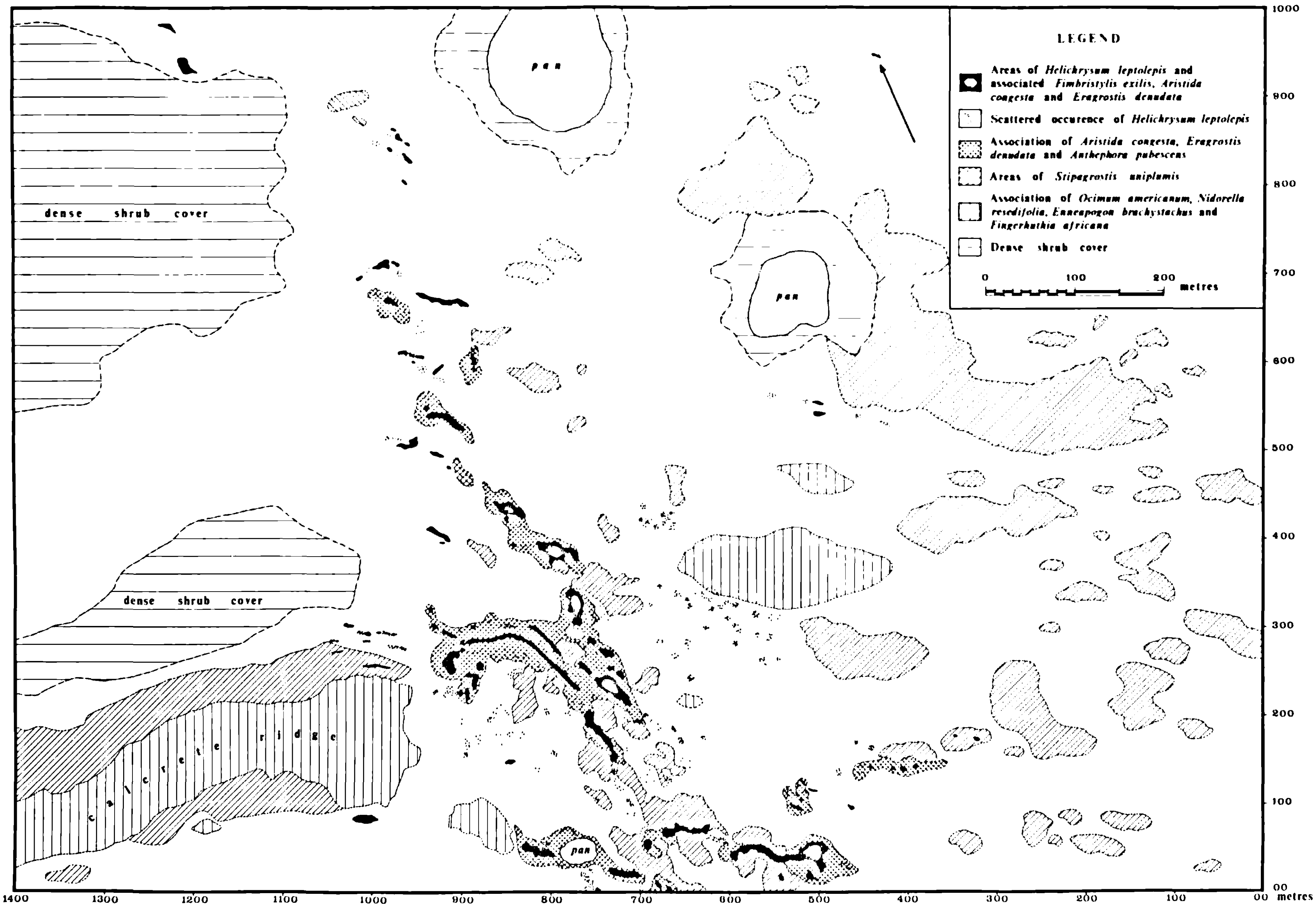


Fig. 27 Distribution of vegetation associations, Malachite Pan Area, Eskadron.

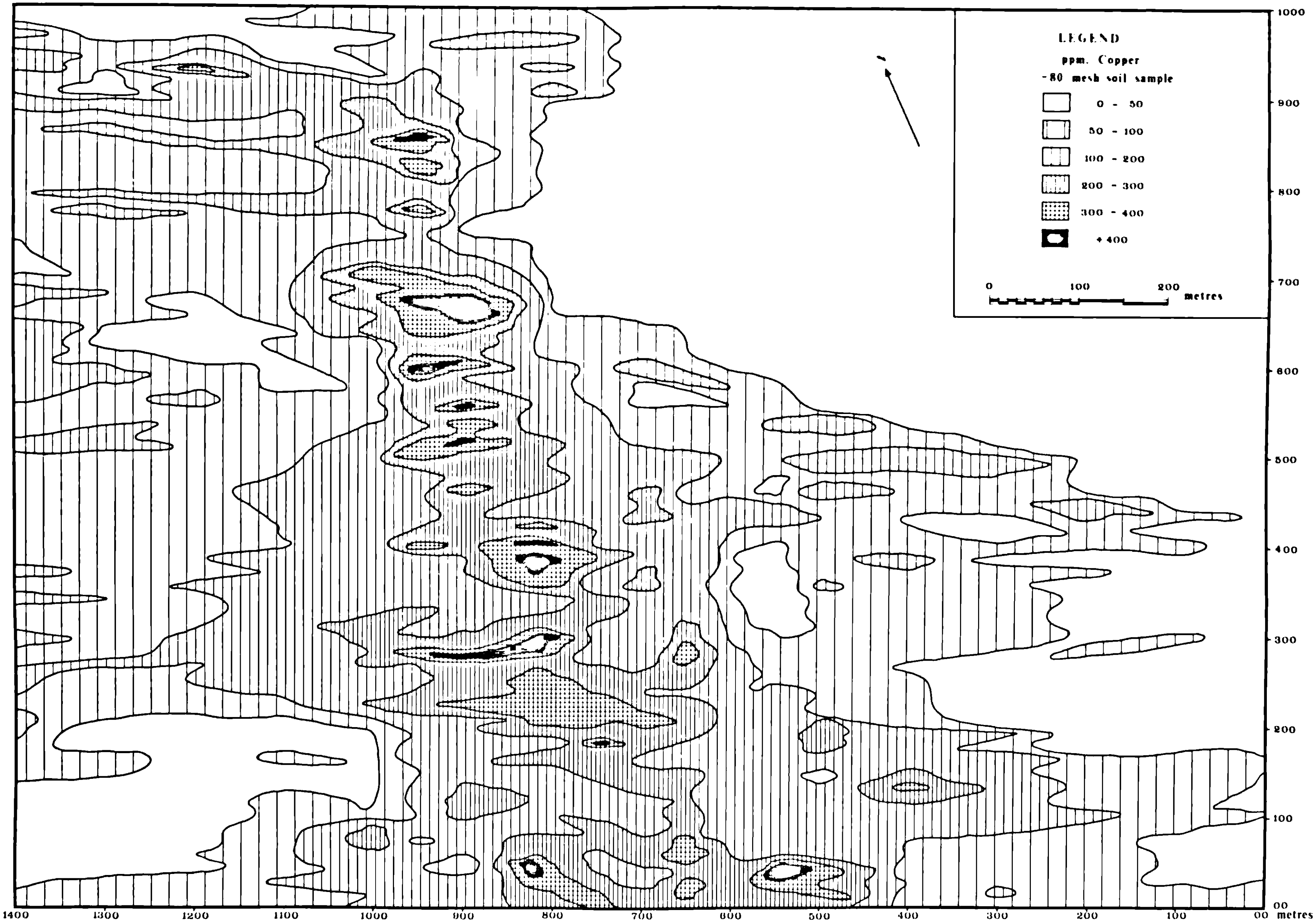


Fig 28. Distribution of copper in the soils at the Malachite Pan Area, Eskadron (-80 mesh).

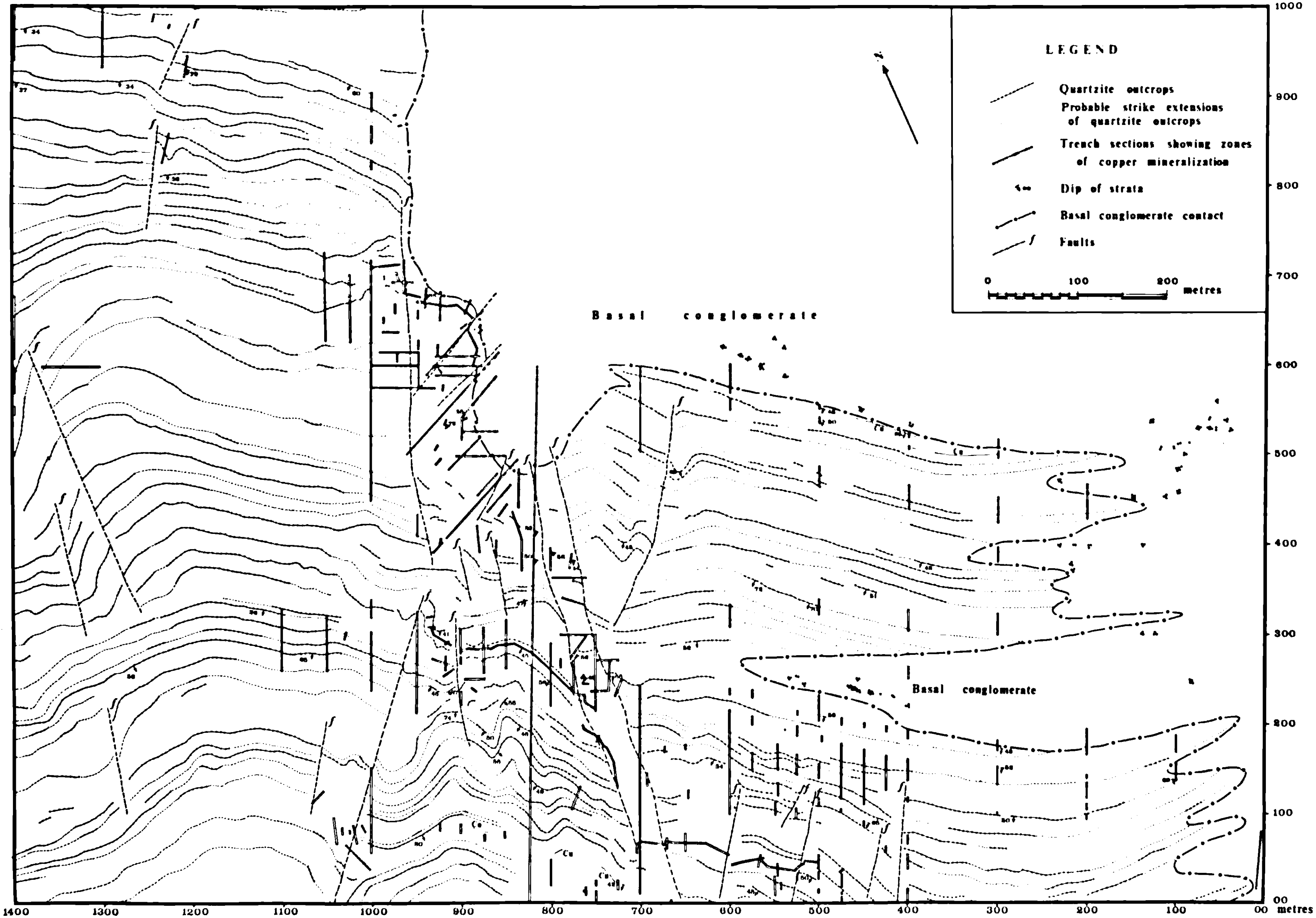


Fig 29. Geological structure of the Malachite Pan Area, Eskadron.

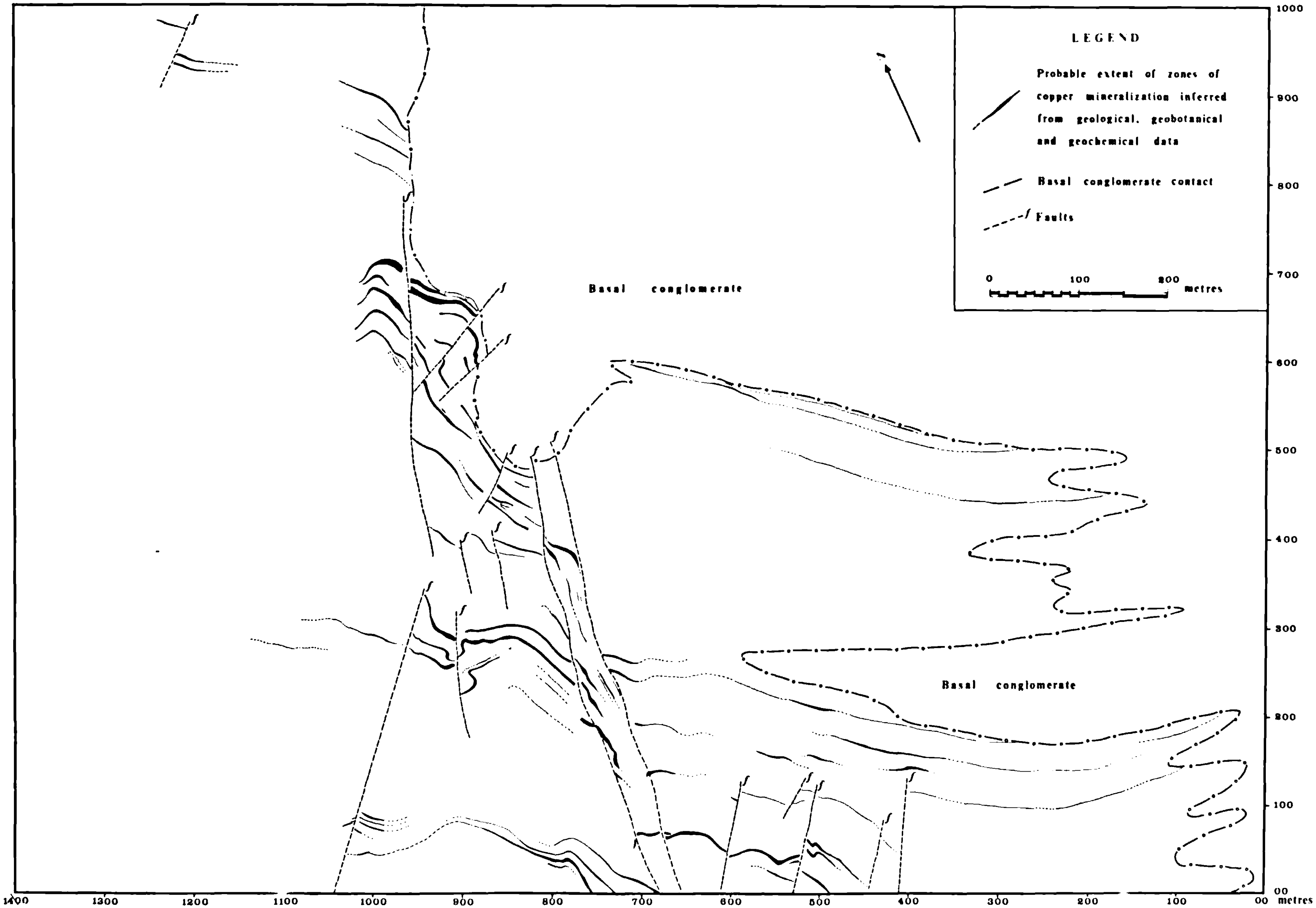


Fig. 30 Probable extent of copper mineralization at the Malachite Pan Area, Eskadron.

fold structures are apparent from the quartzite outcrops in the zone from 700 - 1000 m. NW and quartz veining, brecciation and slickensides are indicative of faults within this zone.

In the east and northeast of the grid there are extensive outcrops of massive conglomerate which is mapped as the basal conglomerate of the Tsumis System (Fig. 29). The pebbles of the conglomerate consist mainly of quartzites, argillites and a variety of acidic and mafic volcanics. The contact of the basal conglomerate with the bedded sediments is located from outcrops, exposures in the trenches and drill intersections.

The only other outcrops are those of mineralized argillite around the pan which is close to the base line between 700 and 800 m. NW. All subsequent geological information of rock types, structure and near surface mineralization is from the trench sections.

The initial trenching program was guided by the geobotanical and geochemical anomalies and further phases were designed to locate strike extensions to the known mineralization. Several strike trenches were opened along the zones of Helichrysum leptolepis to verify the continuity of the mineralization. The results of the trenching showed that in all cases copper mineralization was revealed beneath the zones of anomalous vegetation. The subsequent trenching and extensive wagon drilling programs failed to indicate any additional areas of significant near surface mineralization.

A comparison of the geological, geochemical and geobotanical data, of Figs. 27, 28 and 29, by the overlays shows several significant inter-relationships. The zones of mineralized argillite exposed by the trenching, are coincident with the geochemical highs of the soils and the areas of anomalous vegetation. The width and strike extent of the Helichrysum leptolepis zones closely reflect the width and extent of the mineralization.

The broad N - S belt of geochemical highs and geobotanical anomalies, as noted in the preceeding section, is also a belt of faulting and more intense folding. The stronger mineralization is apparently confined to this region as complete wagon drill sections of lines 600 and 1200 NW failed to locate any substantial zones of mineralization.

An interpretation of the probable extent of copper mineralization, from geological, geochemical and geobotanical data, is shown in Fig. 30.

Transect 48

The transect is orientated to intersect the three main zones of anomalous vegetation of the Malachite Pan area. The ground vegetation and shrub cover recorded along the transect is shown in Fig. 31, together with the soil geochemistry, geology from trench sections and the soil profiles from pits and trenches.

Throughout the area the percentage of outcrop is very small. Pits and trench sections indicate that the bedrock is usually 50 cm. to 1 m. below surface, and in areas of mineralized argillite the overburden is less than 40 cm. Soil horizons are not developed within the profiles but there is generally a sharp contact between the surface sandy layer and the angular to subangular gravel. The surface material consists mainly of medium and fine grained sand, forming 45 - 60% (Fig. 32). The shallow soils over the mineralized argillites contain a greater percentage of gravel; sample 3573 and 3590 contain about 20%, whereas soils from the other profiles contain only 1 - 5% gravel. All the samples have similar amounts of coarse and very coarse sand, approximately 15%, and the silt and clay fraction varies from 4 - 9%. The angular to subangular gravel, lower in the profile, has an average size of about 2 cm. near the upper contact and becomes slightly coarser in depth. The gravel may rest directly on bedrock (Fig. 31, 300 m.) or on large angular blocks of weathered quartzite.

Several trench sections were made on the transect in order to expose the mineralized zones for sampling. The widest

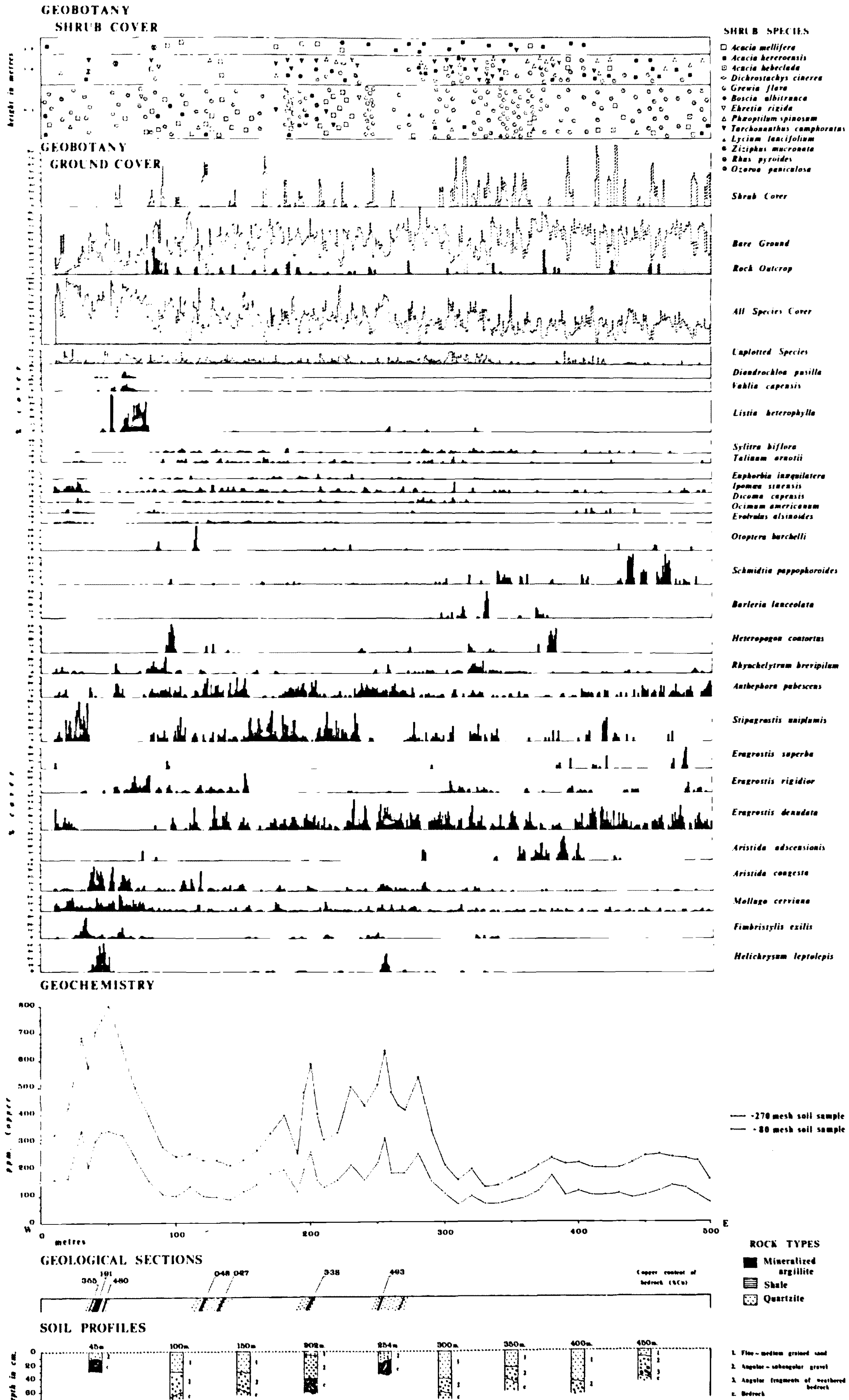


Fig. 31 Transect 48, Malachite Pan, showing the relationship between the distribution of plant species, geochemistry, geology and soil profiles.

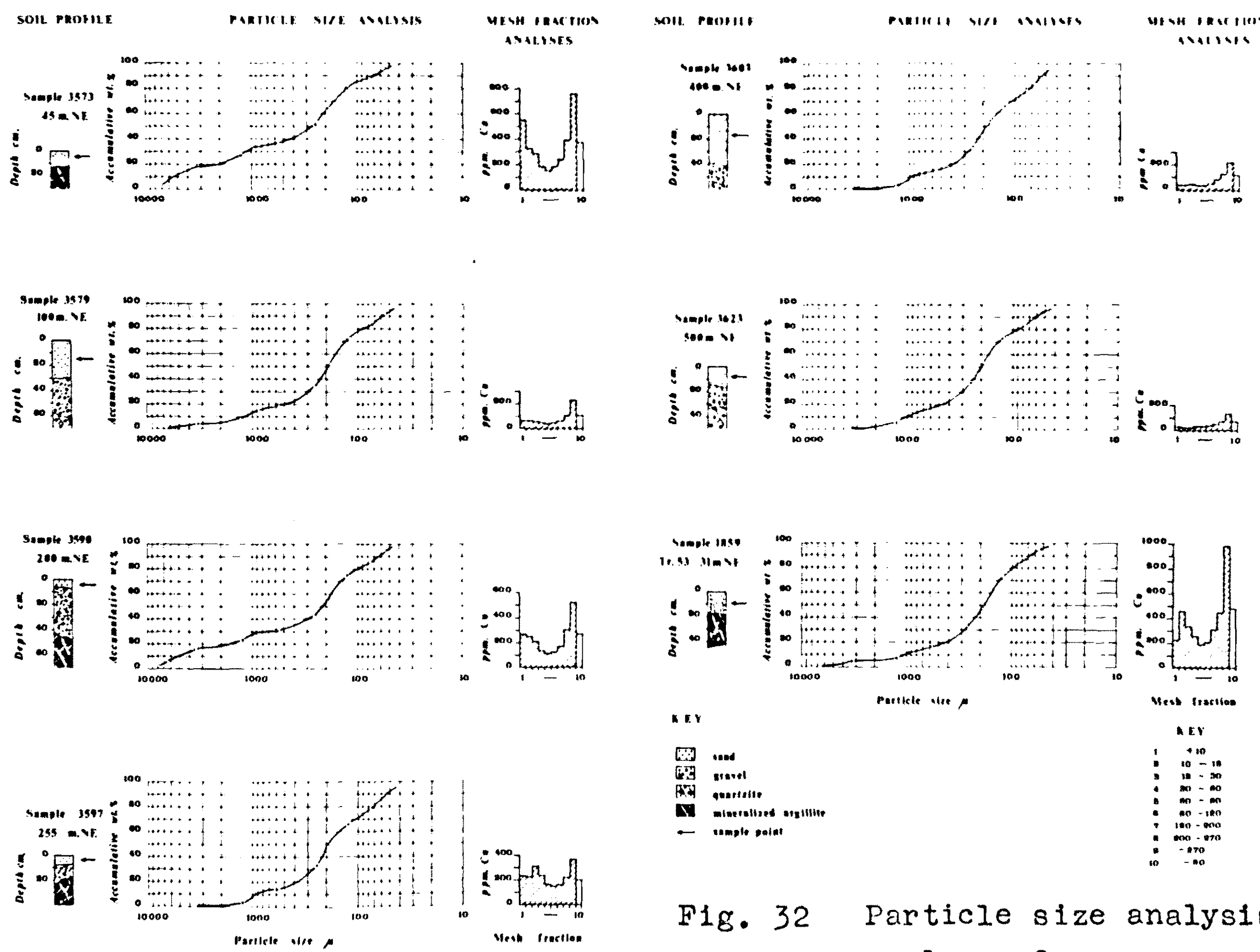


Fig. 32 Particle size analysis and mesh fraction analyses for copper of bulk soil samples collected on Transects 48 (6 samples) and 53 (1 sample), Malachite Pan.

zone is from 35 - 50 m. where three horizons of mineralized argillite are separated by quartzite. In this section the argillite contains 1.9 - 4.8% copper. Two much narrower zones occur at 205 and 255 m. where the argillite also has a high copper content. The geology of the transect is not fully exposed but shales, calcareous shales, limestones and conglomerate are present in the adjacent trenches. Many of the shales including those on Transect 48 from 130 - 140 m. contain upto 0.5% copper, whereas the other rock types have only trace amounts.

The copper content of the soils, collected at 10 m. intervals and from 15 cm. depth, is several times the regional background throughout the transect. The majority of the -80 mesh samples are in the range 100 - 200 ppm. copper with peak values upto 340 ppm. directly over the mineralized zones. The -270 mesh samples have approximately twice the -80 mesh value and also show peaks, reaching 800 ppm., over the mineralization. The copper content of the mesh fractions from the samples over the mineralized argillites (Fig. 32) show a decrease in the 60 - 200 mesh sizes from the coarser fractions. It is possible that the coarse fractions contain fragments of weathered argillite as the bedrock is very close to the surface. The -270 mesh fraction of the sample has the highest copper content. The mesh fractions from the bulk samples collected over quartzites, numbers 3579, 3603 and 3623, have a similar copper content for the +10 - 120 mesh samples and increasing values in the finer fractions.

Geobotany

The vegetation forms an average of 40% ground cover along the transect with a large number of grass species contributing the major portion.

The only species occurring directly over the mineralization are Helichrysum leptolepis, Fimbristylis exilis, Mollugo cerviana, Aristida congesta and Eragrostis denudata. Helichrysum leptolepis has its main occurrence from 35 - 50 m. and 250 - 260 m. coinciding with the geochemical peaks and zones of copper mineralization. In these two areas it forms from 20 - 40% of the ground cover. The mineralized zone at

Plate 30 Steeply dipping mineralized argillite outcropping at the surface. Material excavated from the trench section shown in the background. Location 825/40m.NE Malachite Pan grid. (Ref. MM/SWA 10/33)

205 m. has only a scattering of Helichrysum leptolepis in the line of the transect but the percentage cover increases on the strike extensions of this zone.

Fimbristylis exilis shows a marked increase in the percentage cover on the borders of the Helichrysum leptolepis zone from 35 - 50 m. and also at 210 m. and 250 m. adjacent to mineralization. Mollugo cerviana is found along the entire transect forming about 1 - 5% cover but increases to 10 - 20% between 10 - 70 m. which spans the mineralization. The grass species Aristida congesta has a scattered occurrence along the transect from 0 - 300 m. but shows a greater frequency over the mineralized section at 40 m. It has only a sporadic occurrence for the remainder of the transect from 300 - 500 m. where the copper content of the soils is low.

The vegetation for the major part of the transect, excluding the mineralized areas, is dominated by the grass species Eragrostis denudata, E. rigidior, Anthephora pubescens, Rhyncheletrum brevipilum and Stipagrostis uniplumis. Schmidtia pappophoroides and Aristida adscensionis form a greater proportion of the ground cover from 300 - 500 m. where the copper in the soils decreases.

A distinct vegetation association occurs on the edge of the pan from 50 - 80 m.E. characterised by Listia heterophylla, Vahlia capensis, Diandrochloa pusilla, with Aristida congesta, Eragrostis rigidior and Mollugo cerviana.

Many species of herbs and forbs occur on the transect and the more common are plotted in Fig. 31. Additional species of grasses and herbs recorded on Transect 48 are listed in Table 15. The herbs are generally absent from the areas of Helichrysum leptolepis, over the mineralized zones, but their presence on the transect shows that they can withstand fairly high levels of copper in the soil. Barleria lanceolata occurs on the transect between 300 - 400 m.E where the copper content of the soil is 100 - 150 ppm. but there are no horizons of mineralization indicated. Barleria lanceolata is confined to the main zone of mineralization in the Pos Area.

1. Brachiaria nigropedata	12. Hirpicium gorterioides
2. Eragrostis porosa	13. Indigophera heterotricha
3. Asparagus africanus	14. Kohautia omahekensis
4. Blepharis leendertziae	15. Monechma nepeta
5. Cassia italica	16. Oxygonum dregeanum
6. Celosia linearis	17. Platycarpha carlinoides
7. Chascanum pinnatifidum	18. Portulaca grandiflora
8. Cucumis africanum	19. Scillia sp.
9. Cyphocarpa angustifolia	20. Sida chrysantha
10. Dichoma tormentosa	21. Vernonia fastigiata
11. Eriospermum rautanenii	

Table 15. Plant species also occurring on Transect 48 and grouped as Unplotted Species in Fig. 31.

The transect has a fairly open shrub cover with very few shrubs exceeding 2 metres in height. Over the mineralization from 30 - 50 m., 250 - 270 m. and a narrow zone around 205 m., trees and shrubs are absent. The most commonly occurring species are Acacia hereroensis, A. mellifera, A. hebeclada, Grewia flava, Tarchonanthus camphoratus and Phaeoptilum spinosum. Rhus pyroides which occurs in groups less than 1 metre in height, is also very common and borders the zones of mineralization at 205 and 250 m. The small shrub Ozoroa paniculosa which is not frequently observed in this environment, occurs at 210 m. bordering a zone of mineralized argillite.

Biogeochemistry

Detailed plant sampling on Transect 48 was limited by the poor distribution of trees and shrubs and only four species could be collected at close intervals along the transect (Fig. 33) Of these species only Rhus pyroides and Acacia hereoensis occur close to the mineralization and as the soil values are mainly +100 ppm. copper no true background samples could be collected.

The Grewia flava samples, both leaves and twigs, have the highest copper values between 15 - 70 m. and 230 - 250 m. which are areas adjacent to copper mineralization and where

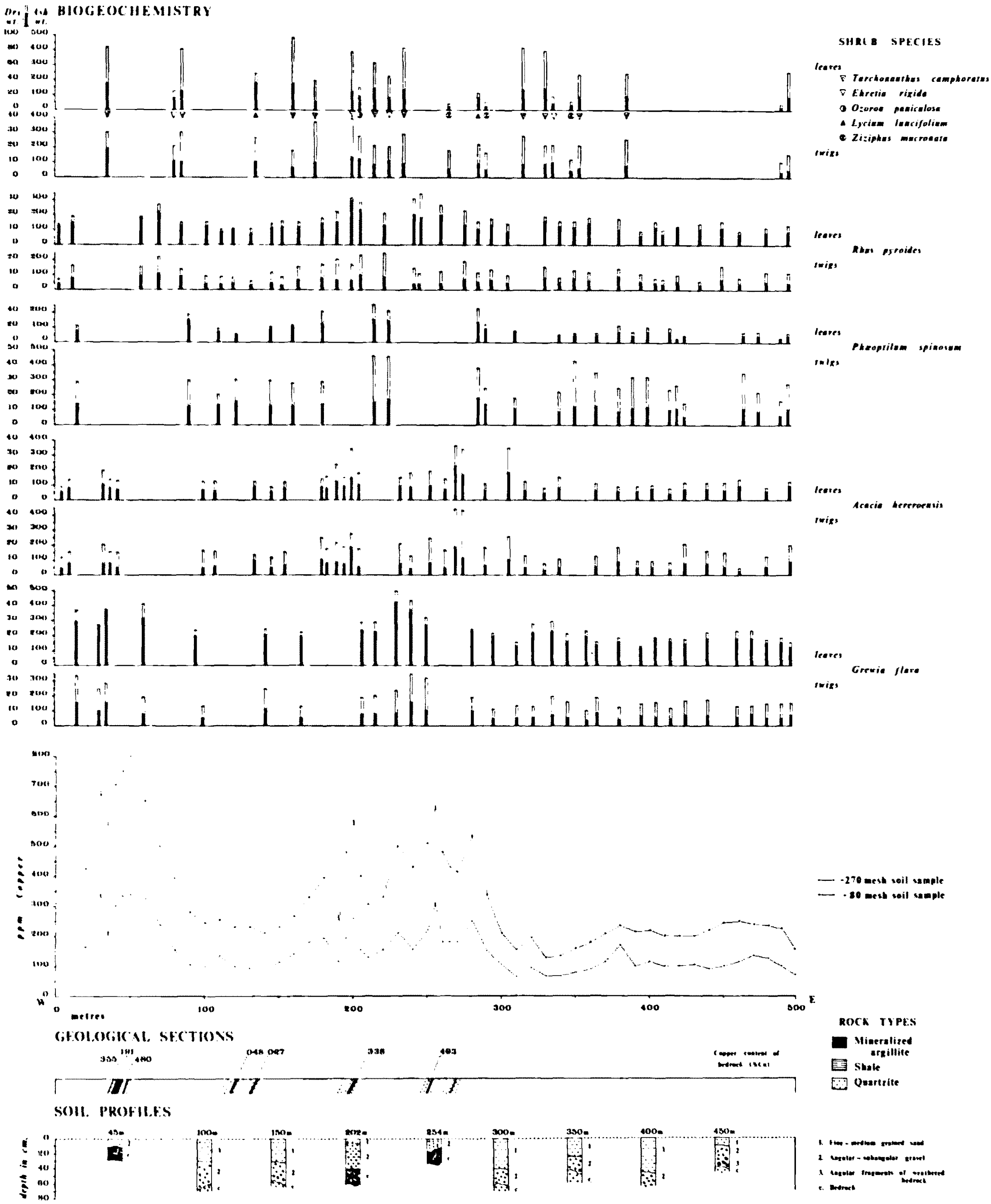


Fig. 33 Transect 48, Malachite Pan, showing the relationship between biogeochemistry, geochemistry and geology.

the soils have the maximum copper content. The leaf samples from these two zones contain between 30 - 40 ppm. copper whereas the samples from 300 - 500 m., where there is no known mineralization range in value from 12 - 20 ppm. The majority of the twig samples are in the range 5 - 8 ppm. and the peak values 14 - 16 ppm. near to mineralization.

The copper content of <u>Acacia hereroensis</u> leaves varies from 4.1 - 22.3 ppm. The maximum value is from a sample at 270 m. which borders a zone of mineralization. The copper content of the twigs for this sample of 18.5 ppm. is also the highest recorded for the transect. In the section 300 - 500 m., where the copper content of the soils is lower, the leaves contain 4 - 8 ppm. copper and the twigs 2 - 7 ppm., whereas several samples exceed 10 ppm. in the section 0 - 300 m. The sample from 306 m. has a very high copper content in the leaves 18.5 ppm. and may indicate mineralization although the soil values are low.

There are no shrubs of <u>Phaeoptilum spinosum</u> growing adjacent to mineralized argillite on Transect 48. The highest values for the leaves are from samples at 90 m., and between 180 - 285 m., which contain from 25 - 30 ppm. copper compared to 5 - 10 ppm. for samples in the section 400 - 500 m. The range of values for the twigs is 5.4 - 17.1 ppm. and all the samples above 13 ppm. occur from 0 - 300 m. where the copper content of the soils is higher.

<u>Tarchonanthus camphoratus</u> has a scattered occurrence along the transect and few of the samples are from sites close to mineralization. The copper content of the eleven leaf samples is high, ranging from 14 - 35 ppm. copper. In the twigs the copper varies from 5 - 13 ppm. with the maximum value from 200 m., near to a zone of mineralization and a geochemical high.

There is very little variation in the copper content of <u>Ziziphus mucronata</u>, ranging from 3 - 7 ppm. for both the leaves and twigs for the four samples collected.

The leaf sample of <u>Lycium lancifolium</u> from 135 m. has a very high copper content of 36.6 ppm. compared to the sample from 285 m., 16.8 ppm., where the copper content of the soil is in a similar range. The mineralized shale containing

0.48% copper in the vicinity of the first sample may account for its higher copper content. The twig samples from these two locations have a similar copper content of 10.1 and 8.6 ppm. copper.

The sample of Ozoroa paniculoza, from 205 m. beside mineralized argillite, has a leaf and twig content of 12 ppm. which is not particularly high for this environment.

Transects 49, 52, 53 and 54.

In addition to transect 48, the vegetation was recorded across four zones of Helichrysum leptolepis and trenches were subsequently opened to reveal the bedrock in these areas. The data recorded for the transects is shown in Fig. 34. Each transect clearly shows the zone of Helichrysum leptolepis selected, the associated geochemical anomaly and the mineralized argillite exposed in the trench sections.

The soil profiles indicate that the mineralized argillites are much closer to the surface than the quartzite horizons. The overburden consists mainly of fine and medium sand with small proportions of gravel, silt and clay. Bulk sample 1859 from 31 m. on Transect 53 (Fig. 32) contains 62% fine and medium sand, 6% gravel and 5% slit and clay combined. This composition is very similar to the bulk samples from Transect 48.

The copper content of the mineralized argillites, below the zones of Helichrysum leptolepis, varies from 1.7 - 3.1% and soil samples from the corresponding sites contain upto 600 ppm. in the -80 mesh fraction. The soils samples are taken at five metre intervals along these transects and the close spacing indicates that the mineralization can be located very accurately for the subsequent trenching phase of exploration. The peak values in the geochemistry indicate the mineralization on each transect and the double peak for Transect 53 distinguishes two horizons of mineralized argillite. The size fraction analyses for sample 1859 (Fig. 32) shows the lowest copper content in the 60 - 120 mesh fractions, of 200 ppm., with a rapid increase in the finer fractions to

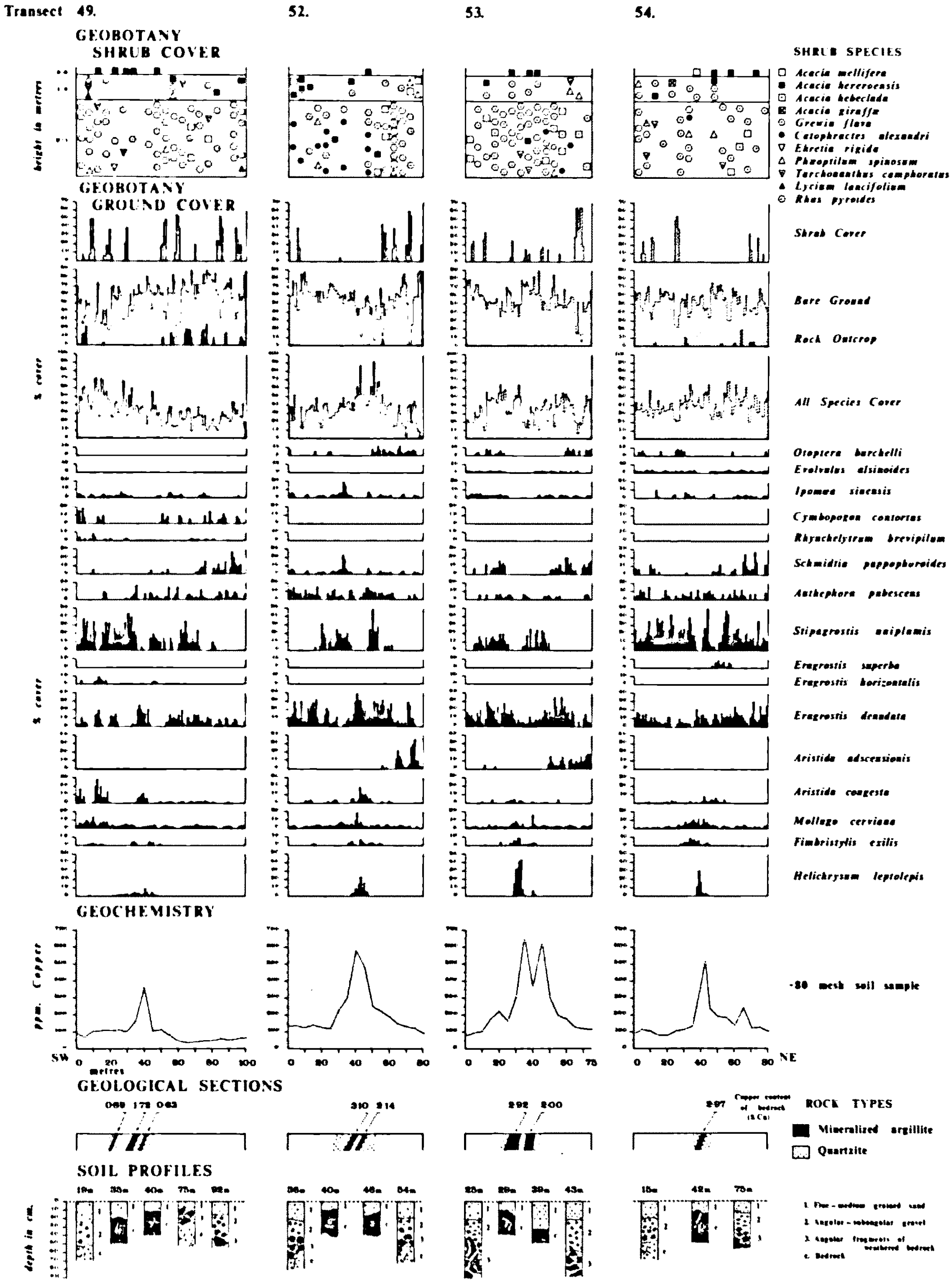


Fig.34 Transects 49, 52, 53 and 54, Malachite Pan, showing the relationship between the distribution of plant species, geochemistry, geology and soil profiles.

Plate 31 View westwards from 900/650m.NE, Malachite Pan grid, showing:-

1. Zone of Helichrysum leptolepis and associated Fimbristylis exilis;
2. The association of the grass species Aristida congesta, Eragrostis denudata and Anthephora pubescens occurring within and bordering the Helichrysum leptolepis zone;
3. Dense cover of the perennial grass Stipagrostis uniplumis forming the major unit of the background vegetation;
4. The shrub species Acacia hebeclada and Rhus pyroides on the left margin of the anomalous zone, with large shrubs of Acacia mellifera in the background.
5. The quartzite ridge of Eskadron homestead in the distance. (Ref. MM/SWA 7/6)

1000 ppm. in the -270 mesh.

Geobotany

The species *Helichrysum leptolepis*, *Fimbristylis exilis*, *Mollugo cerviana* and the grasses *Aristida congesta*, *Eragrostis denudata*, *Anthephora pubescens* grow directly over or adjacent to zones of mineralization. On Transect 53 *Helichrysum leptolepis* forms over 40% of the ground cover over the sub-outcropping argillite. *Mollugo cerviana* occurs throughout the transect line but shows a slight increase in the percentage cover across the mineralization on Transects 52 and 54. *Eragrostis denudata* and *Anthephora pubescens* occur throughout the transect whereas *Aristida congesta* is more confined to the mineralized zones.

Stipagrostis uniplumis and the other grass species shown in Fig. 34 and Table 16 do not occur in association with *Helichrysum leptolepis* in the areas of copper mineralization. *Cymbopogon contortus* a perennial grass tends to occur in areas of quartzite outcrop on Transect 49. The Transects 52 and 53 pass onto the basal conglomerate at approximately 60 m.NE where the vegetation is characterised by the grasses *Schmidtia pappophoroides*, *Aristida adscensionis* and *Eragrostis denudata* and the absence of *Stipagrostis uniplumis*.

1. *Brachiaria nigropedata*	13. *Hermannia damarana*
2. *Cenchrus ciliaris*	14. *Hirpicium gorterioides*
3. *Eragrostis porosa*	15. *Kyllinga alba*
4. *Aptosimum arenarium*	16. *Nidorella resedifolia*
5. *Blepharis leendertziae*	17. *Ocimum americanum*
6. *Cassia italica*	18. *Oxygonum dregeanum*
7. *Celosia linearis*	19. *Platycarpha carlinoides*
8. *Chascanum pinnatifidum*	20. *Scillia sp.*
9. *Cyphocarpa angustifolia*	21. *Sylitra biflora*
10. *Dichoma tormentosa*	22. *Talinum arnotii*
11. *Eriospermum rautanenii*	23. *Tragus berteronianus*
12. *Euphorbia inaequilatera*	24. *Vernonia fastigiata*

Table 16. Plant species occurring on the Transects 49, 52, 53 and 54 and not shown in Fig. 34.

There is a wide variety of herb species listed for the transects. Individual species rarely form more than 10% of the ground cover and the occurrence of the majority of these species is very sporadic. However, none of the species occur over the zones of mineralization.

The shrub cover cuts out across the mineralization but Rhus pyroides and tall Acacia hereroensis often border the zones of Helichrysum leptolepis (plate 28).

Biogeochemistry

Plant samples were collected from the trees and shrubs growing around the well defined zone of Helichrysum leptolepis, which is intersected by Transects 52 and 53 (Plate 31). All the samples are thus from a similar environment, adjacent to mineralization and growing in soils extremely high in copper content. The results of analyses shown in Table 17 indicate that there is a wide variation in the copper content of the various species and also a variation of 2 - 3 times within one particular species. In the four samples of Acacia hereroensis the copper content ranges from 8 - 25 ppm. and 5 - 21 ppm. for the leaves and twigs respectively. For three samples the leaves contain considerably more copper than the twigs and in the fourth sample the twig value exceeds that for the leaves. The copper content for both the leaves and twigs of Acacia giraffae is very low for this environment. In both trees sampled the leaves contain more copper than the twigs. Grewia flava has a very high copper content for the leaves and is six times the value recorded for the twigs. In the species Rhus pyroides the leaves have a higher copper content than the twigs but for the two shrubs sampled the one with the higher leaf value does not have a correspondingly higher value for the twigs. The leaf samples of Tarchonanthus camphoratus contain from 27 - 63 ppm. copper and as with Rhus Pyroides the higher leaf values do not correspond with the higher values of the twigs.

SHRUB SPECIES	LEAVES		TWIGS	
	ppm ash	ppm dry	ppm ash	ppm dry
1. A.hereroensis	132	8.3	129	4.9
2. A.hereroensis	327	20.1	630	21.7
3. A.hereroensis	267	16.7	312	10.0
4. A.hereroensis	450	25.1	222	9.9
5. A.giraffae	85	3.0	90	4.8
6. A.giraffae	49	3.8	65	3.2
7. G.flava	644	56.4	267	8.9
8. R.pyroides	270	18.7	338	14.7
9. R.pyroides	335	27.4	252	9.2
10.T.camphoratus	490	39.0	345	14.4
11.T.camphoratus	348	26.8	182	8.4
12.T.camphoratus	850	63.3	262	9.8
13.T.camphoratus	730	56.9	238	11.4

Table 17. Copper content of plant samples collected around the zone of Helichrysum leptolepis linking Transects 52 and 53.

Biogeochemical Survey

The initial biogeochemical studies at the Malachite Pan, on Transect 48, indicated that there is a wide variation in the copper content of the shrubs across the mineralized sections. The highest values recorded for the three most common species were from shrubs growing adjacent to mineralization. However, insufficient samples were collected for statistical evaluation of the results and as the transect did not extend significantly beyond the mineralized area, the background levels of copper for the species could not be calculated.

In January 1970 a more detailed biogeochemical survey was conducted at the Malachite Pan to see if the mineralized areas could be clearly defined by plant analyses and whether strike extensions to the west of the known mineralization could be detected. From the geochemistry and detailed geobotanical and geological mapping the extent of the near-surface mineralization had been determined. The areas of basal conglomerate to the northeast, do not contain any zones of mineralization and all soil values in this region are less than 20 ppm. copper. The plant samples collected from this area could thus be taken to represent the background for the Malachite Pan region.

The Transects 35, 38, 42 and 45, along the grid lines 200, 500, 900 and 1200, respectively, (Fig. 26) were selected for a detailed sampling programme. The major part of Transect 35 is across the basal conglomerate and only minor zones of mineralization occur between 0 - 200 m. and at 450 m. NE. The section of Transect 38 from 600 - 1000 m. NE is also on the basal conglomerate and several horizons of mineralized argillite are present from 0 - 220 m. and at 550 m. NE. Transect 42 crosses many areas of mineralization and zones of _Helichrysum leptolepis_ in the section from 0 - 700 m. but, the remaining part upto 1000 m. NE is over basal conglomerate. There are no zones of mineralization clearly indicated from the vegetation or soil geochemistry along the section 0 - 900 m. on Transect 45 (Fig. 30) and the biogeochemical sampling could provide additional information for the location of mineralized horizons.

The three shrub species <u>Grewia flava</u>, <u>Acacia hereroensis</u> and <u>Phaeoptilum spinosum</u> were selected for the survey because of their wide distribution and the results obtained for Transect 48. Leaves and twigs were collected for each species, and samples taken at 10 - 20 m. intervals, from shrubs occurring within 10 metres of the transect line. Approximately 600 samples were collected from the four transects and the results of analyses are plotted in Figs. 35 - 38. The copper content of the soils and geology, recorded from trench sections and wagon drilling, is also plotted on the diagrams so that a direct comparison of the biogeochemical results with known mineralization can be made.

In order to make a more satisfactory interpretation of the biogeochemical results, the mean copper content and standard deviation was calculated for the leaves and twigs collected over the basal conglomerate on Transects 35 and 38 (Table 18). The threshold for anomalous samples is taken as the mean plus three standard deviations. The threshold values calculated separately for the two transects are in close agreement.

<u>Transect 35</u>

The major part of the transect is in an area of background as the basal conglomerate extends from 200 - 400 and 500 - 1000 m.NE. Over the basal conglomerate in these sections the -80 mesh soil samples contain less than 20 ppm. copper (Fig. 35). There is one marked geochemical anomaly of 170 ppm. at 450 m. which is directly over a 2 metre zone of mineralized argillite. The wagon drill section 660 intersected this zone at a depth of 20 m. and the copper content of the argillite is 1.07%. A weaker geochemical anomaly exists from 80 - 150 m. NE with peaks of about 50 ppm., which correspond with narrow bands of argillite at 105 and 140 m. exposed in trench sections. The samples of the argillite obtained from the wagon drill sections 344 and 345 contain from 0.5 - 0.6% copper.

Very few of the plant samples collected along the transect exceed the threshold values for the species. The locations of the anomalous samples are shown in Table 19. The

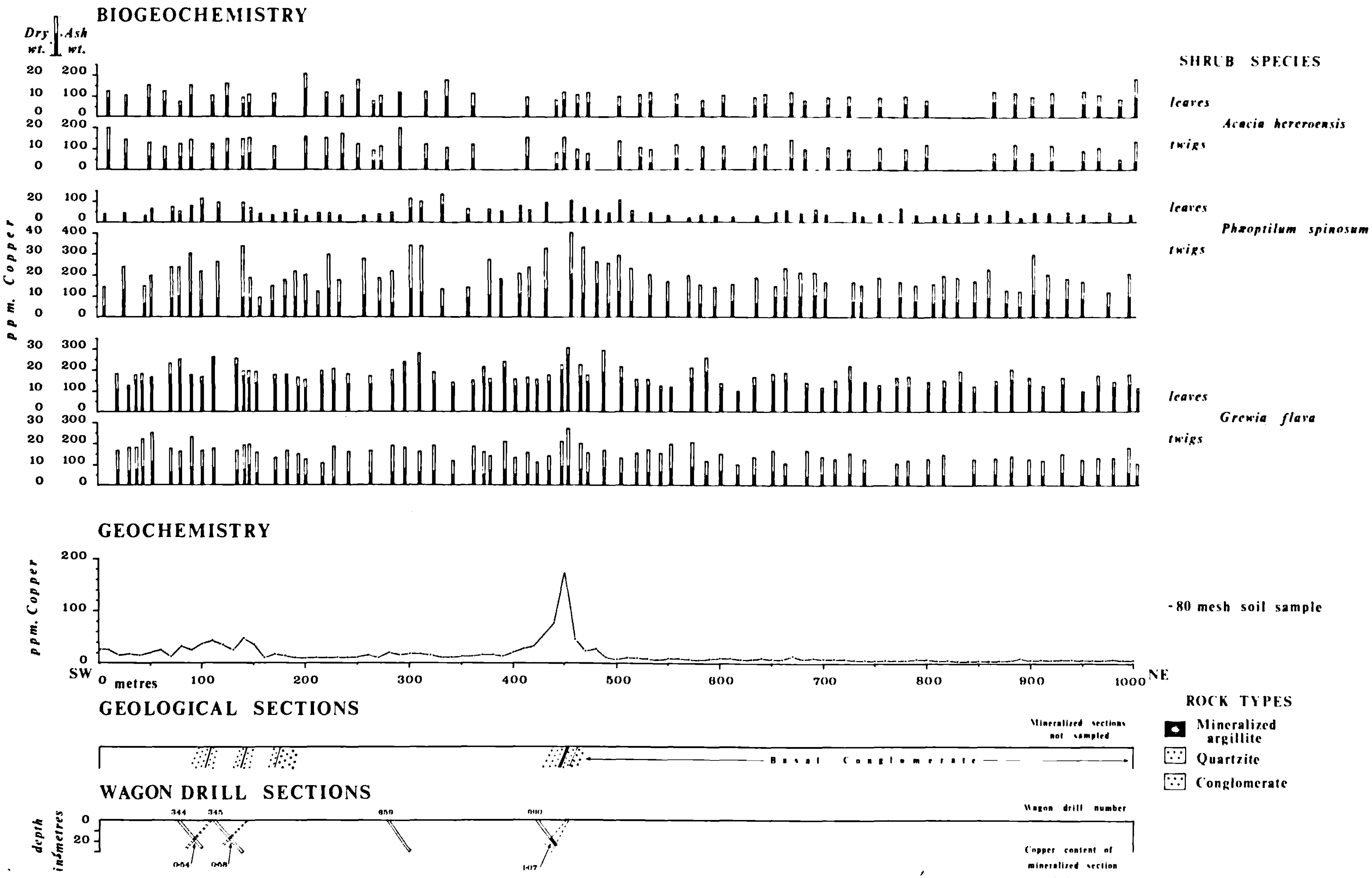


Fig. 35 Transect 35, Malachite Pan, showing the relationship between biogeochemistry, geochemistry and geology.

SHRUB SPECIES	Transect number	No. of samples	Mean ppm.Cu	Standard deviation	Threshold ppm.Cu
<u>Grewia flava</u>					
Leaves	35	57	13.5	2.5	21.0
	38	24	13.2	2.6	21.0
twigs	35	57	5.7	1.0	8.7
	38	24	5.2	1.0	8.2
<u>Phaeoptilum spinosum</u>					
Leaves	35	54	6.5	2.2	13.1
	38	25	6.1	2.0	12.1
Twigs	35	54	7.9	2.1	14.2
	38	25	8.0	2.2	14.6
<u>Acacia hereroensis</u>					
Leaves	35	38	6.6	1.7	11.7
	38	22	5.7	1.6	10.5
Twigs	35	38	4.9	1.2	8.5
	38	22	3.9	1.1	7.2

Table 18. Mean copper content, standard deviation and threshold values for shrub samples collected from background areas at the Malachite Pan.

samples of <u>Grewia flava</u> from 111, 133 and 450 m., which have anomalous copper values for the leaves, are all from sites very close to mineralization and indicate the three horizons of mineralized argillite on line 200. The anomalous value indicated for 308 m. may signify an eastern strike extension of the mineralized argillite exposed in a trench section at 304 m. NE on line 300 (Fig. 30). Four samples have anomalous values for the twigs and the locations of three of the samples from 145, 445 and 450 border known zones of mineralization. The highest value of 10.9 ppm. copper for the twigs is from 52 m. NE but, geochemical and geological surveys did not indicate copper mineralization in this section of the grid.

SHRUB SPECIES	Distance m. NE	Leaves ppm.Cu	Twigs ppm. Cu
G. flava	52	-	10.9
	111	25.9	-
	133	22.6	-
	145	-	9.5
	303	22.9	-
	445	-	8.8
	450	26.9	9.1
P. spinosum	90	15.5	-
	100	16.6	-
	140	14.1	-
	329	16.8	-
	430	17.0	-
	454	17.9	20.0
	500	16.7	-
A. Hereroensis	200	13.3	-
	250	12.7	-
	290	-	10.7

Table 19. Copper content of anomalous samples from Transect 35, Malachite Pan.

The only Grewia flava shrub along the transect that has anomalous values for both the leaves and the twigs occurs at 450 m. NE corresponding to a zone of mineralized argillite and a geochemical anomaly of 170 ppm. in the soil (Fig. 35).

Most of the anomalous values recorded for Phaeoptilum spinosum are from shrubs growing in the vicinity of mineralization. The samples from 100, 140, 430 and 454 m., which have anomalous copper levels in the leaves are adjacent to the three zones of mineralized argillite crossing the transect. The shrub from 454 m., bordering the most strongly mineralized horizon, also has the only anomalous value for the twigs recorded on the transect. Two further leaf anomalies occur at 329 and 500 m., where rocks of the bedded sedimentary sequence overly the basal conglomerate. These high values may indicate an easterly extension of argillite exposed by trenching on line 300.

The results of analyses, of both leaves and twigs, for Acacia hereroensis do not show any anomalous values for samples collected near to known mineralization. The leaf samples from 200 and 250 m. and the twig samples from 290 m.NE which have an anomalous copper content are from areas underlain by basal conglomerate. Samples collected from 445 m., where there is near surface mineralization, contain only 8.0 and 7.6 ppm. copper in the leaves and twigs respectively.

Transect 38

The trenching programme along line 500 indicated nine horizons of mineralized argillite between 0 - 250 m. and two further zones at 540 and 560 m. NE (Fig. 36). The mineralized argillite sampled in the trenches varies in copper content from 1.1 - 4.2% and all the mineralized horizons were confirmed at depth by wagon drilling. Soil anomalies occur over the mineralization and the peak value of 200 ppm. copper from 40 m. coincides with an area of Helichrysum leptolepis. The indicator species is also present on the transect at 110, 150, 540 and 560 m. NE which are also areas of geochemical highs. The soils over the basal conglomerate generally contain less than 20 ppm. copper, with slightly higher values across the pan caused by drainage from the mineralized sediments.

Most of the leaf samples of Grewia flava collected from 0 - 200 m. have an anomalous copper content and all the samples but one exceed the mean background level for the species by two standard deviations. The sample from 90 m. has the maximum value of 32.4 ppm. copper and several values are greater than 25 ppm. Three samples collected between 545 - 555 m. all have an anomalous copper content ranging from 21.4 - 27.6 ppm. The leaf sample from 430 m., where a slight geochemical high occurs, contains 20.7 ppm. copper.

The twigs of Grewia flava have anomalous values for similar locations as the anomalous leaf samples. Eleven sam-

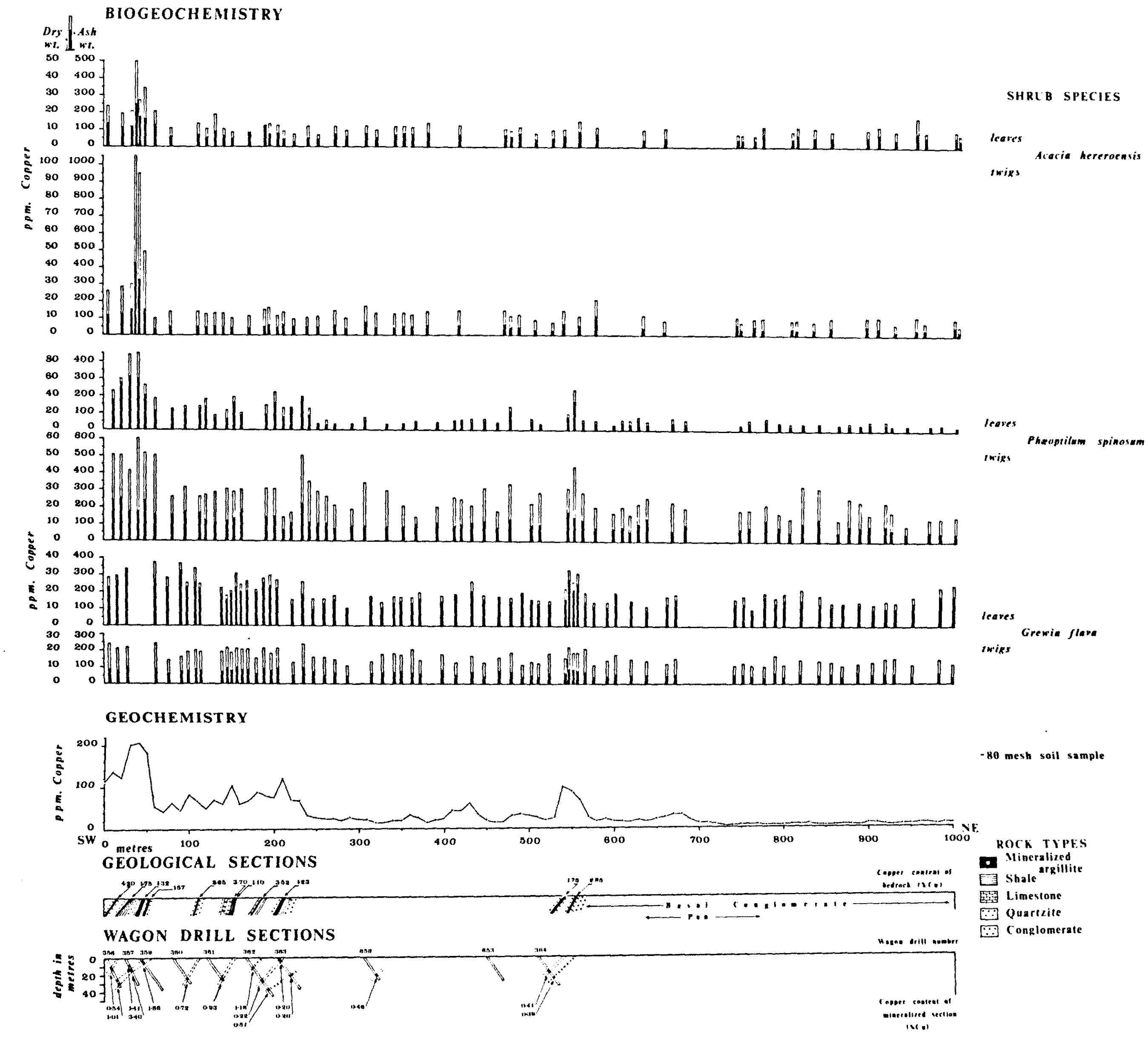


Fig. 36 Transect 38, Malachite Pan, showing the relationship between biogeochemistry, geochemistry and geology.

ples in the section from 0 - 230 m. exceed the threshold value of 8.2 ppm. with the maximum value of 10.2 ppm. in the sample from 152 m. NE. The samples at 545 and 550 m. are also anomalous containing 9.2 and 8.7 ppm. copper respectively.

Very clearly defined anomalies occur in the leaf samples of Phaeoptilum spinosum with the copper level exceeding the threshold of 12.1 ppm. several times. All the samples collected from 0 - 240 m. have an anomalous copper content and the highest values ranging from 41 - 62 ppm., occur between 11 - 45 m. This section contains four zones of mineralized argillite and the soils have 100 - 200 ppm. copper in the -80 mesh fraction. Further anomalous leaf values of 21.7 and 32.8 ppm. occur at 475 and 550 m. which are sites adjacent to known mineralization.

The twigs of Phaeoptilum spinosum have anomalous values for all the samples collected between 0 - 112 m. and 160 - 200 m. and for the individual shrubs at 232 and 550m. NE. The highest value of 25.1 ppm. copper is for the shrub from 20 m., which also has a very high copper content for the leaves.

All the anomalous samples of both leaves and twigs for Phaeoptilum spinosum are from locations along the transect where copper mineralization is present.

The six samples of Acacia hereroensis collected between 5 - 48 m. NE have anomalous values for both the leaves and the twigs. For two of the samples in this section the copper content of the twigs exceeds that of the leaves. The maximum values for the leaves and twigs are 26.0 and 42.0 ppm. respectively from the shrub at 40 m. The zone of anomalous plant values corresponds to the main geochemical anomaly of the transect and a section where four horizons of mineralized argillite occur.

A further anomaly in the leaves occurs at 188 m. and the twigs from 575 m. also have an anomalous copper content. Mineralization is present at 180 m. but an area of basal conglomerate surrounds the location of the second sample.

The mineralized horizons at 120, 150, 220 and 550 m. are not reflected in the copper content of the Acacia hereroensis shrubs sampled nearby.

Transect 42

The transect crosses several areas of anomalous ground vegetation with distinct zones of Helichrysum leptolepis. Trenching across these zones revealed six horizons of mineralized argillite at 230, 260, 275, 525, 610 and 660 m. NE and the wagon drill section also indicates mineralization at 100 m. (Fig. 37). The geochemical profile shows that most of the soil samples from 200 - 700 m. contain over 100 ppm. copper and peaks of 150 - 420 ppm. occur over the mineralization. On the basal conglomerate, at the northeast section of the transect, the soils contain from 40 - 90 ppm. copper which is several times the values obtained for Transects 35 and 38. The higher values in this region are most probably caused by the surface drainage from areas of mineralization into the pan, which occurs between 830 - 1000 m. on the transect.

The copper content of the majority of Grewia flava leaf samples collected between 114 and 700 m. exceeds the threshold value of 21.0 ppm. The higher values in the range 30 - 40 ppm. are from sites adjacent to mineralization and the maximum value of 42.6 ppm. is at 286 m. Further anomalous leaf samples occur at 85 and 86 m. where there is a slight geochemical peak. Fewer of the twig samples are anomalous but all those collected near to the main zones of mineralization exceed the threshold value of 8.5 ppm. copper. All the twigs between 220 - 314 m. and 490 - 680 m. are anomalous with a maximum copper content of 15.2 ppm. at 557 m. NE. This sample borders the zone of mineralized argillite at 560 m. and the soils in this area contain 150 ppm. copper. Anomalous twig samples outside the main areas of mineralization also occur at 85 and 121m.

Phaeoptilum spinosum does not occur in the initial section of the transect but the six samples taken between 175 and 311 m. have anomalous copper values for both the leaves and the twigs. A maximum value of 133.2 ppm. which is ten times the threshold value, occurs in the leaf sample from 258 m. Within the section 370 - 696 m. of the transect all the leaves show anomalous values and most of the twig samples exceed the threshold of 14.5 ppm. copper. Two of the leaf

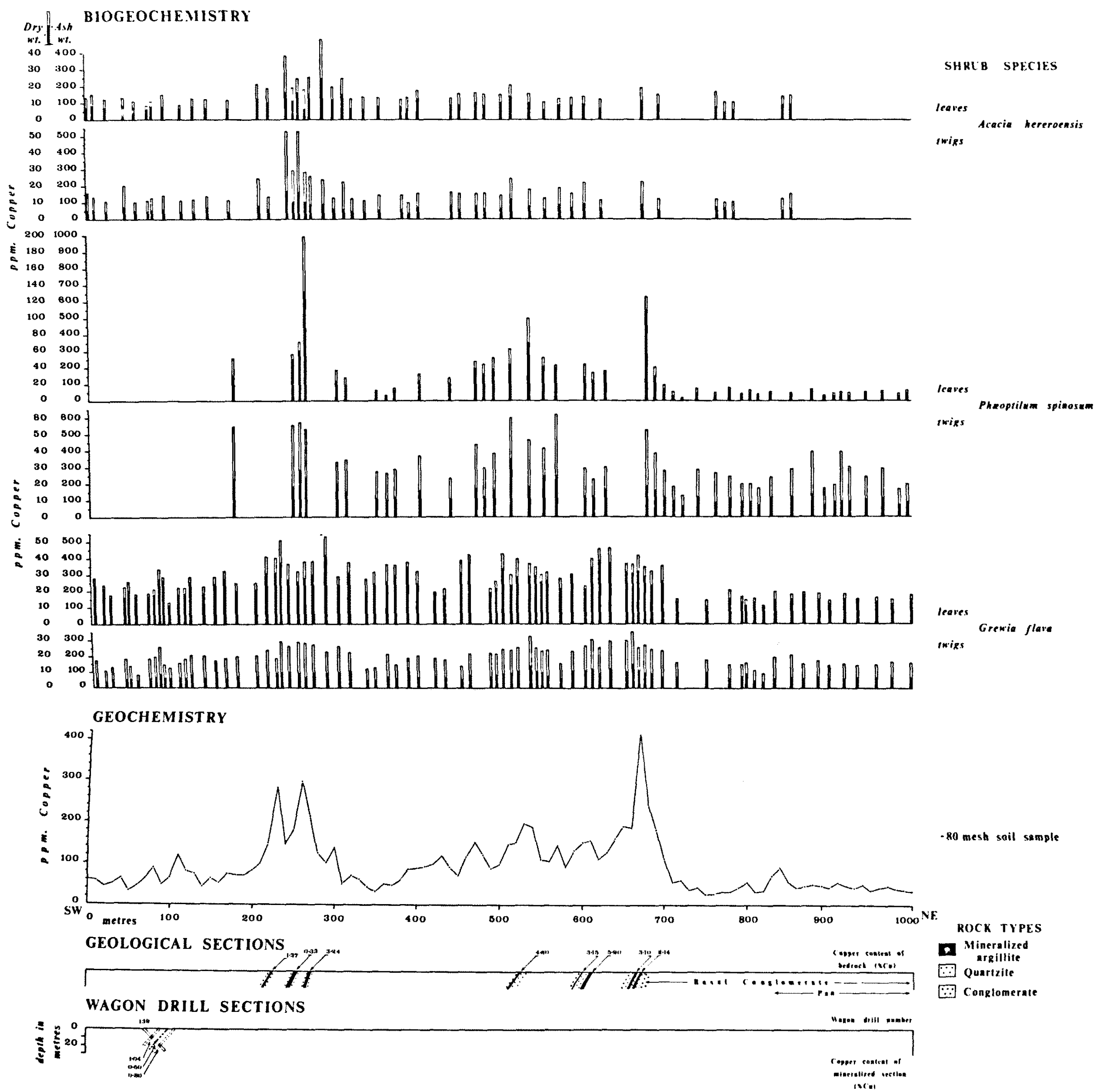


Fig. 37 Transect 42, Malachite Pan, showing the relationship between biogeochemistry, geochemistry and geology.

samples have an extremely high copper content of 107.8 and 69.4 ppm. from 675 and 532 m. respectively, and both these samples are from sites bordering zones of Helichrysum leptolepis. The maximum value for the twig samples in this area is 30.0 ppm. from 510 m.

None of the Phaeoptilum spinosum samples collected over the basal conglomerate have anomalous copper values despite the higher copper content of the soils.

The Acacia hereroensis samples with anomalous values are restricted to the zone 240 - 310 m. and the locations 400 and 512 m. and there are additional anomalous twig samples from 570, 600 and 670 m. The maximum leaf value of 24.7 ppm. copper occurs at 285 m. adjacent to a horizon of mineralized argillite.

Only five shrubs of Acacia hereroensis are from the area of the basal conglomerate and the maximum copper content of these shrubs is 8.8 and 7.2 ppm. for the leaves and twigs respectively.

Transect 45

Towards the western margin of the Malachite Pan the soil cover increases in thickness and in several areas the shrubs have a much denser distribution. The geobotanical mapping indicated only one area of possible mineralization, at 930 m. where a zone of Helichrysum leptolepis occurs. Trenching across this feature revealed two horizons of mineralized argillite (Fig. 38). The soil samples collected along Transect 45 vary in copper content from 5 - 60 ppm. with only one defined peak at 920 m. from the margin of the Helichrysum leptolepis zone. A broad section of higher values occurs from 250 - 330 m. and across the calcrete ridge between 100 - 200 m. the soils contain less than 10 ppm. copper.

In an attempt to trace the western extension of the strongly mineralized argillites exposed on lines 900 and 1000, a series of closely spaced wagon drill sections were completed along line 1200. Many green shale horizons were intersected but only four of these contain appreciable copper mineralization. The values varying from 0.35 - 0.65 copper occur in the wagon drill sections 394, 402, 415 and 155 and when extrapolated to surface the mineralized horizons would form suboutcrops at 340, 450, 720 and 940 m. NE. However, inter-

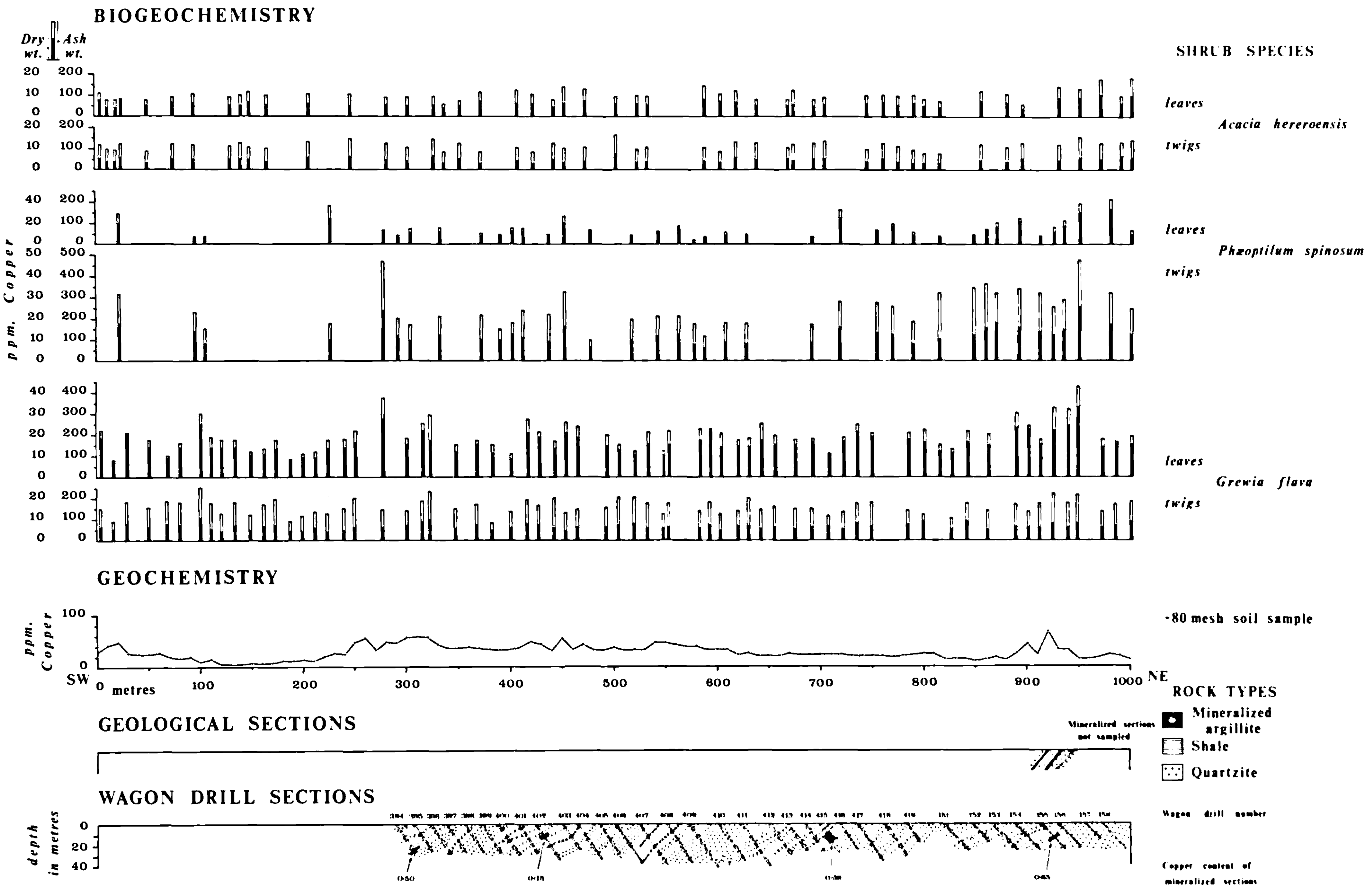


Fig. 38 Transect 45, Malachite Pan, showing the relationship between biogeochemistry, geochemistry and geology.

sections of the same horizons in adjacent wagon drill holes do not show comparable assay values.

Several biogeochemical anomalies are indicated in the samples of Grewia flava collected along Transect 45 (Table 20). The five leaf samples between 884 - 943 m. have an anomalous copper content with a maximum value of 33.1 ppm. for the sample from 943 m. These samples are from the zone of mineralization outlined by the occurrence of Helichrysum leptolepis. However, none of the twig samples from this area show anomalous values. The samples from 100, 210 and 213 m. NE are anomalous for both the leaves and twigs and possibly indicate the western extension of mineralization located on line 1000. The leaf samples from 451 and 731 m. are also anomalous and occur near the sub-outcrops of mineralization indicated by the wagon drilling.

Phaeoptilum spinosum does not occur in the section from 100 - 200 m. across the calcrete ridge but the species has a reasonable distribution throughout the major part of the transect. Thirteen of the shrubs sampled show an anomalous copper content for the leaves and ten of these also have anomalous twig values. The samples occurring between 930 and 975 m., where mineralization is exposed in trench sections, are anomalous and show the maximum values, of 31.9 and 25.6 ppm. copper for the leaves and twigs respectively, for the transect. The locations of other anomalous samples is shown in Table 20 and four sample sites coincide with anomalous samples of Grewia flava.

The samples of Acacia hereroensis do not have any copper values exceeding the threshold of 11 and 8 ppm. for the leaves and twigs respectively. The maximum values recorded for the species were 10.1 ppm. copper for the leaves from 965 m. and 7.7 ppm. for the twigs from 500 m. NE.

The location of anomalous samples for the shrub species Grewia flava, Phaeoptilum spinosum and Acacia hereroensis, collected on Transects 35, 38, 42, 45 and 48, are shown in Fig. 39. An overlay of this map is provided so that the biogeochemical information can be compared directly with geobotanical mapping, geochemistry, geology and the interpreta-

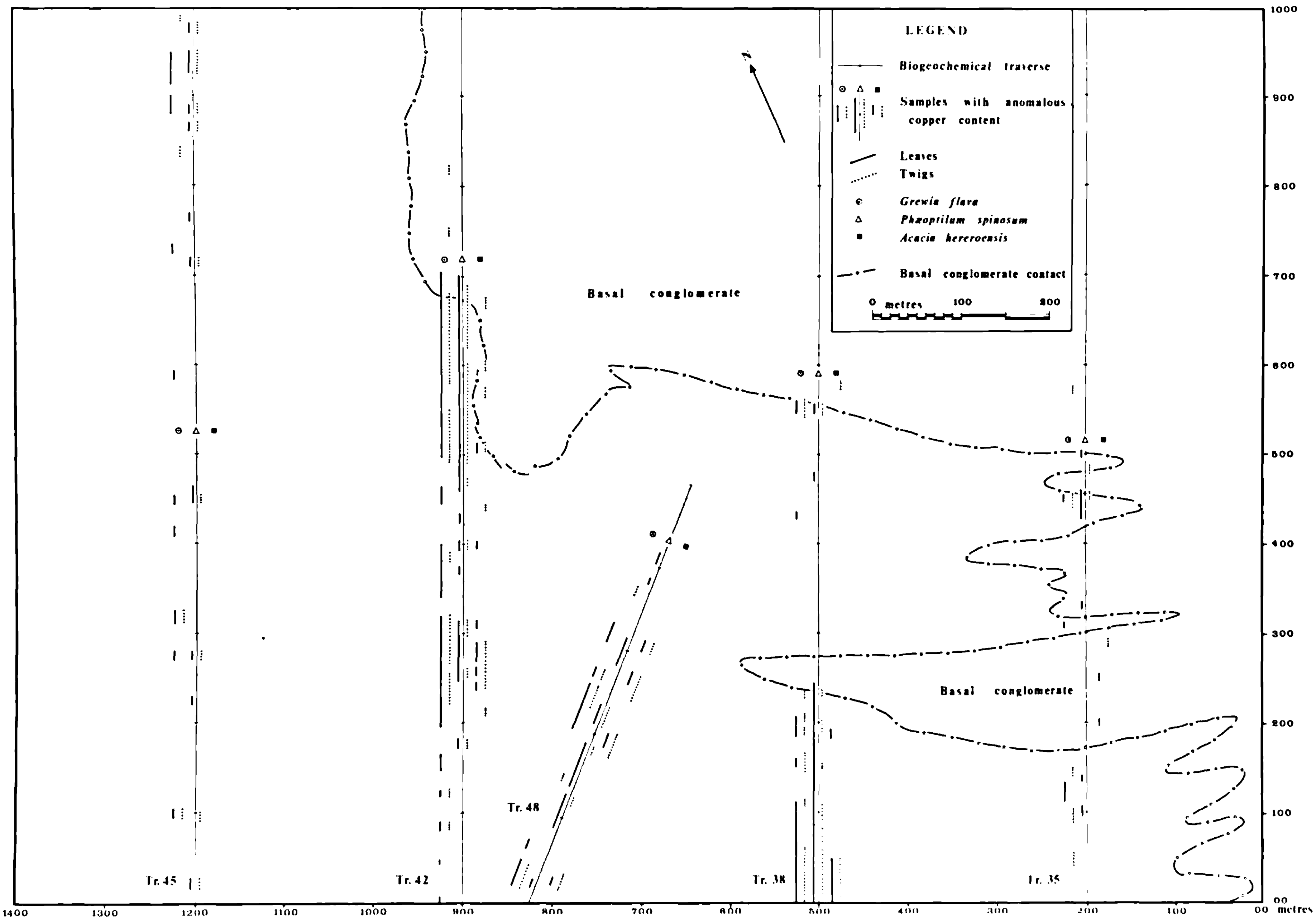


Fig. 39 Location of biogeochemical anomalies in the Malachite Pan Area, Eskadron.

SHRUB SPECIES	Distance m. NE	Leaves ppm. Cu	Twigs ppm. Cu
	100	25.0	10.9
	275*	27.7	-
	313	21.8	8.4
	320	22.5	9.6
	451*	20.9	-
	590	21.5	-
G. flava	731*	21.5	-
	837	-	8.7
	884*	23.3	-
	896	22.7	-
	920 } *	25.0	-
	934 } *	24.6	-
	943 } *	33.1	-
	22	19.4	17.5
	225	24.0	-
	276*	14.2	23.8
	450*	19.8	16.0
	540	13.2	-
P. spinosum	560	13.5	-
	715*	24.1	15.5
	765	15.9	-
	865	15.4	17.4
	887*	20.8	15.6
	930 } *	17.0	14.3
	945 } *	29.7	25.6
	975 } *	31.9	17.1

Table 20. Copper content of anomalous plant samples from Transect 45, Malachite Pan.
(* Locations anomalous for both Grewia flava and Phaeoptilum spinosum)

tion of mineralization of Figs. 27 - 30.

In several sections of the transect all three shrub species show anomalous copper values for both the leaves and the twigs and for the following zones at least four of the six parameters are anomalous:

Tr. 35	450 m.
Tr. 38	0 - 60 m., 190 m., 550 m.
Tr. 42	230 - 310 m., 390 m., 500 - 700 m.
Tr. 48	10 - 35 m., 220 m., 310 m.

These locations also outline the main zones of copper mineralization where assay values for the mineralized argillites are higher.

There is an absence of groups of anomalous values for the three following areas.

Groups of anomalous values do not occur over the basal conglomerate of Transects 35 (200 - 400 m.) and 42 (700 - 1000 m.) or in the section of Transect 38 from 250 - 450 m. where there are no indications of copper mineralization.

On line 1200 the weaker mineralization at 940 m. is reflected by the anomalous values of Grewia flava and Phaeoptilum spinosum. Similar groups of anomalous values for these shrubs occur at approximately 100, 270, 440 and 890 m. and would indicate other probable zones of mineralization on this line.

The copper content of the leaves and twigs, for the samples collected on Transects 35, 38, 42 and 45, is plotted against the copper content of the soil in the scatter diagrams of Fig. 40.

The leaf samples of Grewia flava show a concentration of values in the range 9 - 16 ppm. copper where the copper content of the soil is less than 50 ppm. Eleven samples however, from the low soil areas, exceed the threshold value of 21 ppm. copper for the leaves. This group of samples may indicate that the plants are obtaining copper from below the level of the surface soils that were sampled. The leaves show a general increase in copper content with the increasing soil values and most of the plant samples are anomalous in soils over 100 ppm. copper. The majority of the twig samples of Grewia flava from soils of less than 50 ppm. copper, contain from 3 - 7.5 ppm. copper and only five samples of this group exceed the threshold of 8.5 ppm. For the soils containing over 100 ppm. copper the majority of the twig samples are anomalous.

The leaf samples of Phaeoptilum spinosum with corresponding soil values of less than 50 ppm., show a wide range in copper content from 3 - 32 ppm. The majority of the samples contain from 3 - 8 ppm. but sixteen samples exceed the threshold value of 13 ppm. and may indicate the presence of copper at depth below the surface soils. As the soils increase in copper content the leaves also show increasing values and for soils containing more than 80 ppm. all the leaf samples are anomalous in copper. Several of the twig samples have anomalous copper values with soils of less than 50 ppm. but, most of the samples are in the range 4 - 13 ppm. copper. The twigs show an increase in copper with the higher soil values but, the range of values is much more limited than for the leaves.

The leaves of Acacia hereroensis do not show any marked increase in copper content with the increase of copper in the soils. Values of 3 - 10 ppm. are recorded for the majority of the leaf samples with the soil values ranging upto 100 ppm. copper. In the soils above 100 ppm. the leaf samples are mainly between 7 - 18 ppm. but, many of these samples do not exceed the threshold of 11.5 ppm. The twig samples corresponding to the soil ranges 0-50 and 50 - 100 ppm. copper have the same general copper content of 3 - 8 ppm. For the soils exceeding 100 ppm. the twigs contain from 5 - 16 ppm. and there are three high values from 25 - 42 ppm.

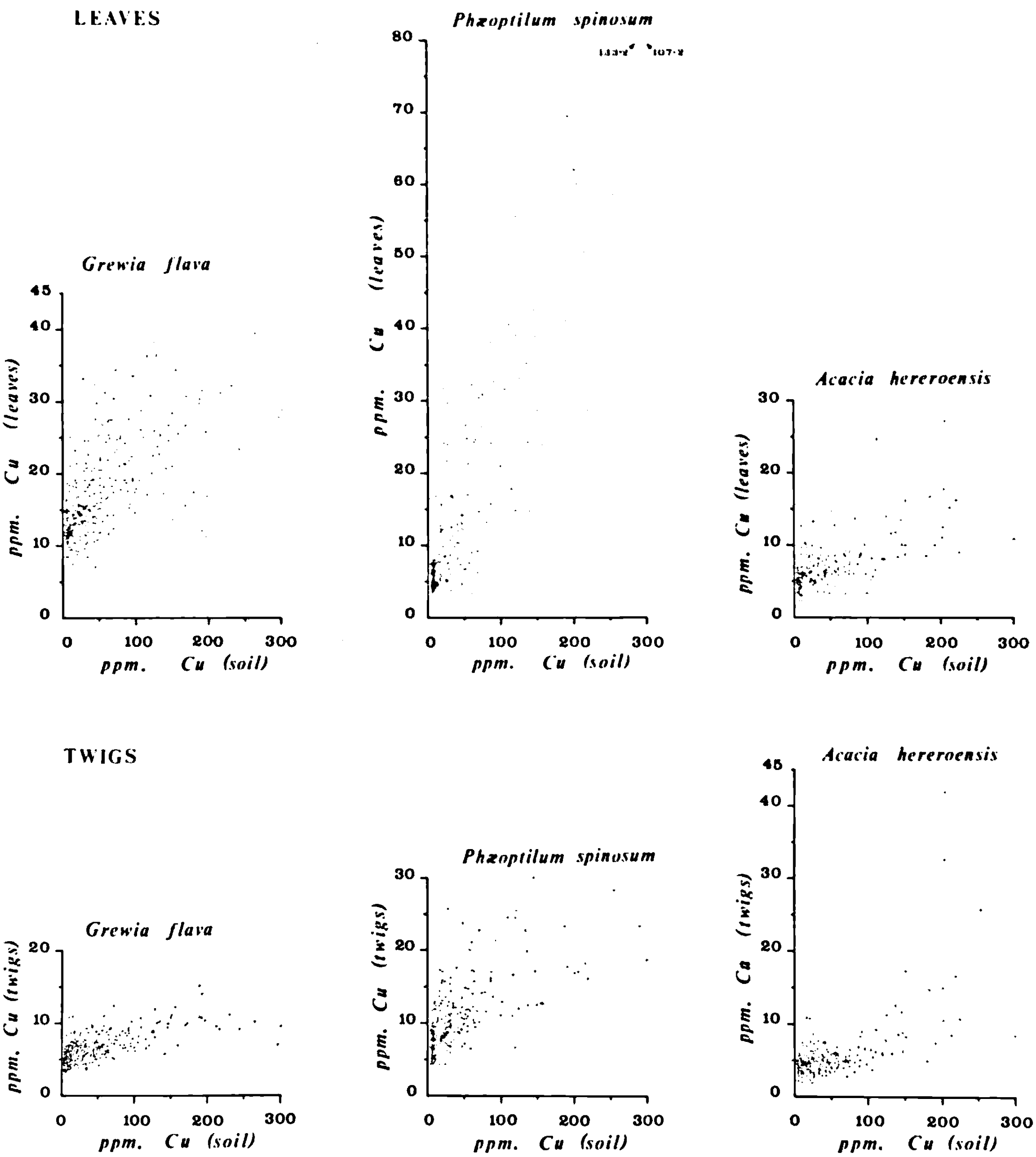


Fig. 40 The relationship between the copper content of the shrub species (leaves and twigs) and the copper content of the soil (-80 mesh), Transects 35, 38, 42 & 45 Malachite Pan.

		Mean Background ppm. copper	Threshold ppm. copper
G. flava	Leaves	13.5	21.0
	Twigs	5.5	8.5
P. spinosum	Leaves	6.5	13.0
	Twigs	8.0	14.5
A. hereroensis	Leaves	6.5	11.5
	Twigs	4.5	8.5

D. Seasonal Biogeochemistry

During the field season November 1969 - June 1970 selected shrubs of *Grewia flava* and *Acacia mellifera* were sampled periodically to determine if there was any significant variation in the copper content of the leaves and twigs throughout the growing season.

Five large shrubs of *Grewia flava*, from both background and anomalous geochemical zones, were marked at the Copper Causeway area for seasonal sampling and eight *Acacia mellifera* shrubs from the Copper Causeway and Pos Areas were selected.

The first samples were collected in mid-November before commencement of the rains and no leaves or current growth were present on the shrubs. 1st., 2nd., 3rd., or 3 - 5th. year twigs were collected. In the subsequent resampling in January, March and May, leaves current growth, 1st. and 2nd. year twigs were collected.

Each sample was split by cone and quartering and duplicate analyses carried out for all samples. The average of the two values for the *Grewia flava* samples are shown in Table 21 and for *Acacia mellifera* in Table 22.

Several general conclusions can be made from the results of the seasonal sampling.

Grewia flava

1. The leaves show an increase of upto 20% through the growing season and then a decrease of 20 - 40% in most samples towards the end of the season.

2. The copper content of the current growth is fairly constant throughout the season.

3. The copper content of the combined 1st. and 2nd. year twigs is fairly constant throughout the season.

4. The leaves contain 2 - 6 times more copper than the twigs.

5. There is a decrease in copper with the older twigs.

Acacia mellifera

1. There is a wide variation in the copper content of the leaves through the season. Four samples show a continual increase of upto 150%, three samples initially show an increase and then a decrease of upto 100%.

2. The copper content of the current growth is fairly constant through the season.

3. No general trend is apparent for the copper content of the 1st. year twigs through the season but, the samples are mainly within ± 20%.

4. Most of the 2nd. year twig samples show very little variation through the season.

5. The copper content decreases in the older wood.

Re-sampling of the leaves of Grewia flava and Phaeoptilum spinosum was carried out along Transect 30 to compare the copper levels in the leaves during the following growing season. These two species had shown a clear contrast in copper levels between samples collected from background and the samples over the mineralization. The results of analyses for the initial sampling in April 1969 and the re-sampling in January 1970 are shown in Tables 23 and 24.

For Grewia flava leaves collected in April 1969 the background values vary from 6 - 15 ppm. and the samples from the mineralized section contain 20 - 29 ppm. copper. The respective results for January 1970 are 14 - 25 ppm. and 32 - 44 ppm. The results of the resampling clearly reflect the mineralized section of the transect but, individual samples show increases in copper content from 20 - 250%. The increase in copper content for the anomalous group of samples covers a smaller range of 20 - 80%.

The results of the re-sampling for the leaves of Phaeoptilum spinosum (Table 24) are generally comparable but the values are 2 - 5 times higher in some cases. The peak values from the initial sampling in April 1969, 23 - 54 ppm. copper from 190, 208, 448 and 457 m.S, show only minor increases of less than 10% from the re-sampling.

The trees and shrubs bordering the anomalous vegetation zone between transects 52 and 53, Malachite Pan, were sampled in July prior to defoliation and again in December after coming into leaf for the following season. The results of copper determinations on these samples are shown in Table 25.

The leaves of the new seasons growth show a decrease in copper content for the species Acacia hereroensis, Tarchonanthus camphoratus and Grewia flava and an increase for Rhus pyroides. The variation in values for one shrub is upto 100% as in the case of Acacia hereroensis. The twigs show much more consistent values in the re-sampling and the majority are within ± 20% of the copper content recorded in July.

Sample Nº	Part of plant	Date of Collection ppm. Cu 10/11/69	ppm. Cu 13/1/70	ppm.Cu 24/3/70	ppm.Cu 7/5/70
	Leaves	-	13.4	16.0	9.5
3559	Ct. growth	-	-	8.6	5.2
CC.	1st.Yr.Twigs	6.0	5.4	6.6	5.1
20n/10E	2nd.Yr.Twigs	5.1	4.2	-	-
	3rd.Yr.Twigs	5.1	-	-	-
	Leaves	-	5.0	7.0	7.4
3560	Ct. growth	6.9)			
CC.	1st.Yr.Twigs	3.7	3.2	3.6	4.3
125N/15E	2nd.Yr.Twigs	3.6	-	-	-
	3rd.Yr.Twigs				
	Leaves	-	16.1	18.4	14.8
3561	Ct. growth	-	8.3	9.5	8.7
CC.	1st.Yr.Twigs	9.1)	6.2	6.4	6.1
202N/10W	2nd.Yr.Twigs	6.1			
	3rd.Yr.Twigs	6.1	-	-	-
	Leaves	-	31.1	37.3	28.8
3562	Ct. growth	-	7.2	7.8	8.2
CC.	1st.Yr.Twigs	9.6)	5.5	6.1	6.0
245N/35W	2nd.Yr.Twigs	7.7			
	3rd.Yr.Twigs	6.9	-	-	-
	Leaves	-	34.0	33.5	31.9
	Ct. Growth	-	6.8	6.2	7.7
	1st.Yr.Twigs	6.7)	5.3	4.3	5.8
	2nd.Yr.Twigs	7.0			
	3rd.Yr.Twigs	5.8	-	-	-

Table 21. Variation in the copper content of Grewia flava leaves and twigs throughout the growing season.

Sample Nº	Part of plant	Date of Collection 10/11/69 ppm. Cu	13/1/70 ppm. Cu	24/3/70 ppm. Cu	7/5/70 ppm.Cu
3551 Tr.30 209/15W	Leaves	-	12.2	15.1	20.3
	Ct. growth	-	-	14.6	15.6
	1st.Yr.Twigs	9.1	13.2	19.0	19.3
	2nd.Yr.Twigs	13.1	23.3	16.8	22.1
	3- 5Yr.Twigs	12.5	-	-	-
3552 Tr.30 209/25W	Leaves	-	18.0	32.9	34.7
	Ct.Growth	-	19.2	-	-
	1st.Yr.Twigs	16.6.	22.9	23.2	19.0
	2nd.Yr.Twigs	22.4	16.5	16.8	16.6
	3-5.Yr.Twigs	4.8	-	-	-
3553 Tr.30 150m.S	Leaves	-	9.2	10.0	12.8
	Ct.Growth	-	9.1	8.8	7.9
	1st.Yr.Twigs	7.0	9.9	10.6	8.1
	2nd.Yr.Twigs	9.4	10.3	9.9	9.5
	3-5.Yr.Twigs	3.4	-	-	-
3554 Tr.30 60m.N	Leaves	-	6.5	9.4	7.3
	Ct.Growth	-	3.8	4.5	3.4
	1st.Yr.Twigs	4.3	4.1	3.3	3.1
	2nd.Yr.Twigs	2.9	3.9	2.9	2.9
	3-5.Yr.Twigs	2.3	-	-	-
3555 CC. 100/8E	Leaves	-	6.3	6.1	12.4
	Ct.Growth	-	5.0	4.5	5.1
	1st.Yr.Twigs	3.8	4.2	4.0	4.1
	2nd.Yr.Twigs	2.7	3.5	-	2.3
	3-5 Yr.Twigs	1.5	-	-	-
3556 CC. 294/18E	Leaves	-	9.7	14.3	7.1
	Ct.growth	-	7.0	6.6	5.4
	1st.Yr.Twigs	4.4	4.8	6.7	4.2
	2nd.Yr.Twigs	3.0	3.4	3.6	4.0
	3-5.Yr.Twigs	2.4	-	-	-
3557 CC. 100/50E	Leaves	-	6.0	6.6	16.4
	Ct. Growth	-	4.7	6.4	7.0
	1st.Yr.Twigs	4.4	3.5	5.2	4.6
	2nd.Yr.Twigs	4.1	3.6	-	2.3
	3-5..Yr.Twigs	2.7	-	-	-
5758 CC. 375/50E	Leaves	-	11.9	16.4	14.8
	Ct. Growth	-	8.8	9.4	9.8
	1st.Yr.Twigs	6.8	7.3	8.0	8.4
	2nd.Yr.Twigs	6.8	7.9	7.3	6.1
	3-5 Yr.Twigs	4.2	-	-	-

Table 22. Variation in the copper content of *Acacia mellifera* leaves and twigs throughout the growing season.

Location	DATE OF COLLECTION			
	14 - 4 - 69		14 - 1 - 70	
	ppm. ash	ppm. dry	ppm. ash	ppm. dry
100N	100	6.0	227	16.8
79N	87	5.8	262	21.3
57N	150	8.1	222	18.0
44N	172	10.9	275	21.0
18N	155	10.3	222	18.5
0	143	10.4	162	14.5
15S	143	10.4	240	19.8
38	227	18.0	360	31.4
63	183	11.9	270	22.1
80	218	15.2	285	25.4
95	107	7.5	282	23.7
120	207	14.3	292	21.5
140	120	8.0	275	20.5
160	205	14.1	252	18.7
170	132	10.1	230	17.6
181	115	9.8	295	25.0
190	257	17.7	317	28.5
198	345	22.5	420	38.1
206	405	29.0	400	34.6
206	395	24.1	360	28.4
212	452	27.9	460	41.4
230	453	29.4	510	44.1
240	360	23.7	375	27.6
250	375	21.8	357	31.1
264	377	26.1	445	36.8
270	288	20.3	405	32.8
294	152	10.2	237	20.0
302	212	13.7	285	22.9
310	135	9.8	260	20.3
318	147	10.3	225	17.5
332	150	10.3	262	20.0
342	142	10.7	305	24.8
364	180	10.9	292	20.5
379	107	7.3	222	17.9
399	132	9.1	250	22.8
418	100	7.0	310	26.0
442	127	9.3	320	25.6
463	190	12.3	225	20.7
546	265	14.5	357	23.4
582S	132	9.5	275	23.9

Table 23. A comparison of the copper content of the leaves of Grewia flava for samples collected on Transect 30, Pos Area, in April 1969 and January 1970.

Location	DATE OF COLLECTION			
	14 - 4 - 69		14 - 1 - 70	
	ppm.ash	ppm.dry	ppm.ash	ppm.dry
62N	47	4.7	87	8.5
57N	40	4.0	90	7.1
7N	60	5.0	140	10.7
2S	120	10.7	217	18.6
30S	92	5.3	290	32.6
50	138	19.1	257	28.9
95	75	9.2	150	17.6
143	42	5.4	140	15.2
190	210	25.2	222	27.8
208	490	54.5	395	55.1
309	115	11.8	390	37.1
342	70	7.2	302	32.8
418	60	9.8	187	18.1
448	145	23.8	202	25.8
457	272	28.5	290	30.0
523	135	13.5	210	22.4
538	190	21.4	315	30.5
570	67	9.8	80	8.9
588S	102	9.2	117	11.2

Table 24. A comparison of the copper content of the leaves of Phaeoptilum spinosum for samples collected on Transect 30, Pos Area, in April 1969 and January 1970.

Plant species	DATE OF COLLECTION			
	19 - 6 - 69		16 - 12 - 69	
	ppm. ash	ppm. dry	ppm. ash	ppm. dry
A. giraffae	*L 85 *T 90	8.0 4.8	85 65	5.2 5.4
A. giraffae	L 49 T 65	3.8 3.2	60 42	3.4 2.7
A. hereroensis	L 267 T 312	16.7 10.0	228 175	14.4 7.8
A. hereroensis	L 327 T 630	20.1 21.1	190 295	10.4 12.2
A. hereroensis	L 295 T 230	16.8 8.9	115 188	8.5 9.0
A. hereroensis	L 730 T 222	56.9 9.9	480 198	40.3 8.0
A. hereroensis	L 132 T 130	8.3 4.9	120 193	7.8 9.1
T. camphoratus	L 850 T 262	63.3 9.8	615 255	50.0 8.7
T. camphoratus	L 730 T 238	56.9 11.4	480 255	40.3 8.5
T. camphoratus	L 490 T 345	39.0 14.4	400 475	33.4 16.8
T. camphoratus	L 348 T 182	26.8 8.4	420 245	34.4 8.5
R. pyroides	L 270 T 338	18.7 14.7	483 290	44.7 14.9
R. pyroides	L 335 T 252	27.4 9.6	363 210	34.8 8.9
G. flava	L 664 T 267	56.4 8.9	353 295	32.1 11.5

*L - leaves, T - twigs

Table 25. A comparison of the copper content in June and December 1969 for selected trees and shrubs at the Malachite Pan.

Chapter 7

INVESTIGATIONS IN AREAS OF SAND COVER

A. NORTHERN OKATJIRUTE WEST

Introduction

In July 1968 Anglovaal began a phase of regional trenching using a mechanical digger. The programme was designed to locate areas of mineralization within the strike projections of known copper occurrences. The initial trenches upto two kilometres in length were across the northern extension of the zone linking the Copper Causeway and Okatjirute West homestead (Fig. 3). The overburden of this region is less than 5 metres and several minor copper anomalies are indicated from the regional geochemical survey. The vegetation is low tree and shrub savanna characterised by the species Acacia hereroensis, Acacia mellifera, Grewia flava and Phaeoptilum spinosum and the ground cover is dominated by the perennial grass Stipagrostis uniplumis.

The excavation of Trench H.7, about 3km. north of Okatjirute West homestead, exposed mineralized limestone beneath a cover of sand and gravel. This was the first instance of mineralization masked by wind blown sand and orientation studies were undertaken to determine whether the copper mineralization could be detected by geochemistry or biogeochemistry. Profile samples were collected from the trench face across the zone of mineralization and soil and plant samples were collected along Transect 67, which is parallel to the trench and 20 metres to the north.

Profile samples Trench H.7

The mineralization occurs in a limestone and two chip samples taken across the zone from fresh bedrock gave assays of 1.30 and 0.28% copper over a combined width of 1.6 metres

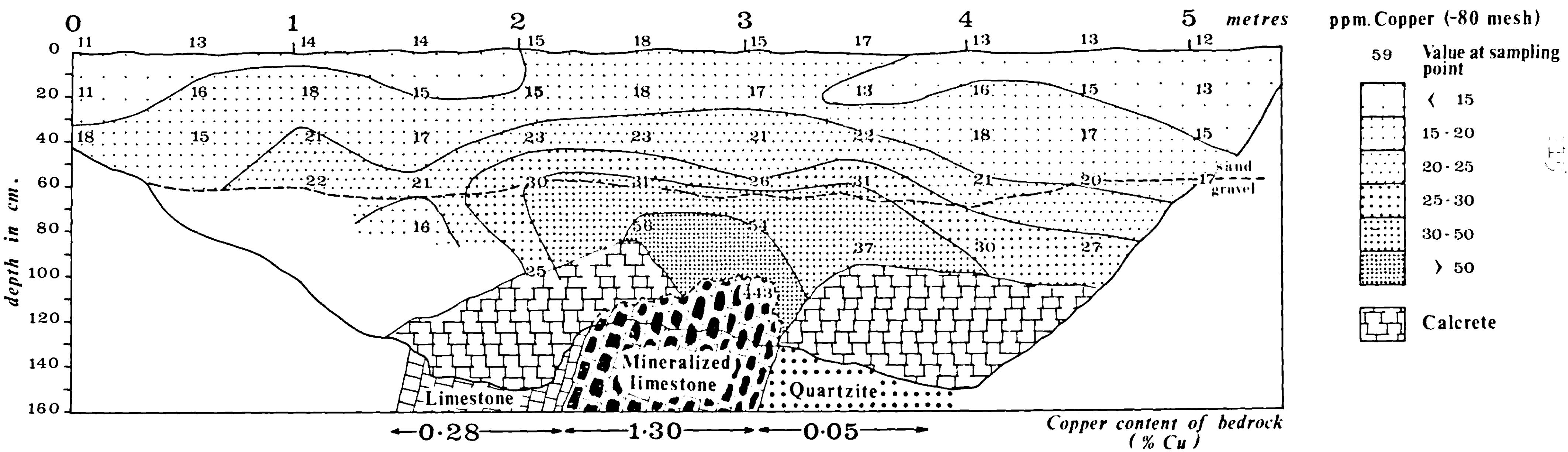


Fig. 41 Distribution of copper in the overburden of sand and gravel, overlying mineralized limestone at 1961 m. Trench H.7, northern Okatjirute West.

(Fig. 41). The quartzite also exposed in the trench contains only trace amounts of copper. Calcrete occurs over the weakly mineralized limestone and the quartzite and the irregularities in the bedrock surface are concealed by a variable thickness of gravel and a layer of fine to medium grained sand.

Profile samples, spaced at half metre intervals across the mineralized zone, were collected from the sand and gravel layers every 20 cm. from the surface down to bedrock. The copper content of the -80 mesh fraction for these samples is shown in Fig. 41.

The dispersion of copper from the mineralized limestone is extremely limited both laterally and vertically. The gravels resting on the bedrock contain only 50 ppm. copper and the lower section of the sand about 20 ppm. There is no apparent anomaly from the samples collected from a depth of 20 cm. directly over the mineralized bedrock. These samples contain 15 - 18 ppm. copper compared to 11 - 13 ppm. for samples outside the zone. The normal reconnaissance geochemistry of collecting the -80 mesh fraction from a depth of 15 - 20 cm. and 20 - 30 m. intervals would not detect this horizon of mineralized limestone.

Particle size analysis and mesh fraction analyses were carried out on two bulk samples from the profile above the mineralization and also for profile samples from an area of barren quartzite.

The surface sandy horizon from the two profiles at 1763 m. and 1961 m., represented by the samples 1972, 1971 and 1965 of Fig. 42 is very uniform in composition, consisting of approximately 80% fine and medium grained sand (50 - 500u), 15% gravel and coarse sand and 5% silt and clay. The samples 1969 and 1960 from the gravel layer of the two profiles also have a similar composition, containing approximately 70% granule and pebble size material of quartz and quartzite, 10% coarse and medium grained sand, 20% fine grained sand and less than 1% silt and clay combined.

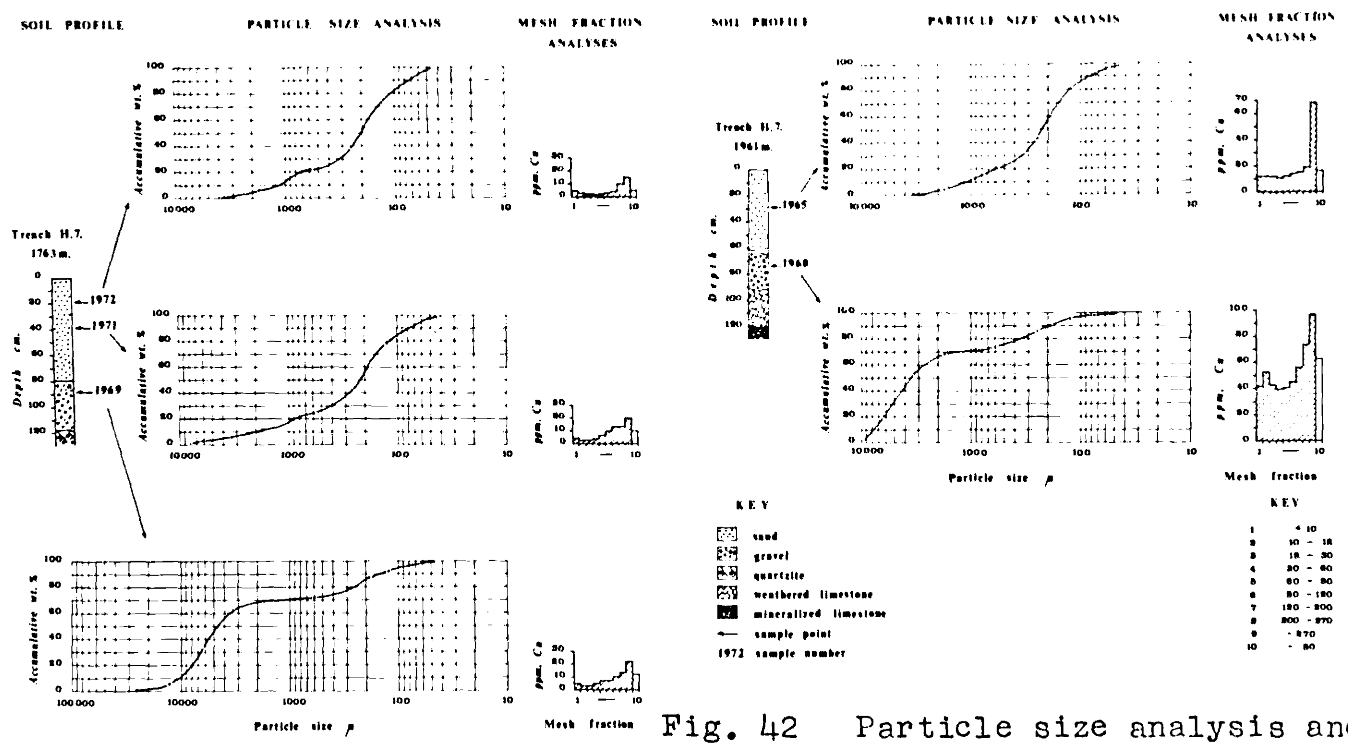


Fig. 42 Particle size analysis and mesh fraction analyses for copper of bulk soil samples collected from Trench H.7, northern Okatjirute West. (1763 m. and 1961 m. Trench H.7 correspond to the distances 288 m. and 90 m. of Transect 67.)

The mesh fractions sieved from the profile samples were analysed for copper content and the results shown in Fig. 42. In sample 1972, taken from a depth of 20 cm. at 1763 m., the total -80 mesh fraction and the fractions upto 200 mesh all contain 5 ppm. copper or less. The -270 mesh fraction has the highest value of 15 ppm. copper approximately three times the total -80 mesh value. The samples from the equivalent horizon over the mineralized limestone, 20 cm. depth at 1961 m., have from 10 - 15 ppm. copper in the fractions upto 200 mesh and the total -80 mesh fractions, and 70 ppm. in the -270 mesh.

In the sample 1969, from the gravel layer 90 cm. below the surface at 1763 m., the total -80 mesh and most of the other fractions contain less than 15 ppm. and the -270 mesh fraction 22 ppm. copper. All the mesh fractions for the sample 1960, from the gravel layer above the mineralized limestone, contain over 40 ppm. copper; the -270 sample has 100 ppm. and the total -80 mesh fraction has 60 ppm. copper.

This single comparison, of profile samples over barren quartzite and mineralized limestone, shows that an anomalous contrast is present in all mesh fractions for the samples taken from the gravel layer and should be easily detectable in routine analyses. In the near surface soils, 20 cm. depth, a better contrast is given by the -270 mesh fraction (15:70 ppm.).

Transect 67

The transect is located parallel to the trench H.7 and 20 metres to the north to avoid any possible contamination. The point of origin of the transect is not the same as for the trench and as shown in Fig. 42, 90 m., Tr. 67 = 1961., H.7. The overburden and geology for Transect 67 can be extrapolated from the trench.

The nature and thickness of the overburden is extremely variable. Calcrete occurs in many places directly over bedrock and is present at the surface from 140 - 150 m. and from 500 - 530 m. SE where it forms a low ridge. For the major part of the transect the overburden consists of

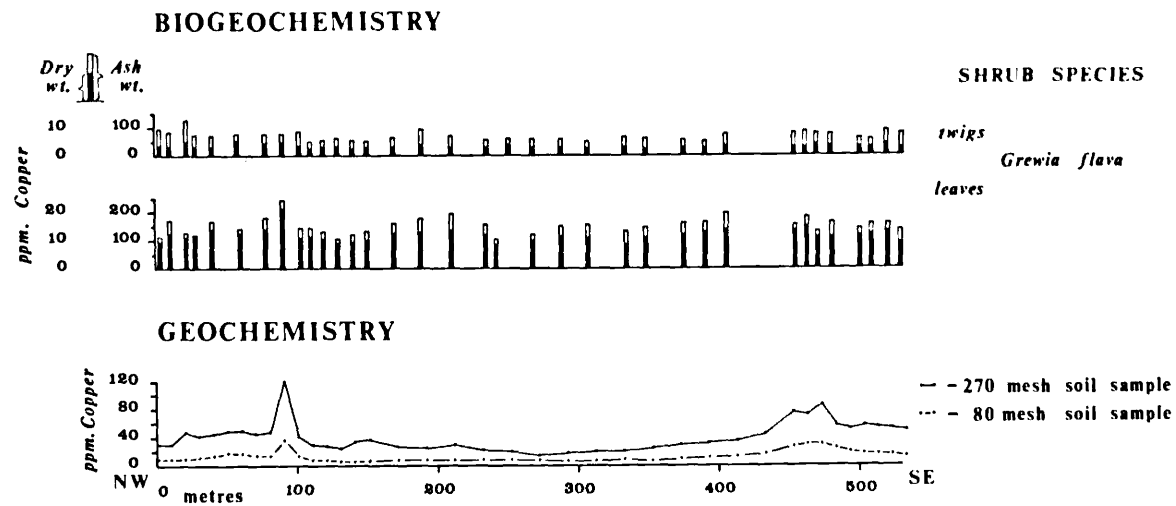


Fig. 43 The copper content of the leaves and twigs of <u>Grewia flava</u> and the copper content of the soil, Transect 67, northern Okatjirute West.

two distinct horizons which are a surface horizon of fine to medium grained wind-blown sand and a lower horizon of angular to sub-angular gravel of quartz and quartzite. The gravel may rest on calcrete or directly on weathered bedrock. The combined thickness of the sand and gravel horizons varies from less than 30 cm. to 2 - 3 metres (Plate. 32).

The majority of the bedrock exposures in the trench are quartzites. Mixed volcanic rocks are present in the section 0 - 40 m. SE, which indicate the margin of the Opdam/ Skumok Formation. Several horizons of limestone occur from 50 - 100 m. and there is a broad zone of grey to green shales between 460 - 580 m. SE. The only copper mineralization occurs in a limestone at approximately 90 m. SE.

The vegetation of the area is very uniform and the only variation in species occurs over the sections of calcrete. The tree and shrub cover is extremely open and Grewia flava is the only commonly occurring species. There are occasional small trees of Acacia giraffae and shrubs of Acacia hebeclada, Acacia hereroensis and Ziziphus mucronata are scattered throughout the area. The ground cover consists of an association of Stipagrostis uniplumis, which is the dominant grass species, Aristida congesta and Schmidtia pappophoroides. The most common herbs recorded along the transect are Sylitra biflora, Trichodesma angustifolium, Geigeria ornativa and Portulaca grandiflora.

In the areas of surface calcrete the dominant shrub species are Tarchonanthus camphoratus and Acacia hebeclada and the ground cover consists of an association of the grasses Enneapogon cenchroides and Stipagrostis ciliata, with the herbs Aptosimum leucorrhizum, Hermannia damarana and Evolvulus alsinoides.

Soil samples were collected at 10 and 15 metre intervals from a depth of 20 cm. and the -80 mesh and -270 mesh fractions analysed for copper content. Geochemical highs are apparent in both mesh fractions for the sample from 90 m. SE with values of 37 and 120 ppm. copper for the -80 and -270 mesh respectively (Fig. 43). A second zone of higher values

Plate 32 View north-westwards along Trench H.7, northern Okatjirute West.
The overburden in this area varies from less that 30cm. to 3m. and consists of calcrete, quartz and quartzite gravel and wind-blown sand. (Ref. MMC/SWA 22/7)

for the -270 mesh fraction extends from 450 - 480 m. which corresponds to a section of shales in the trench. The copper content of the -80 mesh fraction for this area varies from 25 - 30 ppm. compared to less than 10 ppm. for the major part of the transect.

Grewia flava is the only shrub species which occurs at reasonably close intervals along the transect and samples of leaves and twigs were collected from all the Grewia flava shrubs within 20 metres of the transect line. The results of analyses for copper are plotted in Fig. 43.

The maximum value recorded for the leaves of 21.5 ppm. is from the shrub at 90 m. which is on the strike extension of the mineralized limestone. All other values for the leaves are within the range 8 - 15 ppm. copper and two of the higher values are from 450 - 460 m. where the soils are slightly higher in copper content. The twigs show a very narrow range for copper, from 2 - 5 ppm., and there is no apparent relation between the higher values in the twigs and the higher values in the leaves.

B. DAHEIM

Introduction

The initial geochemical reconnaissance survey of the Witvlei Concession indicated an area of anomalous copper values in north-western Daheim (Fig. 6). Peak values of upto 130 ppm. copper were recorded, and values above the 20 ppm. background occur for sections of several hundred metres along the traverses.

The vegetation for the major part of this region is a low tree and shrub savanna characterised by trees of Acacia giraffae, Terminalia sericea and the ground vegetation is composed mainly of the grasses Stipagrostis uniplumis and Schmidtia pappophoroides. In several areas savanna grassland predominates where Aristida stipitata and Eragrostis pallens are the most common species. The surface soils consist of medium to fine grained sand, which is most probably wind-borne, and seismic readings in the area indicate that the over burden exceeds five metres.

This region is within the strike projection of the Pos Area mineralization outlined by Garskie (Fig. 3) and during the regional trenching programme, in the latter part of 1968, two trenches were located across the area. One trench was in the northern section of Okatjirute East and the second in western Daheim near to the traverse lines that showed anomalous copper values. No significant zones of mineralization were discovered by the trenching and further work in this area was suspended until February 1970 when wagon drilling was undertaken. A section line was drilled across the geochemical anomaly on the Daheim - Okasandu boundary and several zones of copper mineralization were outlined. (Fig. 45) The most significant was an intersection of five metres grading 1.3% copper. A trench was located over the surface projection of this zone and a section of mineralized shales was exposed beneath approximately 1.5 metres of gravel and wind-blown sand. A second line of wagon drill holes were completed 100 metres to the south across the strike projection of the mineralized shales and a zone of several metres grading 2.69% copper was intersected. However, further drilling across strike 200 metres from the boundary fence failed to locate mineralization (Fig. 45).

The wagon drilling was extremely difficult in the overburden of sand, gravel and often calcrete and a better definition of the zones of mineralization was needed prior to drilling. Geochemical and biogeochemical surveys were carried out for this purpose. Work in the area was restricted to the southern side of the boundary fence between Daheim and Okasandu as this is also the boundary of the concession. A 100 metre grid was surveyed for vegetation mapping, geochemical and biogeochemical sampling, with the known mineralization in the central section of the grid. The transect lines 99 - 104

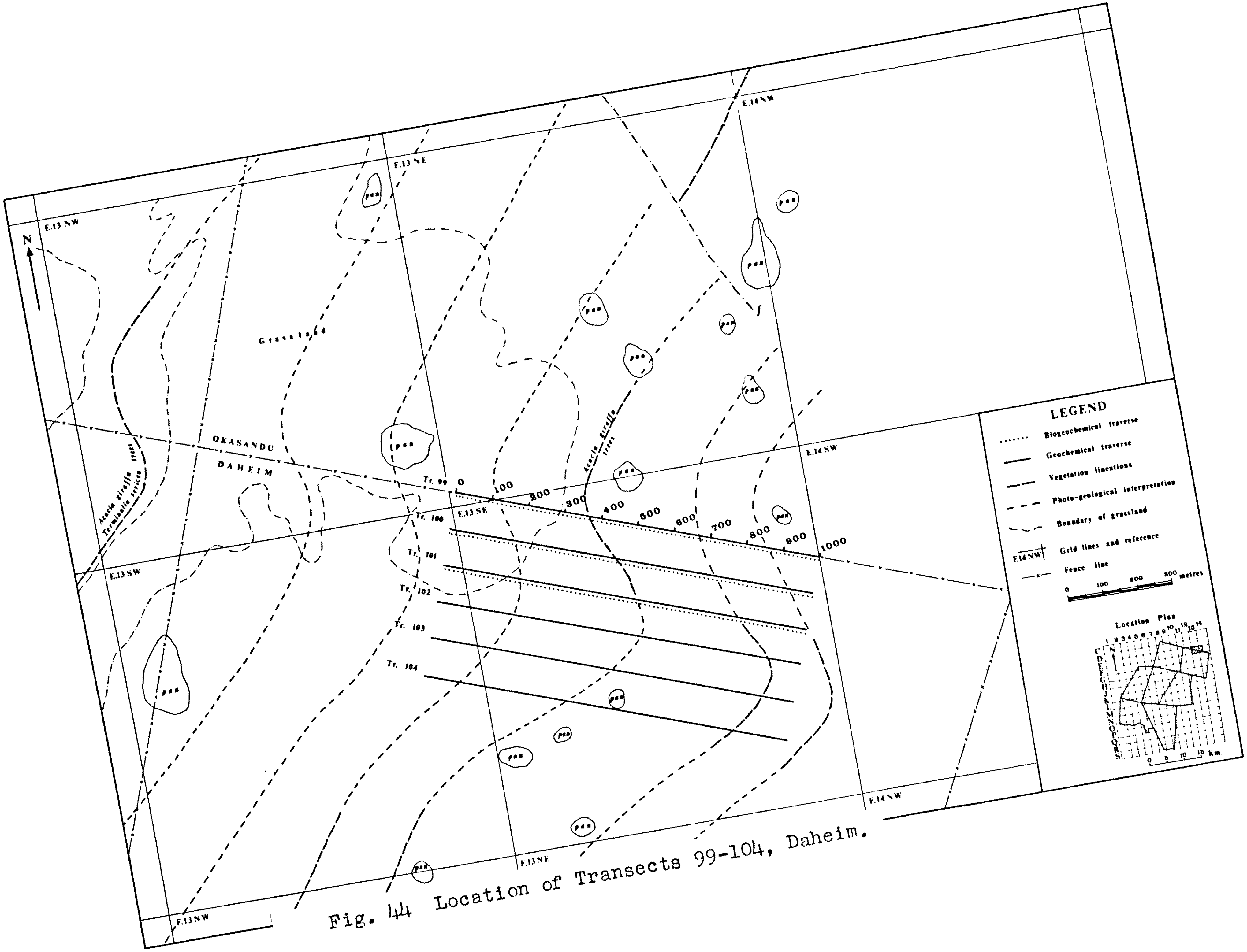


Fig. 44 Location of Transects 99-104, Daheim.

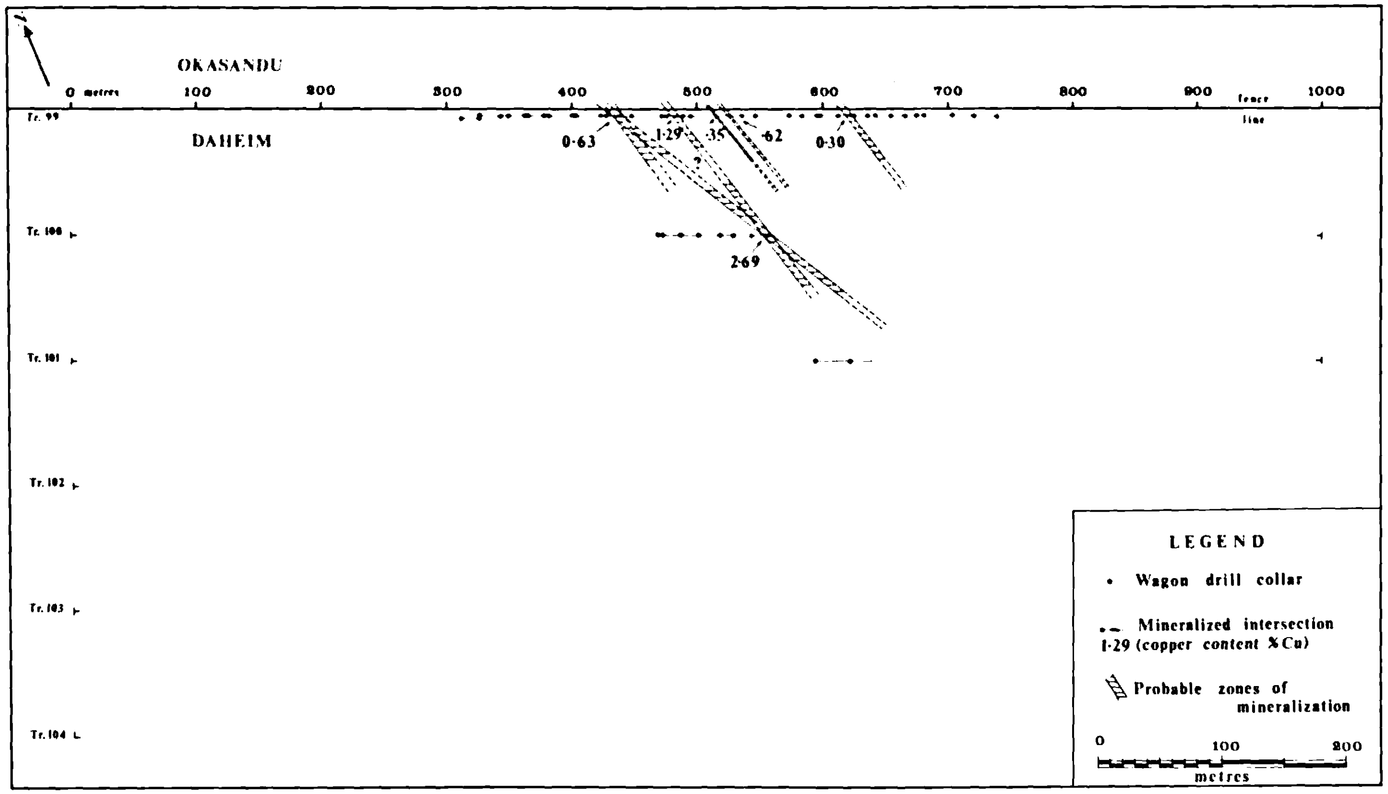


Fig. 45 Location and extent of probably zones of copper mineralization indicated by wagon drilling, Daheim Grid.

(Fig. 44) are parallel to the boundary fence and cross the regional strike at approximately right-angles.

Vegetation

The major part of the area within the grid has a low tree and shrub savanna vegetation characterised by the species Acacia giraffae, Tarchonanthus camphoratus and Grewia flava (Fig. 46 and Plate 33). The shrubs Acacia hebeclada, Acacia mellifera and Rhus pyroides are also scattered throughout these sections. The ground layer of vegetation is composed of a dense cover of the grass species Stipagrostis uniplumis and Schmidtia pappophoroides and scattered herbs of which Trichodesma angustifolium, Neorautanenia amboensis and Kohautia omahekensis are the most common. In places the vegetation is dominated by Acacia giraffae trees 7 - 10 metres in height and one area forms a defined belt which extends northeastwards into Okasandu. Tarchonanthus camphoratus shrubs also occur in these areas and Stipagrostis uniplumis is the most common grass species.

The north-western part of the grid has a grassland vegetation which becomes much more extensive to the north. The species Aristida stipitata and Eragrostis pallens form a uniform dense cover of grass about one metre high. The small shrub Ozoroa paniculosa occurs in this grassland association. Two further vegetation associations are recognised in the area; one occurs in areas of scattered surface calcrete and the other in the vicinity of drainage pans. The dense cover of Stipagrostis uniplumis and Schmidtis pappophoroides cut out across the areas of calcrete and the vegetation consists of Acacia hebeclada shrubs, Enneapogon brachystachus and Eragrostis porosa grasses, with Pseudogaltonia clavata, and Crotalaria argyraea (Plate 34). Around the pans and drainage features the vegetation consists of Ziziphus mucronata and Acacia hebeclada shrubs (Plate 33). Many of the drainage areas are barren of vegetation (Plate 35) but the grass species Echinochloa holubii occurs in the pans which contain water.

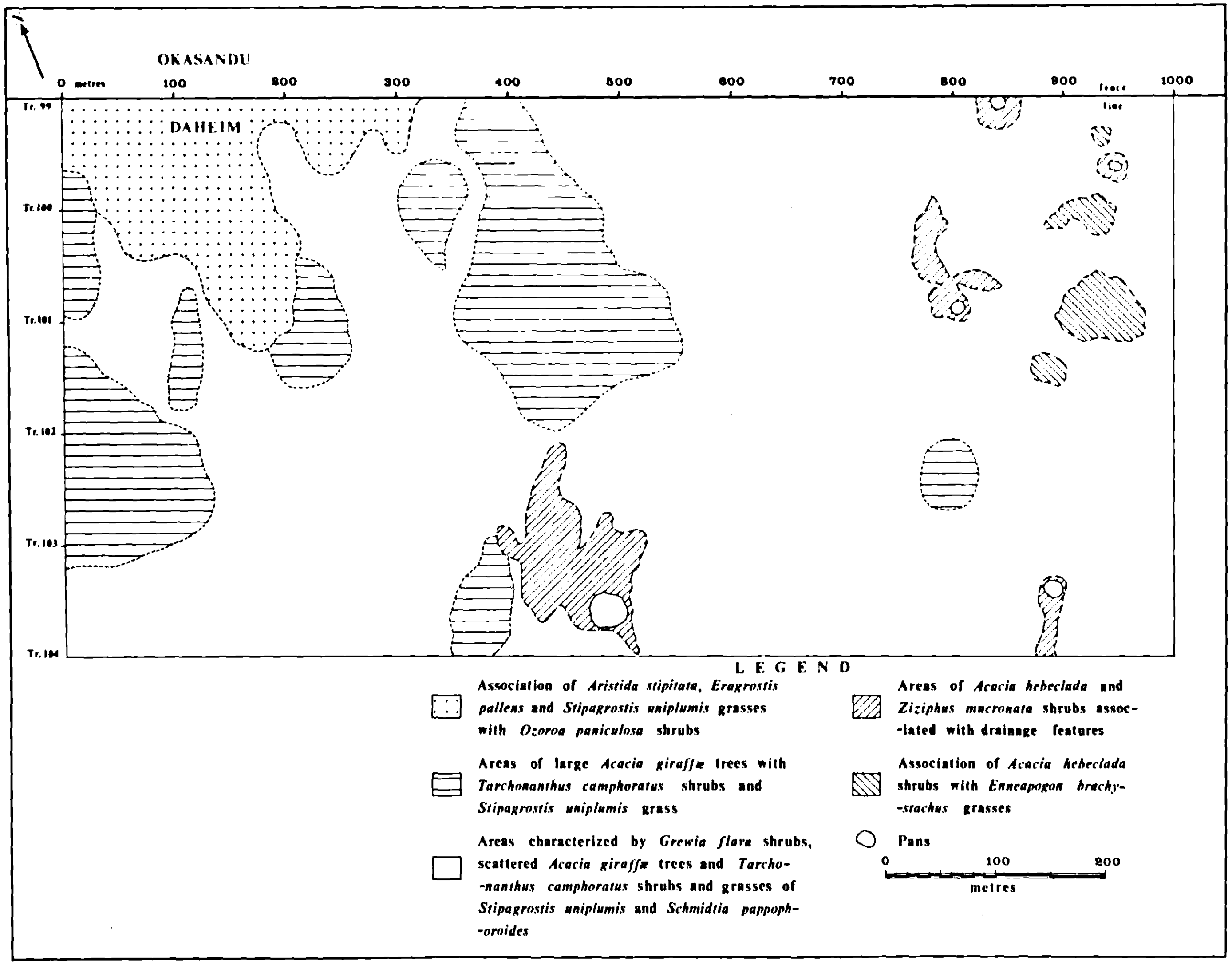


Fig. 46 Vegetation associations and their distribution within the Daheim Grid.

Plate 33 View westwards along the Daheim - Okasandu boundary fence, and the line of Transect 99 Daheim Grid, showing;

1. Foreground:- drainage pan surrounded by a shrub vegetation of Ziziphus mucronata, Acacia hebeclada and Acacia mellifera;
2. Middle distance:- an area of tree and shrub savanna characterised by the species Acacia giraffae, Grewia flava and Tarchonanthus camphoratus;
3. Background:- a N - S belt of tall Acacia giraffae trees.

(Ref. MM/SWA 27/58.)

Plate 34 View southwards from the location 920/190m.S Daheim Grid showing:-

1. Foreground:- vegetation association of the grass species Enneapogon brachystachus, the lily Pseudogaltonia clavata and the herb Crotalaria argyrea in an area of scattered surface calcrete;
2. Background:- low tree and shrub savanna characterised by the species Acacia giraffae, Tarchonanthus camphoratus and Grewia flava, with a ground vegetation dominated by the grasses Stipagrostis uniplumis and Schmidtia pappophoroides;
3. Location of pit No 6 at 925/205m.S

(Reg. MM/SWA 27/54.)

Plate 35 View northwards from 440/420m.S Daheim Grid showing an open drainage feature surrounded by low shrubs of Acacia hebeclada. Acacia giraffae trees occur in the background. (Ref. MMC/SWA 48/28A.)

Throughout the area no plants of Helichrysum leptolepis were discovered or other vegetation associations indicative of copper mineralization.

Geochemistry

Soil samples were collected at 10 metre intervals, and from a depth of 20 cm., along the transect lines 99 - 104. The copper content was determined on the -270 mesh fraction and the results shown by the isopleth map of Fig. 47. Only one zone of anomalous values is indicated and this has a limited southern strike extension. The broadest section of the anomaly is on Transect 99, along the boundary fence, where values exceed 100 ppm. from 420 - 610 m. E. Southwards the anomalous zone decreases in width and intensity and on Transect 101, 200 metres to the south, the peak value is only 85 ppm. A possible extension to the zone of mineralization is indicated at 630 m. on Transect 103 where the soil values are in the range 40 - 60 ppm. which is slightly above the background.

The soils collected across the drainage feature, from 380 - 530 m. E on Transect 103 (Fig. 46) do not show any increase in copper content. In the area of savanna grassland in the north-western part of the grid the copper content of the surface soils is extremely low with the majority of the values less than 10 ppm.

Profile samples from the trench section and from pits were also collected for analyses. Samples were taken at 20 cm. intervals down the face of the trench between 478 - 486 m. on Transect 99, and the -270 and -80 mesh fractions were analysed for copper (Fig. 48). Each profile shows an increase in copper with depth and the -270 mesh values are approximately twice the -80. At the surface the -270 mesh fractions vary in copper content from 120 - 160 ppm. and show an approximate increase of 25% in the lower sections of the wind-blown sand. The values increase much more rapidly with depth in the gravel layer and the -270 mesh fractions sieved

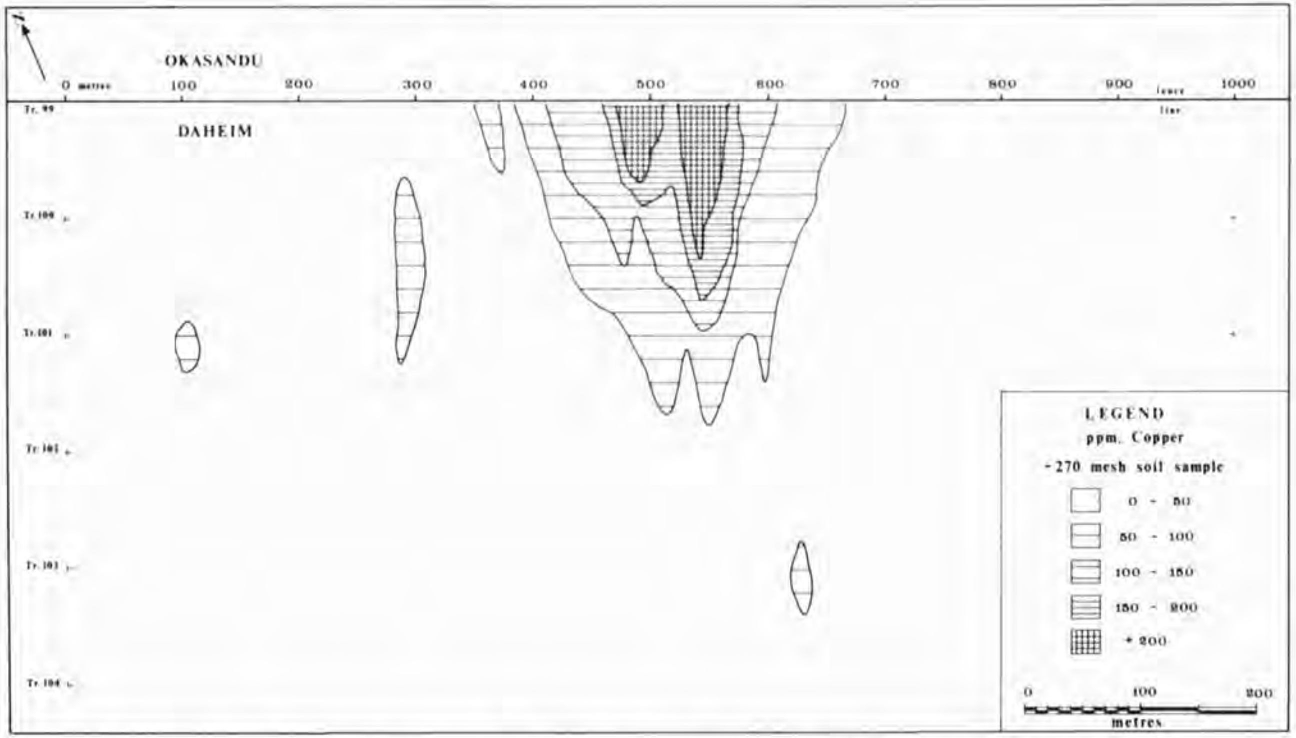
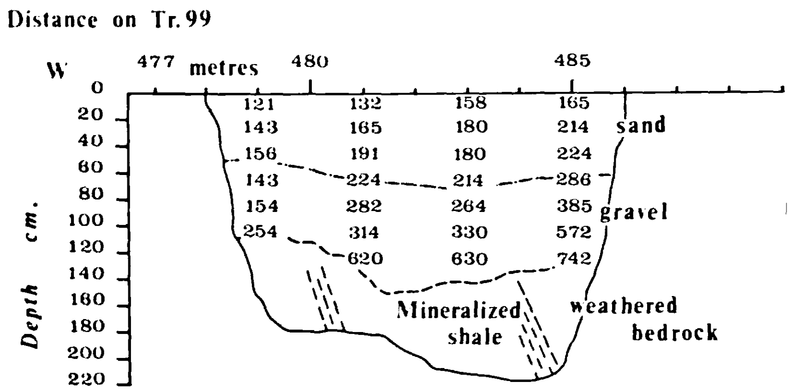


Fig. 47 Distribution of copper in surface soils of the Daheim Grid. (The data is for the -270 mesh fraction of samples collected at 10 metre intervals and from a depth of 20 cm.)

- 270 mesh



- 80 mesh

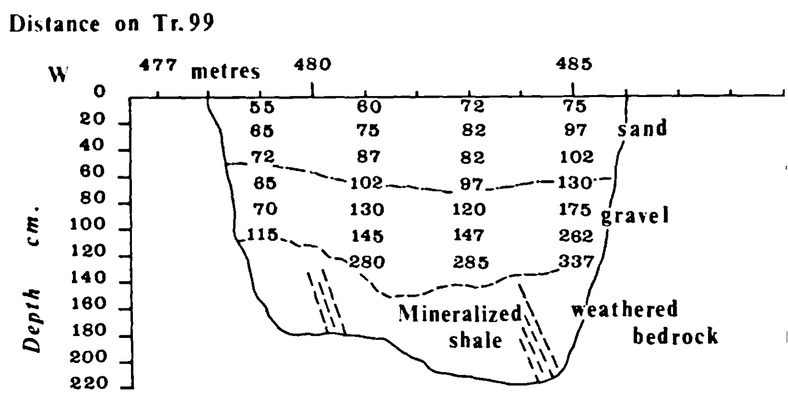


Fig. 48 Distribution of copper in the overburden of sand and gravel overlying mineralized shale, from the trench section on Transect 99, 478 - 486 m.E, Daheim Grid. (Data for -80 and -270 mesh fractions.)

from the gravel resting on weathered mineralized shale contain 620 - 740 ppm. copper.

Mesh fraction analyses for copper were carried out on bulk soil samples from the pits (Fig. 49). Samples 6469 and 6472, from depths of 30 and 90 cm. in Pit 1, show increasing copper values with the finer mesh fractions. The fractions coarser than 60 mesh contain from 30 - 50 ppm. whereas the -270 mesh fractions of the samples contain 200 - 230 ppm. copper. A similar trend is apparent for the samples from the sand horizon of Pits 2 and 3 with the finer fractions having higher copper values. The sample from Pit 4, which is in an area of savanna grassland, has an extremely low copper content for all fractions, 4 - 12 ppm., with the maximum value for the -270 mesh. The samples collected above the calcrete from Pits 5 and 6 have less than 10 ppm. copper in all mesh fractions except the -270 which contain 35 ppm.

Biogeochemistry

Several tree and shrub species occur within the Daheim Grid area and samples for analyses were collected from *Acacia giraffae*, *Tarchonanthus camphoratus*, *Rhus pyroides*, *Ozoroa paniculosa* and *Grewia flava*. However, *Grewia flava* is the only species that has a sufficient density of distribution so that samples can be taken at close intervals along a transect. Leaf samples of *Grewia flava* and samples of the grass *Stipagrostis uniplumis* were collected at approximately 10 metre intervals along Transects 99, 100 and 101. The biogeochemical data for these transects is shown in Figs. 50, 51 and 52.

The mean copper content and standard deviation was calculated for the samples of *Grewia flava* and *Stipagrostis uniplumis* from the background sections of the transects. This is from 0 - 300 m. and 700 - 1000 m. E where the copper content of the soil is low (Fig. 47). The threshold value for probably anomalous samples is taken as the mean plus three standard deviations.

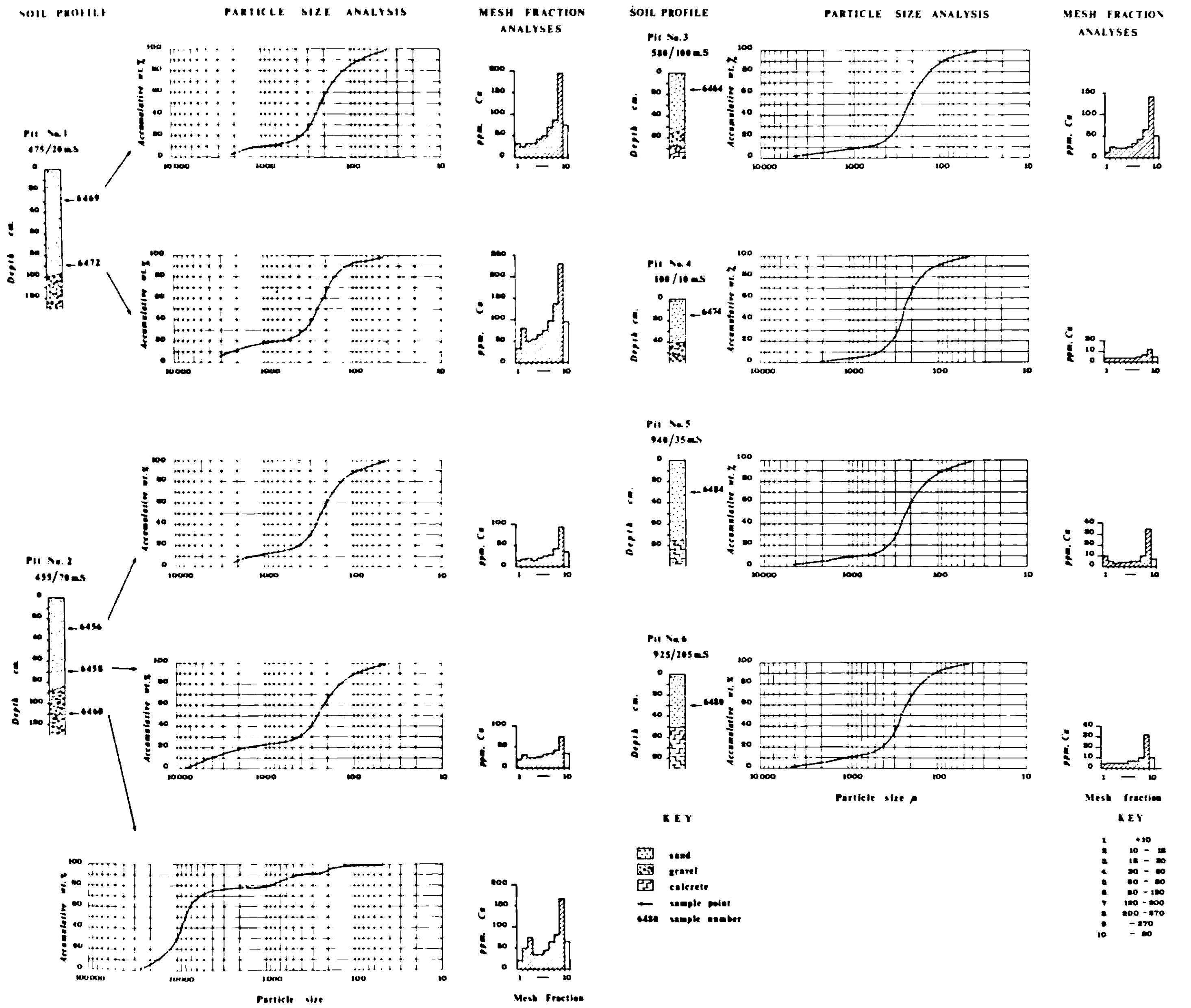


Fig. 49 Particle size analysis and mesh fraction analyses for bulk soil samples collected from pits within the Daheim Grid.

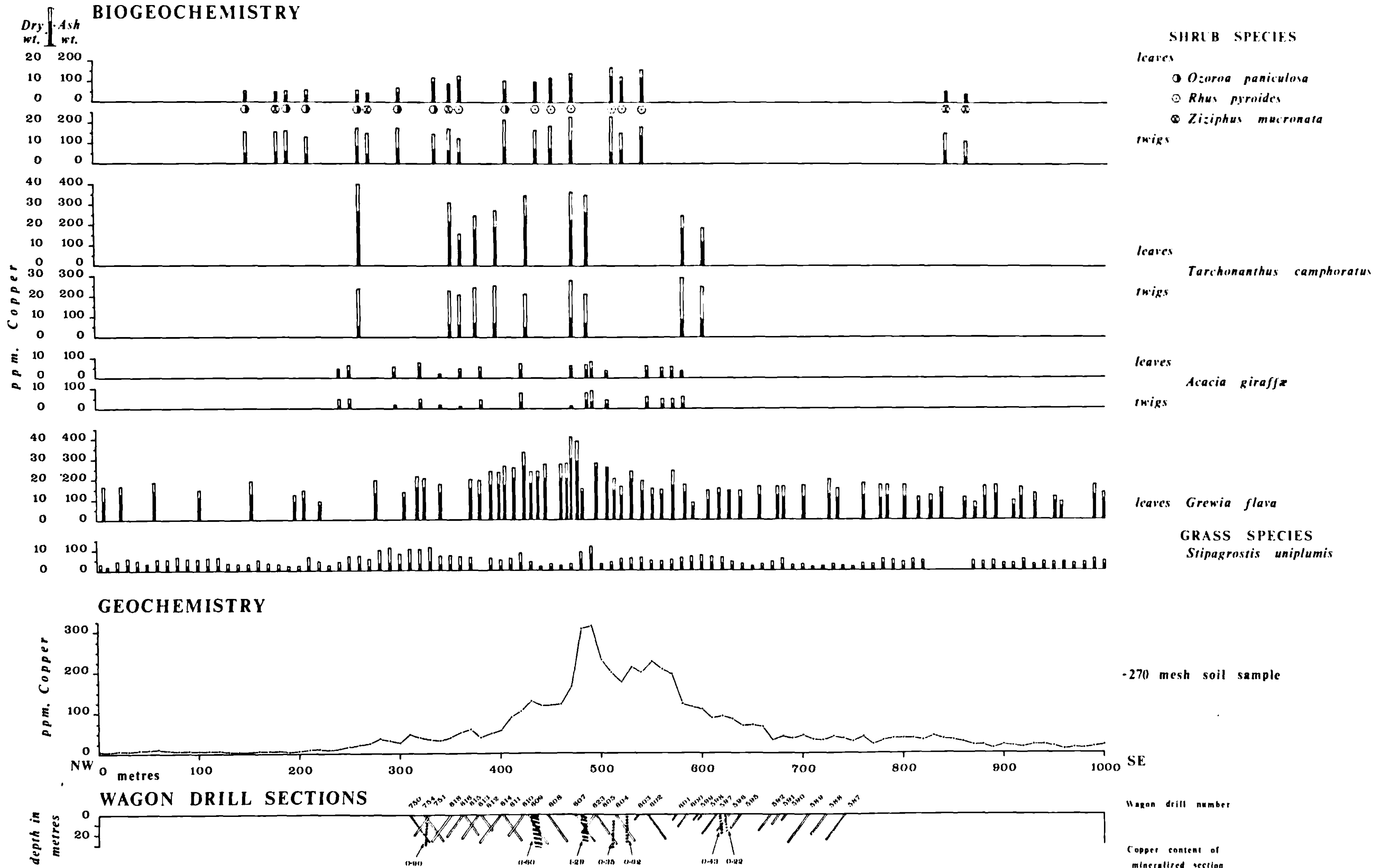


Fig. 50 Transect 99, Daheim Grid, showing the copper content of plant samples, geochemistry and wagon drill sections.

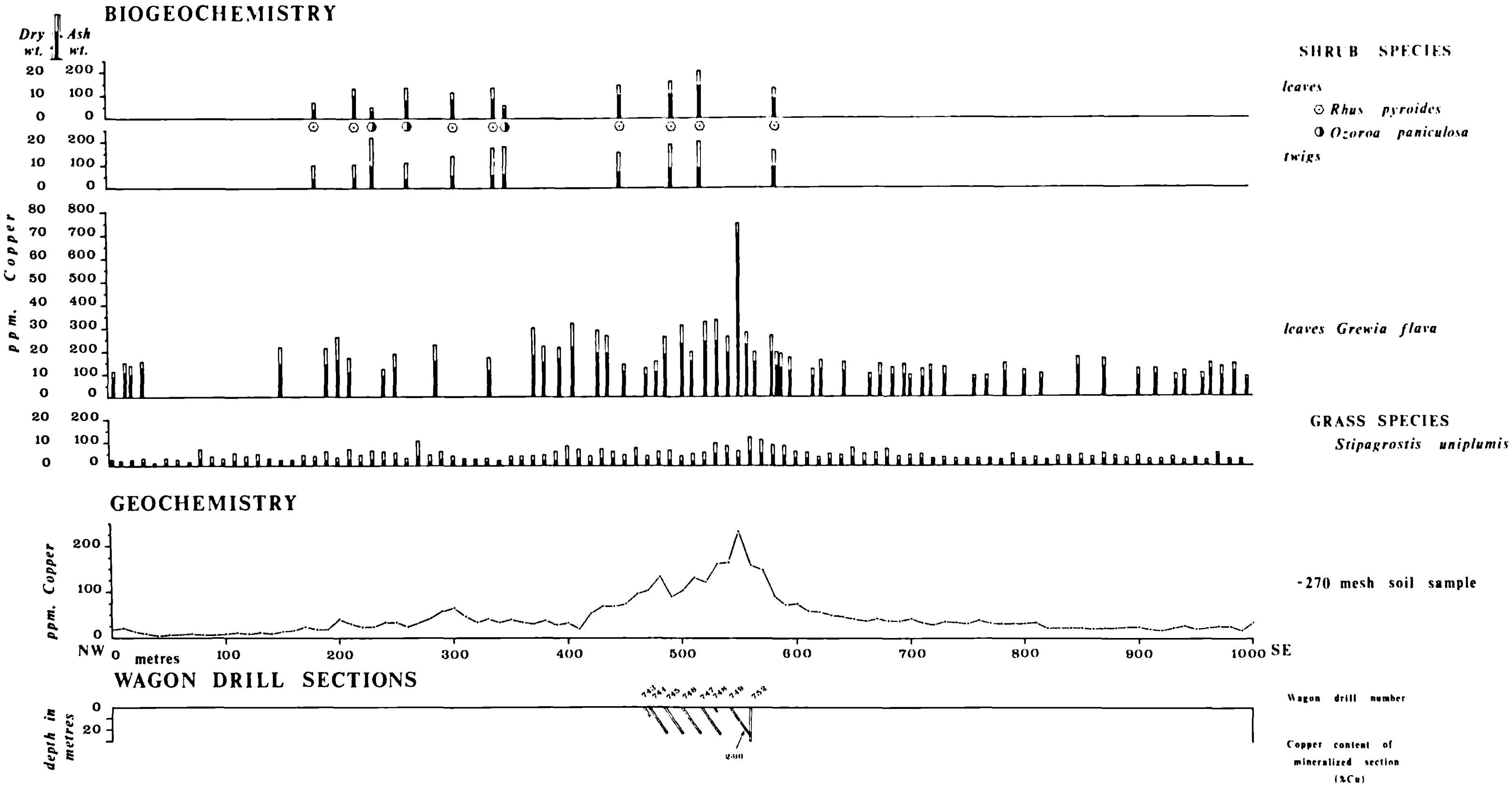


Fig. 51 Transect 100, Daheim Grid, showing the copper content of plant samples, geochemistry and wagon drill sections.

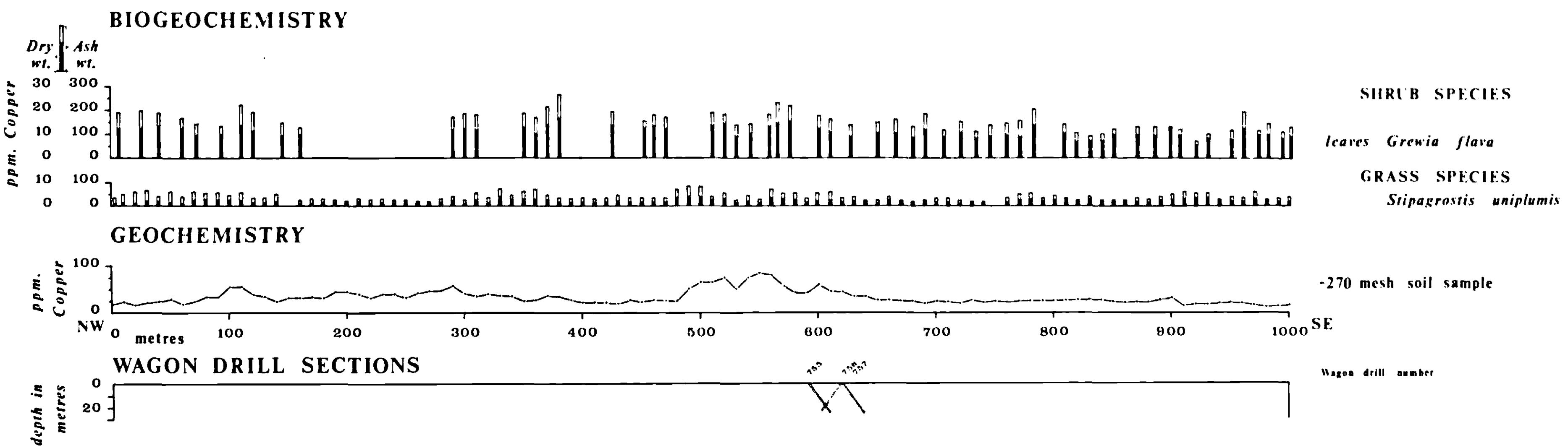


Fig. 52 Transect 101, Daheim Grid, showing the copper content of plant samples, geochemistry and wagon drill sections.

SPECIES	Number of samples.	Mean copper content	Standard deviation	Threshold ppm.copper
G. flava	98	10.2	2.2	16.8
S. uniplumis	175	2.1	0.8	4.5

Table 26. Mean, standard deviation and threshold values of copper for background samples of Grewia flava and Stipagrostis uniplumis from Transects 99, 100 and 101 Daheim Grid.

Grewia flava leaves with anomalous copper content occur from 390 - 505 m. and 529 - 570 m. E on Transect 99 (Fig. 50). These sections of the transect coincide with the main geochemical anomaly. The maximum value recorded for the leaves is 30.1 ppm. copper from 469 m. E. All samples from 485 - 578 m. on Transect 100 (Fig. 51) have anomalous copper values with the maximum of 70 ppm. occurring at 550 m. which is also the location of the peak geochemical value. Further anomalies on Transect 100 occur at 370 and 405 - 435 m. E where the soil values range from 40 - 60 ppm. copper. None of the samples from Transect 101 (Fig. 52) show anomalous values and only two samples exceed the mean by two standard deviations. These samples of 15.7 and 16.7 ppm. copper are from 575 and 380 m. E respectively.

A total of 259 samples of Stipagrostis uniplumis were collected on Transects 99 - 101 and 175 samples are from the background section of the transects. The mean copper content of these samples is 2.1 ppm. and only six samples from the transects exceed the threshold value. On Transect 99 there are two anomalous samples of 5.7 and 8.1 ppm. copper from 480 and 490 m. E. This zone is a geochemical high and mineralized shale occurs in the trench section from 478 - 486 m. Several samples of S. uniplumis from Transect 99 are in the range 3.7 - 4.5 ppm. which is the mean plus two standard deviations.

These samples are from 290, 330, 420, 540 m. and four samples between 530 - 610 m. E. Four anomalous samples with a maximum value of 6.9 ppm. copper occur on Transect 100 between 550 and 580 m. E. The copper content of the soils in this zone varies from 150 - 230 ppm. for the -270 mesh fraction. The highest copper value for the samples collected on Transect 101 is 4.1 ppm. from 500 m. and only two other samples from 330 and 490 m. exceed 3.7 ppm., the mean plus two standard deviations.

Samples were collected from all the trees and shrubs occurring within 10 metres of Transect 99, and the copper content of these samples is shown in Fig. 50. The leaf samples of Acacia giraffae vary in copper content from 2.2 - 5.3 ppm. and the twigs from 0.8 - 4.3 ppm. The samples from 480 - 510 m., across the zone of high geochemical values and near to known mineralization, do not contain appreciably more copper than the samples from the remainder of the transect.

Tarchonanthus camphoratus, like Acacia giraffae, has a limited distribution along the transect and samples could only be taken from 260 - 600 m. E. The leaves show a wide range in copper content from 11.3 - 26.6 ppm. with the maximum value from 260 m. The three samples from 425 - 485 m. within the main geochemical anomaly vary from 22 - 26 ppm. copper. The twig samples from the transect have a much lower copper content and range from 5.1 - 9.5 ppm. The maximum value is for the sample at 470 m. which is from the zone of high soil values.

Eight samples of Ozoroa paniculosa were collected from Transects 99 and 100. All the samples are from the section 160 - 400 m. E where the copper content of the soils is low. The copper values for the leaves and twigs vary from 3.5 - 6.5 and 4.4 - 9.3 ppm. respectively and in all cases the copper content of the twigs exceeds that for the leaves.

Most of the Rhus pyroides samples collected on transects 99 and 100 are from within the broad geochemical anomaly where the soils contain 50 - 150 ppm. copper in the -270 mesh fraction. However, the samples adjacent to known mineralization do not have appreciably higher copper levels. The ranges of values are 3.9 - 13.8 ppm. and 3.8 - 10.8 ppm. copper for the leaves and twigs respectively.

The Ziziphus mucronata samples are all from background sections of transect 100 and both the leaf and twig samples have low copper values.

Summary of results

The geochemical and biogeochemical surveys of the Daheim Grid do not indicate any southern strike extensions to the known zones of mineralization or reveal any further areas of mineralization in this region. However, the geochemical anomalies narrowly define the mineralized horizons showing that the drilling could have been restricted to the section 460 - 570 m. on Transect 99. Similarly the peak geochemical value on Transect 100 defines a drilling target.

The biogeochemical anomalies shown by the leaves of Grewia flava define the sections 400 - 570 m. Tr. 99 and 470 - 580 Tr. 100 which correspond to the geochemical anomalies and areas of known mineralization. No anomalous values occur on Transect 101 on the projected strike extension of the mineralized zone.

Chapter 8

INVESTIGATIONS IN AREAS OF CALCRETE

Introduction

During the exploration programme in the Witvlei Concession copper mineralization was never discovered in an area where there is a thick covering of calcrete over bedrock. However, in several places, mineralized outcrops were located where calcrete is a dominant surface feature.

The distribution of the tree and shrub species and the ground vegetation associations were studied in three of these areas and geochemical and biogeochemical samples were collected along transects crossing the zones of mineralization. The locations of the three transects 84 - 86 are shown in Fig. 7.

Transect 84

During the phase of geological mapping in the area surrounding the Malachite Pan copper mineralization was discovered in an area of calcrete about 500 m. southwest of the Eskadron homestead. The mineralization could be traced for 200 m. along strike from the scattered outcrops of argillite. A short trench was made across the outcrop and calcrete, but only a narrow zone of mineralization was exposed. No further trenching or drilling was carried out on this zone of mineralization.

The tree and shrub vegetation of the area is dominated by large *Acacia mellifera* bushes 2 - 4 m. in height. In places young *Acacia mellifera* less than 1 m. grow beneath the larger shrubs. *Lycium lancifolium*, *Acacia hebeclada* and *Grewia flava* occur fairly frequently along the transect (Fig. 53) whereas the other tree and shrub species have merely a scattered occurence.

The greater part of the ground surface is covered with calcrete and very little herb or grass vegetation occurs.

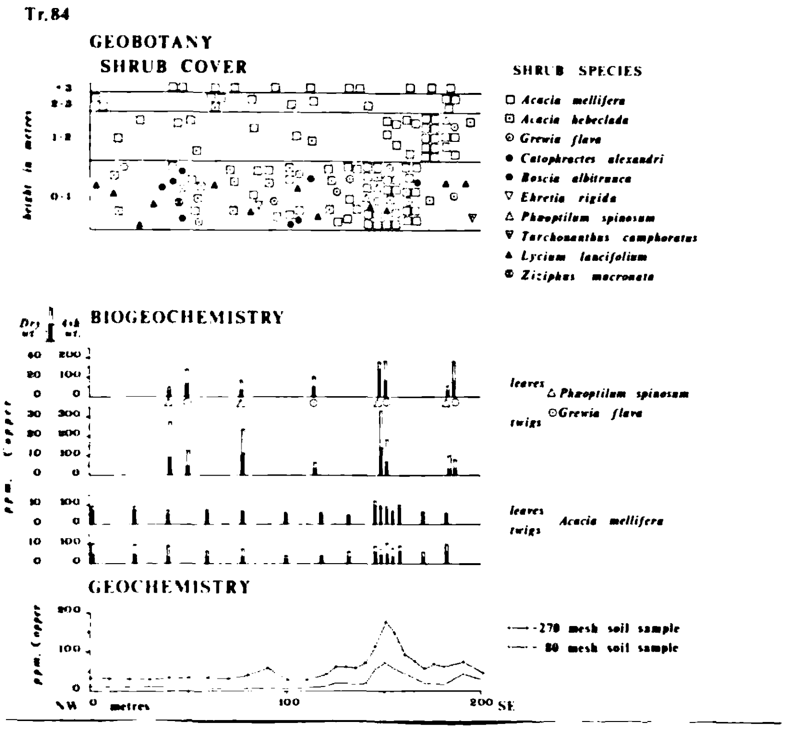


Fig. 53 A comparison of the distribution of shrub species, biogeochemistry and geochemistry for Transect 84, Eskadron.

The first 50 m. of the transect is in a drainage feature where there are scattered occurrences of *Aristida congesta* and *Barleria lanceolata* beneath the *Acacia mellifera* shrubs. The remainder of the transect is over calcrete where *Enneapogon cenchroides* and *E. brachystachys* are the dominant grass species. Throughout this area *Leucas pechuellii* and *Zygophyllum suffructicosum* are the most common herb species with associated *Hermannia damarana*, *Leucosphera bainsii*, *Ocimum americanum* and *Nolletia gariepina*. Directly after the rains in January 1970, *Tribulus zeyheri* covered large parts of the calcrete area. Near the mineralization at 150 m. the shrub cover is fairly open and an association of *Melolobium candicans*, *Aptosimum leucorrhizum*, *Limeum argute-carinatum* and *Celosia linearis* occurs (Plate 36).

The soils over the calcrete section of the transect are very shallow and consist of 5 - 10 cm. of sand and calcrete rubble. In many places animal burrows have disturbed the surface. In the drainage area from 0 - 50 m. soil pits showed 40 - 50 cm. of red-brown sand resting on calcrete. The pH of the soils on the calcrete varies from 7.8 - 8.6 and the sample from 152 m. adjacent to the known mineralization is 8.2. In the wash area the soil is slightly acid with a pH of 6.8 and at the southeastern end of the transect where the vegetation has been removed for cultivation the pH of the soil is 7.3.

The copper content of the soil, (Fig. 53) shows a marked increase in both the -80 and -270 mesh fraction over the mineralization at 150 m. The -80 mesh sample from this location contains 70 ppm. copper whereas the background level is less than 10 ppm. The higher values are only obtained within 10 m. of the mineralized outcrop.

Biogeochemical sampling was limited to three species and of these only *Acacia mellifera* could be collected at regular intervals along the transect. The samples of *Acacia mellifera* collected directly over the mineralization contained slightly more copper than the other samples (Fig. 53). The copper content of the leaves from the background areas varied from 4 - 7 ppm. whereas four of the five samples near to the

Plate 36 View southwestwards from Transect 84, Eskadron, showing the vegetation association over the area of calcrete. The shrub vegetation consists of large Acacia mellifera with Acacia hebeglada and Phaeoptilum spinosum. The ground vegetation is characterised by the herb species Mellolobium candicans, Aptosimum leuchorrizum, Celosia linearis and Limeum argute-carinatum with Enneapogon brachystachus grass.

mineralization were in the range 8 - 10 ppm. with the maximum value for the sample from 147 m. The twig samples varied in copper content from 2.8 - 6.4 ppm. with the maximum value from the sample at 147 m.

One sample of Phaeoptilum spinosum and Grewia flava was collected as near as possible to the mineralization and three other samples were taken from the background area for comparison. The Phaeoptilum spinosum sample from 150 m. contained considerably more copper in both the leaves and the twigs than the other samples. The leaf sample contained 29.1 ppm. compared to 6 - 7 ppm. for the other three background samples. The Grewia flava sample also from 150 m. had the highest copper content with leaf and twig values of 17.5 and 7.3 ppm. respectively. However, the increase in copper content compared to the background samples is not as marked as Phaeoptilum spinosum.

Transect 85

The mineralized argillites of the Malachite Pan area continue eastwards into Okatjirute West and in places cross low calcrete ridges. Transect 85 was located to intersect two of these mineralized zones which formed outcrops in areas of calcrete (Fig. 54). Further horizons of argillite are present in this region and geological mapping indicates that copper mineralization may be present at 120, 185 and 250 m. on the transect, in addition to the known occurrences at 150 and 225 m. No trench sections were made in this area, but, the results of wagon drilling indicate that the mineralized argillites are narrow, varying between 30 cm. and 1.50 m. and have a copper content between 0.3 and 2.1 percent.

The areas of calcrete are defined by a change in both the shrub vegetation and the ground cover species. In the surrounding sand covered area the most common shrub species are Grewia flava, Rhus pyroides, Phaeoptilum spinosum and Acacia hebeclada with occasional taller shrubs of Acacia hereroensis. Over the calcrete rise from 225 - 260 m. (Fig. 54) and continuing northeastwards along the feature, the shrub

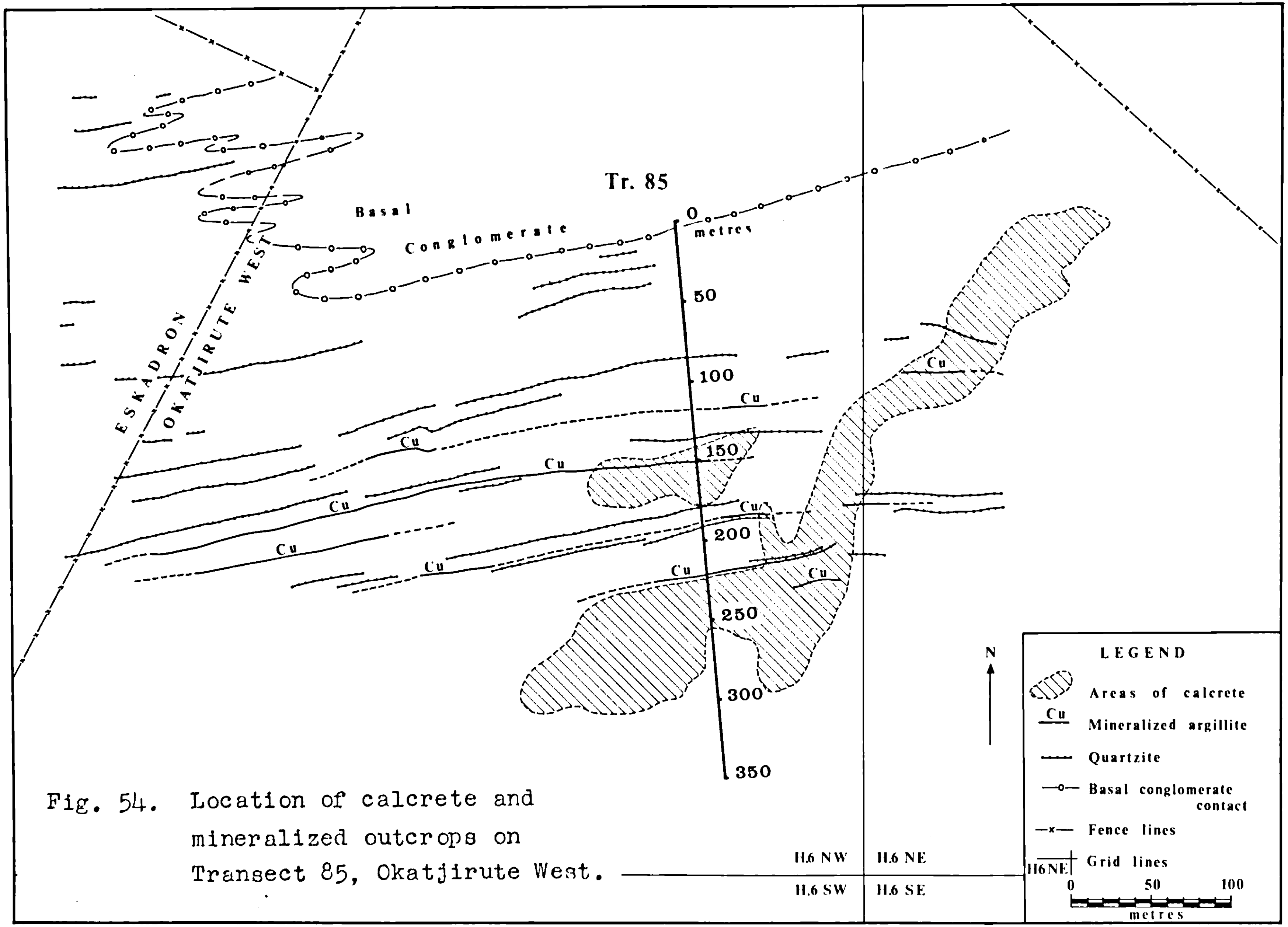


Fig. 54. Location of calcrete and mineralized outcrops on Transect 85, Okatjirute West.

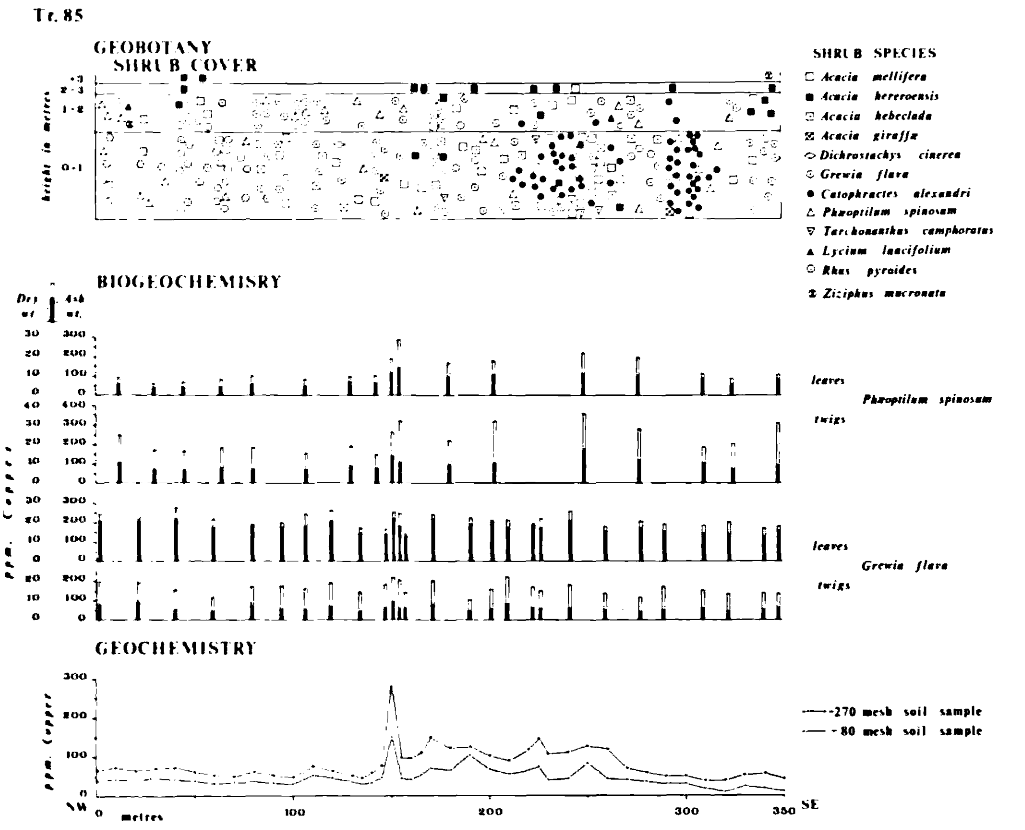


Fig. 55 A comparison of the distribution of shrub species, biogeochemistry and geochemistry for Transect 85, Okatjirute West.

vegetation is characterised by Acacia mellifera, Catophractes alexandri and Tarchonanthus camphoratus which form a fairly dense cover. Catophractes alexandri also occur from 290 - 310 m. where calcrete may extend from the ridge beneath the cover of sand.

The ground vegetation is composed mainly of grass species of which Stipagrostis uniplumis, Anthephora pubescens, Aristida congesta, A. adscensionis, Rhynchelytrum brevipilum and Eragrostis porosa are the most common. There are scattered occurrences of the herbs Geigeria ornativa, Kohautia omahekensis and Mollugo cerviana. On the areas of calcrete the dominant grass species are Enneapogon brachystachus and E. cenchroides associated with the herbs Hermannia damarana, Justicia guerkeana, Leucosphera bainsii and Monechma nepta. On the smaller area of calcrete from 140 - 180 m. the herbs are dominated by Ocimum americanum, Otoptera burchellii and Melolobium candicans. Between the areas of calcrete and towards the end of the transect the ground vegetation is composed mainly of Stipagrostis uniplumis.

On the calcrete rises the soils are very shallow and consist of 5 - 10 cm. of fine to medium grained sand and calcrete rubble. In places the calcrete covers the entire surface. Soil pits on other parts of the transect revealed 10 - 50 cm. of sand resting on a gravel of quartz and quartzite. The pH of these soils varies from 6.2 - 6.6 whereas a sample from 240 m. on the crest of the calcrete rise is 7.5. Near the mineralized outcrops at 150 and 225 m. the soils are weakly acid and pH values of 6.6 and 6.8 were recorded.

Soil samples for geochemical analyses were collected at 10 m. intervals along the transect and a closer spacing of 5 m. over the mineralization. The samples from 140 - 260 m. have a higher copper content, varying between 40 and 150 ppm., than the soils from the remainder of the transect (Fig. 55). Minor peaks are present at 150, 190, 225 and 250 m. which are distances where copper mineralization is indicated from the geological mapping. Over the mineralized argillite at 150 m. a maximum value of 150 ppm. copper was recorded from the analyses of the -80 mesh fraction. However, the samples from

5 m. on either side of the outcrop contain only 47 and 44 ppm. copper. The -270 mesh fraction show a much higher copper content than the -80 mesh and also outline the section 140 - 260 m. as an area of possible copper mineralization.

Samples of the leaves and twigs of Grewia flava and Phaeoptilum spinosum were collected along the transect and the results of copper analyses are shown in Fig. 55. The copper content of Phaeoptilum spinosum leaves shows most clearly the area of mineralization with all the values from 145 - 277 m. being higher than the remaining samples. The samples from the mineralized area range in copper content from 18.6 - 27.2 ppm., with the maximum value at 250 m., whereas the other samples contain from 6 - 13 ppm. copper. The twig sample from 250 m. also has the maximum copper content for the transect of 16.9 ppm. and the twig samples from the area of mineralized argillite zones have higher copper contents than the other samples.

The samples of Grewia flava leaves show a range of values from 12.7 - 21.9 ppm. copper but the higher values in this range also occur in samples from 0 - 40 m. where there is no copper mineralization. The other values of 17 ppm. and over occur from samples at 150, 172 and 242 m. where copper mineralization is suggested from the mapping. The twigs of Grewia flava show a similar trend in copper content as the leaves. The samples range from 4.6 - 9.6 ppm. with most of the higher values from areas of known copper mineralization.

Transect 86

Copper mineralization was found originally in this area from the excavation of the foundations for farm buildings of the Okatjirute West homestead. Outcrops of mineralized argillite are present in the kraals and can be traced to the south-west and north-east of the homestead. The outcrops are more numerous to the north-east where five or six distinct horizons of mineralization can be recognised (Fig. 56). Trenching operations to fully expose the mineraliza-

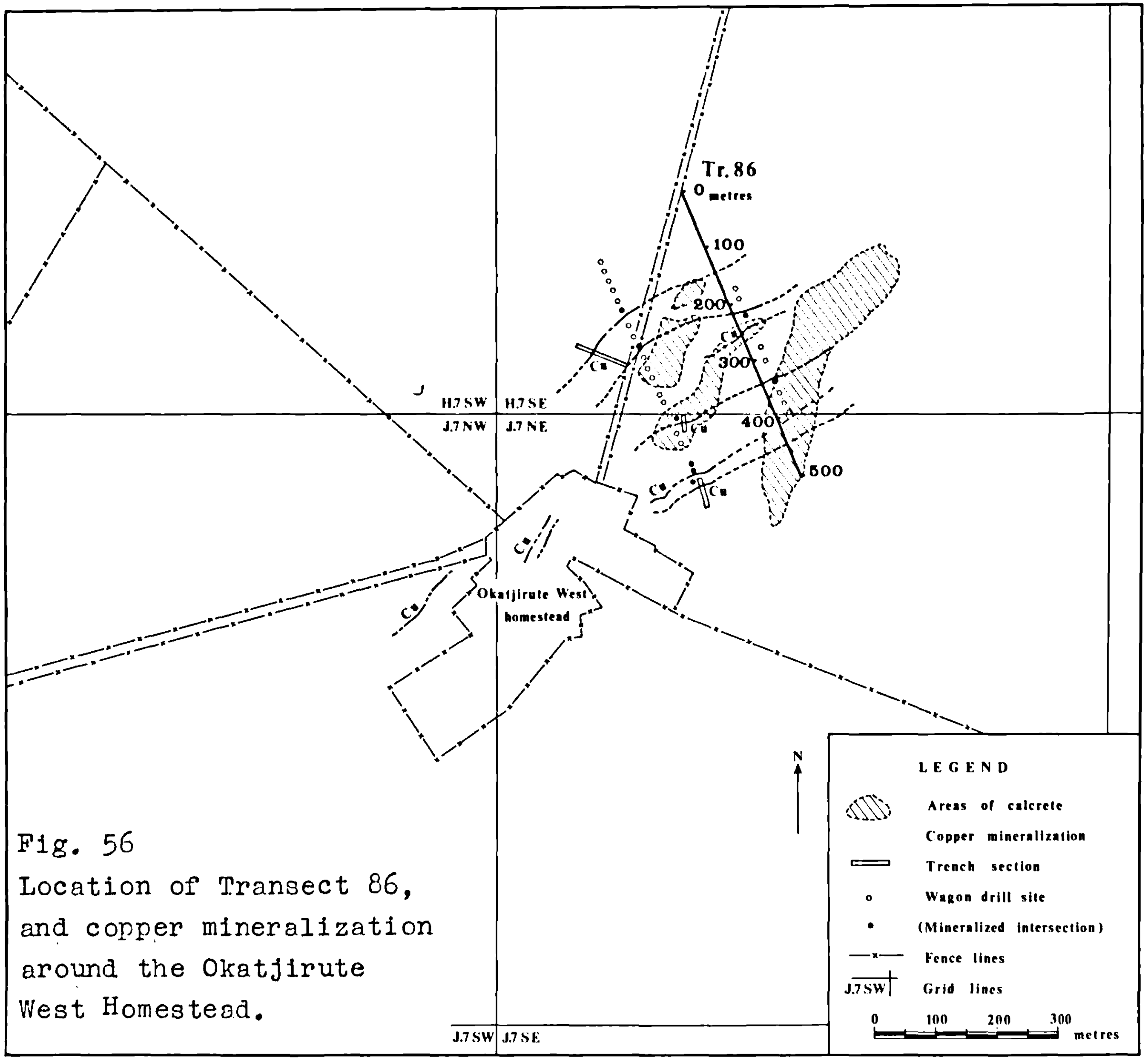


Fig. 56
Location of Transect 86, and copper mineralization around the Okatjirute West Homestead.

tion proved very difficult because of the calcrete layer on the bedrock and further exploration work was carried out by wagon drilling. Mineralized intersections from the drilling vary from 0.5% copper over 2.0 m. to 2.0% copper over 4.3 m.

The area around the homestead is heavily overgrazed and the vegetation is now dominated by Acacia hebeclada shrubs and Aristida congesta grass although distinct vegetation associations still occur on the calcrete ridges.

Transect 86 was located across the zones of mineralization where they are generally masked by the calcrete to see if geochemical or geobotanical anomalies exist in this environment. Areas of calcrete occur on the transect from 245 - 295 m. and 310 - 500 m., where there are distinct ridges, and from 110 - 130 m. The soils over these areas are very shallow and consist of red-brown sand mixed with varying quantities of calcrete rubble. In places there are bare calcrete outcrops and also areas where loose calcrete rubble covers more than 50% of the surface. The pH of the soils from these areas varies from 7.5 - 8.5 and the sample from 250 m. near to copper mineralization in outcrop has a pH of 7.6.

Over the remainder of the transect from 0 - 240 m. and 300 - 340 m. there is a cover of medium to fine red-brown sand which varies between 30 and 60 cm. in depth. The soil samples from these localities all gave an acid reaction with the pH between 6.4 and 6.8.

There is only one occurrence of mineralization in outcrop on the transect and this is on the crest of the calcrete ridge at 255 m., where finely disseminated chalcocite is visible in the argillite. Mineralization was also detected in two wagon drill sections at 220 m. and 350 m. where the samples contained 0.7 and 0.5% copper respectively. Outcrops of quartzite, grit and limestone also occur on the transect and dip steeply to the south-east.

The copper content of the soils is very low even across the mineralized outcrop, where there is a maximum value of 30 ppm. for the -80 mesh fraction (Fig. 57). However,

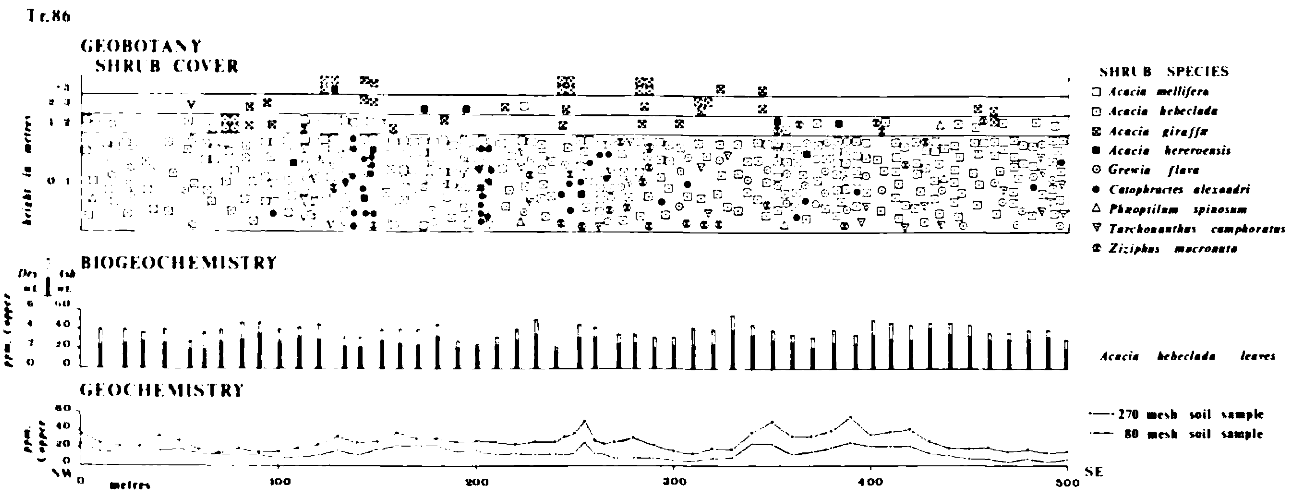


Fig. 57 A comparison of the distribution of shrub species, biogeochemistry and geochemistry for Transect 86, Okatjirute West Homestead.

from some parts of the transect the soil values are less than 10 ppm. and those samples in the range 20 - 30 ppm. are from areas where copper mineralization is indicated from the extension of outcrops and wagon drill intersections. The higher -270 mesh samples also occur at 255 m. and from 340 - 430 m., where copper mineralization is most probably present, but no clearly anomalous samples are apparent.

The area along the transect has been overgrazed and probably many of the naturally occurring species of shrubs, herbs and grasses have disappeared from the area. Acacia giraffae trees upto 5 m. in height are scattered throughout the region and the shrub vegetation is dominated by Acacia hebeclada, with associated Grewia flava and Tarchonanthus camphoratus. Small groups of Catophractes alexandri are present on some of the calcrete ridges otherwise the tree and shrub vegetation is fairly uniform throughout the area. In those parts where sand forms the surface covering the ground vegetation consists mainly of Aristida congesta grass with Cassia italica, Ocimum americanum and Acrotome inflata herbs. Stipagrostis uniplumis grass is present in the area growing under the protection of shrubs.

On the calcrete rises (Plate 37) Enneapogon brachystachus is the most common grass species and is associated with Leucosphera bainsii, Melolobium candicans, Justicia guerkeana and Acrotome inflata. Scattered occurrences of the herbs Pegolettia pinnatilobata and Lasiosiphon microphyllus are also present on the areas of calcrete.

Leaf samples of Acacia hebeclada were collected along the transect and the results of the copper analyses are shown in Fig. 56. The mean copper content of the leaves is 2.6 ppm. with a range of values from 1.7 - 4.1 ppm. The four highest values of 3.5 ppm. and over occur at 90, 340, 430 and 440 m. on the transect, and do not coincide with known copper occurrences. The samples from 252 and 254 m., nearest to the mineralized argillite outcrop contain 3.1 and 2.4 ppm. copper respectively.

Plate 37 View south-eastwards along the calcrete ridge of Transect 86 towards Okatjirute West Homestead. Trees of Acacia giraffae and shrubs of Acacia hebeclada occur on the calcrete ridge associated with Enneapogon brachystachus grass and the herb species Leucosphera bainsii, Justicia guerkeana, Acrotome inflata and Mellolobium candicans.

Summary of results

No distinct geobotanical anomalies were recognised along the outcrop or suboutcrop of zones of copper mineralization within the calcrete environments studied. The grass and herb species recorded are all common to calcrete areas and no marked variation in species or density of the shrubs was observed.

The copper content of the soils is extremely low, but peak values with limited lateral spread occur directly over some zones of mineralization.

Phaeoptilon spinosum and Grewia flava appear to be the more favourable species for biogeochemical surveys, as leaf samples collected from shrubs adjacent to zones of mineralization have a much higher copper content than the background samples.

Chapter 9

AN ASSESSMENT OF GEOBOTANY, BIOGEOCHEMISTRY AND GEOCHEMISTRY IN EXPLORATION FOR COPPER WITHIN THE WITVLEI AREA

Geobotanical studies in the Witvlei Area assisted the exploration program in both the reconnaissance and follow-up phases.

The composition and distribution of the major vegetation units clearly reflects the nature and extent of the overburden. The savanna parkland association of Acacia giraffae and Terminalia sericea characterises areas of deep sand cover and the association Boscia albitrunca, Acacia mellifera and Catophractes alexandri indicates areas of extensive calcrete development. A mixed low tree and shrub savanna composed of Acacia mellifera, A. hereroensis, A. hebeclada, Grewia flava Phaeoptilon spinosum and Tarchonanthus camphoratus dominates the areas of near surface bedrock, and the species Combretum apiculatum, Albizia anthelmintica, Grewia flavescens and G. bicolor are restricted to rocky elevated outcrops. Recognition of these vegetation units both in the field and on aerial photographs enables a rapid regional assessment of the environment. Photo-lineations formed by density and composition changes in the tree and shrub vegetation, define the regional geological strike and in places indicate fold structures and faults.

Detailed geobotanical transects in areas of near surface bedrock show that the association of the species Helichrysum leptolepis and Fimbristylis exilis is an excellent indication of copper mineralization. Narrow corridors of Helichrysum leptolepis and Fimbristylis exilis, bordered by an association of the grass species Aristida congesta, Eragrostis denudata and Anthephora pubescens, clearly define the sub-outcrop of horizons of mineralized argillite. The herb species Ocimum americanum, Cassia italica, Crotalaria argyraea, Vellosia humilis, Mollugo cerviana and Barleria lanceolata may occur within this anomalous vegetation association, but all trees and shrubs and the wide variety of herbs and grasses, of the low tree and shrub savanna, are markedly absent.

Within the Witvlei Area all occurrences of Helichrysum leptolepis are associated with copper mineralization. Recognition of this indicator species and the anomalous vegetation association provides immediate trenching or drilling targets and a rapid appraisal of the mineral potential of an area.

Throughout the exploration program in the Pos, Copper Causeway and Malachite Pan areas extensive trenching and drilling beyond the zones of anomalous vegetation failed to locate any near surface strike extensions of the copper mineralization.

In the areas of extensive overburden of sand and calcrete no anomalous vegetation associations related to copper mineralization were defined.

The biogeochemical technique of mineral exploration was initially thought to be most applicable for the areas of deeper overburden. However preliminary studies in species distribution and rooting habits indicated that no commonly occuring deep rooted species existed in the sand and calcrete environments.

Detailed biogeochemical transects were carried out across zones of known mineralization in regions of near surface bedrock at the Pos, Copper Causeway and Malachite Pan areas. The background copper values for 22 tree and shrub species, the grass species Stipagrostis uniplumis and Aristida congesta and the herb Barleria lanceolata are shown in Table 27.

Several species show a good contrast in copper content between the anomalous and background sections of the transects. Leaf samples of Grewia flava, Phaeoptilon spinosum, Acacia mellifera, Acacia hereroensis, Tarchonanthus camphoratus, Boscia albitrunca, Rhus pyroides, Erhitia rigida and Lycium lancifolium, and twig samples of Grewia flava and Phaeoptilon spinosum would be suitable for biogeochemical surveys.

PLANT SPECIES \ COLLECTION SITE	Traverse No. 30	32	35	38	42	45	48	55	67	74	76	84	85	86	87	99	100	101	Spot samples †C.C.	M.P.	Dh.	Ok.W.	Total samples Leaves	Twigs	Average % ash Leaves	Twigs	■ ppm. Cu Dry wt. Leaves	Twigs
Acacia giraffæ																				9	17		26	26	6·84	5·56	3·5 (15)	2·2 (15)
Acacia hebeclada								32						51*									32	83	6·76	6·26	2·2 (52)	1·9 (14)
Acacia hereroensis	9		45	55	50	51	38	31	4										14	8			305	305	5·80	4·00	6·3 (81)	4·6 (81)
Acacia mellifera	42							21				15							6				84	84	8·51	4·54	7·3 (38)	4·2 (38)
Albizzia anthelmintica	7	5																				2	14	14	6·34	3·74	7·4 (7)	3·0 (7)
Boscia albitrunca	33							12											1	9			55	55	9·60	5·40	6·3 (20)	3·7 (20)
Catophractes alexandri	38																			9			47	47	6·81	3·19	8·2 (12)	5·7 (12)
Combretum apiculatum	2	5																				3	10	10	6·94	4·51	5·5 (8)	4·0 (8)
Commiphora pyracanthoides	4																					2	6	6	10·35	4·56	5·4 (2)	4·5 (2)
Dichrostachys cinerea	4	5						11														2	22	22	5·97	3·37	7·0 (12)	3·5 (12)
Ehretia rigida	5						3	4															16	12	11·11	4·35	10·6 (3)	8·7 (3)
Grewia bicolor	4	4																					8	8	7·60	4·53	6·6 (4)	3·5 (4)
Grewia flava	40	18	77	70	84	66	31	40	35		57*	4	28		102*	68*	61*	59*	28	1			869	522	7·69	3·77	11·6 (250)	5·2 (125)
Grewia flavescens	6																						6	6	8·60	3·88	8·8 (2)	4·4 (2)
Lycium lancifolium							2	9											4				15	15	16·85	4·49	14·2 (6)	8·5 (6)
Ozoroa paniculosa							1													9	9		19	19	7·35	3·79	4·5 (8)	6·8 (8)
Phæoptilum spinosum	19	11	43	66	68	38	25	38				4	17						18				347	347	14·74	4·29	6·6 (107)	7·1 (10)
Rhigosum brevispinosum	4																					2	6	6	6·16	3·06	4·8 (5)	5·7 (5)
Rhus pyroides							41	5											2	9	17		74	74	7·22	4·19	9·5 (13)	5·8 (13)
Tarchonanthus camphoratus	21						12	30											10	4	10		87	87	7·34	3·32	19·6 (33)	5·7 (33)
Terminalia sericea																					8	5	13	13	5·97	6·38	5·1 (13)	5·8 (13)
Ziziphus mucronata	1						4	11											3	8	5		33	33	9·47	3·62	5·2 (12)	4·2 (12)
Aristida congesta								34															34		5·55		1·6 (14)	
Stipagrostis uniplumis								76		64	60					95	101	100	52				548		5·74		2·3 (289)	
Barleria lanceolata	8																			6		4	18	18	15·76	3·50	9·4 (4)	5·2 (4)
Fimbristylis exilis	9																		3				12		14·56			
Helichrysum leptolepis								13											13	26			52 (Flowers 52)	52	13·50 (10·94)	8·25		

* Leaf samples only

† C.C.~Copper Causeway; M.P.~Malachite Pan; Dh.~Daheim; Ok.W.~Okatjirute West

■ Average copper content of background samples

(15) number of samples

Table 27. Location of biogeochemical samples and average copper content for background areas.

More detailed biogeochemical studies were carried out at the Malachite Pan, involving the collection of Grewia flava (290 samples), Phaeoptilon spinosum (215 samples) and Acacia hereroensis (201 samples) leaves and twigs.

The mean, standard deviation and threshold values were calculated for the background samples and the biogeochemical anomalies (mean + 3 std.) thus indicated, especially for Grewia flava leaves and twigs and Phaeoptilon spinosum leaves, correlate very well with the known zones of mineralization.

For areas of near surface bedrock the results indicate that zones of copper mineralization can be detected from biogeochemical anomalies. However in such areas the mineralization can be located and outlined more easily and rapidly by geobotanical and geochemical surveys.

In sand covered areas the only common deep rooted species is Acacia giraffae. Analyses of leaf and twig samples show extremely low copper content with mean background values of 3.5 and 2.2 ppm. copper respectively. Samples collected from trees adjacent to mineralization at the Malachite Pan show no appreciable increase in copper values.

Terminalia sericea and Acacia mellifera are both common species in sand covered areas but have a shallow lateral root system. No comparative data was obtained for Terminalia sericea as all samples were from background regions.

Grewia flava and Tarchonanthus camphoratus are common in sand covered areas and have a root penetration of approximately one metre. The leaves of both species show good contrasting values for anomalous and background areas in near surface bedrock environments and the copper results for Grewia flava leaves define the mineralized zone on Daheim Grid where there is 1 - 2 metres of overburden.

The most common shrub species in the calcrete covered areas in Catophractes alexandri, followed by Acacia mellifera, Acacia hebeclada, Tarchonanthus camphoratus and Grewia flava. Catophractes alexandri has a shallow branching root system and would not be suitable for biogeochemical surveys in areas of thick calcrete development. However the results of copper analyses of leaf samples from Transect 30, show contrasting values for the mineralized zones and background sections of the transect. Acacia mellifera has a shallow lateral root system and although a wide range of copper values were recorded for the leaf samples the results for background and anomalous areas are somewhat erratic. Acacia hebeclada has a shallow tap root but no significant variation in copper values was recorded for leaf samples collected on Transect 86 where several zones of mineralization are indicated from wagon drilling.

Periodic sampling of Grewia flava, Phaeoptilon spinosum and Acacia mellifera shrubs indicated that there is a wide variation in the copper content of leaves and twigs throughout the growing season, and from one season to the next. The more consistent values, usually within ±20%, were obtained for the current growth, 1st. and 2nd. year twigs but variations in the copper content of the leaves were 20-40% for Grewia flava and upto 150% for Acacia mellifera. Shrubs which were re-sampled the following season recorded variations in copper content upto 250%, but the biogeochemical anomaly on the transect was repeated.

It is apparent that for the use of biogeochemistry as a regional exploration method in the Witvlei Area, sampling would have to be limited to a narrow time period or a seasonal correction factor applied to the results to make all values comparable.

Sample collection of leaves and twigs is generally a time consuming process, especially for the thorned varieties, and cheap field labour is a necessity for large scale biogeochemical exploration. The additional stages in laboratory procedure, involving several phases of weighing and ashing, also increases the cost of biogeochemical surveys when compared to geochemical methods.

The precision obtained for the biogeochemical methods (see Appendix IIB), calculated from the repeat analyses of split samples, was within ±10% at the 95% confidence level for the leaves and twigs of the majority of species.

Soil geochemistry proved an excellent exploration method in areas of near surface bedrock for both regional and detailed surveys.

The copper mineralization of the Witvlei Area occurs within a calcareous argillite interbedded in a mixed sedimentary sequence of sandstones, quartzites, conglomerates shales and limestones. The mineralized zones of ore grade are of limited strike extent, less than 500 metres, and extremely narrow. The regional background for soils over the barren sediments is less than 20 ppm. copper for the -80 mesh fraction. In areas of mineralization soil values are generally in the range 50-100 ppm. copper with peak values upto 500 ppm. over the zones of mineralized argillite.

For phases of regional exploration, to trace strike extensions or locate new areas of mineralization, traverse lines crossing the strike should be at approximately half kilometre intervals and sample spacing 30-50 metres, This will allow a rapid coverage of areas, eliminating background sections and indicating regions of interest which can be followed up in greater detail.

In the geochemical evaluation of an anomalous area the line spacing should not exceed 100 metres and sample interval 10 metres. The results for this phase, as for the Pos Area, Copper Causeway and Malachite Pan, will clearly limit the area of interest and define individual horizons of mineralization which can be tested by trenching or drilling.

A comparison of the copper values for -80 and -270 mesh fractions, in areas of near surface bedrock, show a similar anomaly contrast, with the -270 mesh copper values approximately twice the -80 mesh.

In the sand and calcrete covered regions no suitable orientation areas were available. The geochemical studies carried out in these environments indicate that the dispersion of copper from mineralized bedrock is extremely limited both vertically and laterally. Thus background values for copper from soil surveys do not eliminate the possibility of mineralization.

The accuracy and control of geochemical analyses is particularly important during the regional phase of exploration when copper values are extremely low, and anomalies only two or three times the background. The laboratory method of sample digestion in nitric acid and determination of copper by atomic absorption spectrophotometry proved to be much more relieable than colorimetric techniques (see Appendix IIA).

Vegetation studies, geobotany and soil geochemistry can be successfully applied in both the regional and follow-up phases of an integrated exploration program for copper mineralization in the Witvlei Area. The biogeochemical technique however did not show sufficient encouragement to be widely used in mineral exploration in this environment.

For a regional assessment of the area, vegetation associations, photogeology, reconnaissance geology and reconnaissance geochemistry would provide the most comprehensive data for the elimination of ground and the selection of targets of follow-up surveys. Recognition of anomalous vegetation associations and the indicator species *Helichrysum leptolepis*, during the regional geological and geochemical phases would provide immediate trenching or drilling sites.

Detailed exploration within areas selected for follow-up surveys would consist of soil geochemistry, geological and geobotanical mapping. This phase will indicate the probable extent of near surface copper mineralization which could then be tested by trenching and drilling.

APPENDIX

APPENDIX I

ROOTING SYSTEMS OF COMMON TREES AND SHRUBS

Grewia flava occurs throughout the Witvlei area in regions of near surface bedrock, wind-blown sand and surface calcrete. The root systems examined for shrubs in all three environments were similar consisting of branching and descending lateral roots with fibrous roots around the base. One shrub from the Copper Causeway area, 1.3 m. in height and 1.5 m. in diameter for the aerial parts, had twelve main branching lateral roots 1 - 3 cm. in diameter. The majority of these roots descended into the gravel layer, 40 - 50 cm. below surface, within 1.5 m. of the base of the shrub. A lateral root was traced for a distance of 3 m. at an approximate depth of 30 cm. before turning down into the gravel horizon. Many fibrous roots 10 - 20 cm. in length occur around the base of the shrub. The roots of two shrubs, growing in the cover of wind-blown sand on the Daheim Grid, were also exposed for examination. The shrub 2 m. in height and 2 m. across had three main lateral roots upto 2.5 m. in length and 10 smaller roots descending at angles of about 60 degrees within 1 m. of the base. A second shrub at Daheim 1.5 m. in height had 15 roots between 1 - 3 cm. in diameter most of which pass through the layer of sand to a depth of 80 - 100 cm. within 1 m. of the base of the shrub. A few of the roots extend laterally for 3 m. and there are many groups of fibrous roots below the central part of the shrub.

Phaeoptilum spinosum is most common in areas of near surface bedrock and has a scattered occurrence in the areas covered by sand, gravel and calcrete. The shrubs growing at the Malachite Pan and in deep sand, accumulated along the foot of the Witvlei Ridge, have a tap root with one or several lateral roots branching from the tap root, 20 - 40 cm. below the ground surface. One shrub, 1.5 m. in height and a spread of 2 m., from the sand covered area had a tap root 10 cm. in diameter reducing to 6 cm. at a depth of 1.2 m. A root branched horizontally for 30 cm. from the tap root, at 60 cm. below the surface, and then descended vertically into the gravel horizon.

Acacia hereroensis usually occurs in areas of near surface bedrock and the root systems of several shrubs from the Copper Causeway and Malachite Pan areas were examined. All roots extend laterally for 1 - 10 m. then, pass into the gravel layer above the bedrock. One shrub 3 m. in height, with four main stems about 10 cm. in diameter, had 20 lateral roots from 1 - 3 cm. in diameter. The longest root exposed was 7 m. and within 10 cm. of the surface and was then traced vertically to a depth of 50 cm. into the gravel horizon.

The root system of Acacia mellifera, examined in areas of near surface bedrock and regions of sand cover, is essensially one of long lateral roots 10 - 20 cm. below the ground surface. Observations were made for one shrub occurring in a sand covered area at the base of the Witvlei Ridge. The shrub was 2.5 m. in height with 9 main stems 7 - 10 cm. in diameter. The roots were exposed for three of these stems which came together below the surface. Five main lateral roots 3 - 4 cm. in diameter, fanning out through 180 degrees, were traced for distances between 7.5 and 10.5 m. at a depth of 10 - 20 cm. A second rooting system exposed on Daheim, for a shrub 2 m. in height and an aerial spread of 3 m., had 12 lateral roots 3 - 4 cm. in diameter. One root was traced for 12.8 m., 20 - 30 cm. below the surface.

Acacia giraffae most commonly occurs in the sand covered areas of the Witvlei Concession but, small trees of the species are occasionally found in areas of near surface bedrock. The root system was exposed for several trees in the Daheim Grid area and generally consists of roots which extend horizontally from the base of the tree and then descend vertically. One tree 3 m. in height and 20 cm. in diameter at the base, had four main roots 5 - 7 cm. in diameter which initially spread laterally. Three of these roots then pass vertically through the sand into the gravel horizon and the fourth root spreads laterally for 2.4 m. before passing into the gravel at 1.1 m. below the surface. Another tree of similar size also had four main lateral roots all of which turned to penetrate vertically into the sand within 1 m. of the base. The roots were traced to the compact gravel layer at a depth of 1 m., where the root diameter varied from 2 - 5 cm.

Terminalia sericea is only found in areas of deep sand cover and the rooting system was examined for trees growing in the wind-blown sand accumulated at the base of the Witvlei Ridge. One tree 3.5 m. in height and 25 cm. in diameter had six main lateral roots 8 - 10 cm. in diameter. The roots extended for 6 - 10 m. from the base of the tree, only 10 cm. below the surface, and branched several times. The tips of the roots descended vertically through the sand to a minimum depth of 1.2 m. A second tree 4 m. in height had seven branching lateral roots, one of which was traced for 15.6 m. from the base of the tree.

Tarchonanthus camphoratus is fairly common in all environments and the rooting systems were exposed for several shrubs occurring in the sand covered region of Daheim. A shrub with four main stems from 1.5 - 2 m. in height had one large root descending at an angle of about 60 degrees to a depth of 1.4 m. and five lateral roots upto 3.5 m. in length. The shrub also had many fibrous roots in the surface soils beneath the area covered by the aerial parts.

The root system of Rhus pyroides was also examined as this species occurs in areas of mineralization and is also common within the Daheim Grid. The shrubs less than 1 m. in height have both lateral and fibrous roots at the base. Some of the lateral roots 1 - 1.5 cm. in diameter were traced for distances upto 3.6 m. whereas others descended into the gravel layer within 1 m. of the base of the plant.

Boscia albitrunca occurs as shrubs less than 1 metre in height and also as trees 4 - 5 metres high. The rooting system was exposed for shrubs growing in areas of near surface bedrock. The shrubs have a tap root which in some cases initially increases in cross-section with depth. One shrub 60 cm. in height and 1 m. across had a tap root which was 7 cm. in diameter at the ground surface and 12 cm. at a depth of 70 cm., where the root entered the gravel layer.

Catophractes alexandri, a shrub generally confined to areas of calcrete, has a branching lateral root system. The shrubs have several main roots upto 2 cm. in diameter extending 3 - 5 m. from the base of the plant and descending to 30 - 50 cm. below surface.

APPENDIX II

A. LABORATORY METHODS FOR GEOCHEMICAL SAMPLES

Geochemical samples collected in the Witvlei area were initially sent to the Anglovaal laboratory at Rand Leases Mine and subsequently to their geochemical laboratory in Windhoek. Both laboratories used a potassium bisulphate fusion and colorimetric determination of copper following the method of Stanton (1966). The laboratory in Windhoek was geared to producing 1,000 copper determinations per day.

Soil samples collected along the geobotanical transects were analysed in the Bedford College Geography Laboratory using a nitric acid extraction. 0.2 grams of sieved soil sample was digested in 1N HNO_3 for 2 hours in a water bath at 95°C. The solution was allowed to cool and the copper content determined by atomic absorption spectrophotometry. The instrument used was a Southern Analytical A3000 and the settings for copper determination as follows; wavelength 3521 Å, burner height 3, slit width 1, current 7.5 mA., air pressure 7.1, acetylene 1.7. Using standards containing 1 - 10 micro-grams of copper per litre the instrument gave a reading range for copper from 0 - 500 ppm.

In order to compare the precision of the two laboratory methods and to control the analyses throughout the project, a series of standard samples was included in the batches of soil samples submitted for analyses. Eight bulk soil samples (-80 mesh) A - H were collected across the Copper Causeway mineralization to give a range of copper content from background of less than 10 ppm. to anomalous values over 300 ppm. The samples A and G were included twice to give the standard series 1 - 10 and the sample order was reversed for the series 11 - 20. The standard series was included in batches of 100 samples submitted to the laboratories for copper determination. The results for the series, analysed several times by the Anglovaal Windhoek laboratory and the Bedford College laboratory are shown in Tables II.1. and II.2. respectively.

Table II.1. Copper analyses for the standard series of soil samples 1 - 20 (-80 mesh) included in six batches of geochemical samples submitted to the Anglovaal laboratory in Windhoek for colorimetric determination, May 1970.

BSS	SS Nº	I	II	III	IV	V	VI
A	1	45	12	41	31	30	63
A	2	34	11	53	22	32	120
B	3	45	33	66	45	52	69
C	4	90	58	87	60	73	80
D	5	34	108	94	84	180	66
E	6	140	168	96	160	126	132
F	7	138	231	368	147	336	105
G	8	176	189	120	176	352	132
H	9	69	332	88	94	320	58
H	10	352	320	322	160	352	48
H	11	368	308	320	112	308	126
H	12	368	336	115	135	368	100
G	13	336	192	100	160	368	99
F	14	161	168	84	63	336	80
E	15	115	138	125	160	69	140
D	16	126	87	87	100	41	126
C	17	99	55	66	38	69	100
B	18	84	31	37	77	88	88
A	19	30	11	21	54	30	84
A	20	21	13	20	45	30	66

BSS	Mean	Std.%
A	38	44
B	60	32
C	72	25
D	91	33
E	130	20
F	166	73
G	200	46
H	227	44

BSS - Bulk soil sample
SS Nº - Standard series number

Table II. 2. Copper analyses of the standard series of soil samples 1 - 20 (-80 mesh) included in five batches of geochemical samples submitted to the Bedford College laboratory, May 1970.

BSS	SS Nº	I	II	III	IV	V
A	1	7	10	10	7	5
A	2	7	7	10	7	5
B	3	28	22	20	25	25
C	4	65	60	60	65	65
D	5	95	95	97	95	90
E	6	165	165	165	167	165
F	7	212	197	205	210	202
G	8	207	195	195	197	192
H	9	410	410	447	437	420
H	10	422	455	435	405	420
H	11	427	395	402	402	405
H	12	427	427	387	395	365
G	13	212	207	207	202	195
F	14	215	210	207	202	185
E	15	170	177	177	165	165
D	16	87	87	92	87	87
C	17	57	55	55	55	55
B	18	25	20	25	22	25
A	19	10	10	10	7	10
A	20	7	10	10	5	10

BSS	Mean	Std.%
A	8	23
B	24	11
C	59	7
D	91	4
E	161	1
F	204	4
G	204	4
H	418	5

BSS - Bulk Soil Sample

SS Nº - Standard series number

The results of the Windhoek laboratory, where a bisulphate fusion and colorimetric determination was used, show an extremely wide variation in the copper content of the samples

A - H. The background sample A varied from 11 - 120 ppm. copper and sample H from 69 - 368 ppm. The percentage standard deviation for the samples varies from 20 - 73 and the average value for the samples is 39%.

The groups of samples digested in nitric acid and analysed by atomic absorption spectrophotometry in the Bedford college laboratory show a much higher degree of analytical accuracy. The results for sample A range from 5 - 10 ppm. copper and for sample H from 365 - 455 ppm. The standard deviation for the samples A - H varies from 1 - 23%. The reason for the apparently poor precision for the samples of lower copper content is that with the settings listed above for the atomic absorption unit one scale division represents 5 ppm. Excluding sample A the average standard deviation for the samples is 5% indicating a mean precision at the 95% confidence level of ± 10%.

Following this test group of analyses the standard series was passed through the Windhoek laboratory a further ten times in two batches of 100 samples to see if the precision of colorimetric analyses could be improved. In the first batch the results for sample A varied from 11 - 33 ppm. and sample H from 34 - 384 ppm; the percentage standard deviation for samples A - H ranged from 12 - 44% with an average of 25%. In the second batch of 100 samples the copper values for A varied from 20 - 32 ppm. and for sample H from 115 - 488 ppm.; the standard deviation for samples A - H was from 11 - 54% with an average value of 33%.

The colorimetric method as outlined by Stanton indicates that a mean precision of better than ± 25% at the 95% confidence level should be attained whereas the results of the Windhoek laboratory vary from ± 50% to ± 78% at the 95% confidence level. The precision of these results was not acceptable for geochemical prospecting in the Witvlei area and all soil samples collected on the geochemical grids were subsequently analysed in the Bedford College laboratory by acid digestion and atomic absorption spectrophotometry.

The samples collected during the initial geochemical reconnaissance of the Witvlei Concession were analysed by the colorimetric method in the Rand Leases laboratory and the samples were not retained. The analytical precision for this group of samples is not known.

A standard series of -270 mesh samples was also prepared to control the analyses of the -270 mesh soil samples collected on the transects and soil grids in areas of wind blown sand. The copper content of the standard series samples included in five batches of soil samples are shown in Table II.3. The precision attained for the -270 mesh samples was similar to that for the -80 mesh samples using the method of acid digestion and copper determination by the atomic absorption unit. The copper content of bulk sample A varied from 10 - 20 ppm. and sample H from 840 - 910 ppm. Omitting sample A, the mean precision for the -270 mesh bulk samples is ± 10% at the 95% confidence level.

The chemical attack using the bisulphate fusion should provide the total copper content of the soil sample whereas the nitric acid digestion will give only a partial extraction. A comparison of the mean copper contents obtained for the bulk samples A - H (-80 mesh), by the two extractive methods shows that higher values were recorded for samples A - C using the bisulphate fusion. However, for the samples D - H higher values are recorded from the nitric acid digestion.

Tests were carried out with the nitric acid digestion using varying times of digestion from 1/4 - 8 hours. The results of Table II.4. show a gradual increase of detectible copper with the increasing digestion period. A 60 - 80% extraction is obtained after two hours with the higher percentage extraction for the samples of greater copper content.

Table II. 3. Copper analyses of the standard series of soil samples 1 - 20 (-270 mesh) included in five batches of geochemical samples submitted to the Bedford College Laboratory June 1970.

BSS	SS Nº	I	II	III	IV	V
A	1	10	14	20	14	14
A	2	10	10	20	20	20
B	3	54	50	54	64	54
C	4	140	134	144	150	140
D	5	194	204	204	200	184
E	6	294	284	294	214	290
F	7	414	404	424	404	400
G	8	524	510	555	524	490
H	9	884	894	874	894	884
H	10	894	900	874	884	894
H	11	874	890	854	890	874
H	12	854	910	890	840	910
G	13	510	530	490	480	490
F	14	390	424	410	400	414
E	15	310	304	314	294	304
D	16	194	204	220	220	190
C	17	150	154	154	144	144
B	18	50	50	50	64	64
A	19	10	10	14	14	20
A	20	10	14	14	20	14

BSS	Mean	Std.%
A	15	25
B	55	12
C	145	4
D	210	5
E	290	5
F	416	3
G	510	4
H	866	4

BSS - Bulk soil sample
SS Nº. - Standard series number

Table II. 4. Variation in the recorded copper content of the bulk samples A - G (-80 mesh) with the digestion time in the water bath.

BSS	Hours in water bath at 95° C									
	1/4	1/2	1	2	3	4	5	6	7	8
A	5	5	6	8	10	10	10	11	12	11
B	15	17	20	22	24	28	34	34	38	36
C	37	40	41	58	61	69	79	81	90	92
D	63	69	83	90	96	114	131	134	138	143
E	141	144	162	167	184	195	217	204	222	223
F	160	170	178	192	212	225	240	242	262	246
G	160	167	176	205	216	225	241	253	256	273
H	318	336	248	408	430	455	475	488	511	513

B. LABORATORY METHODS FOR BIOGEOCHEMICAL SAMPLES

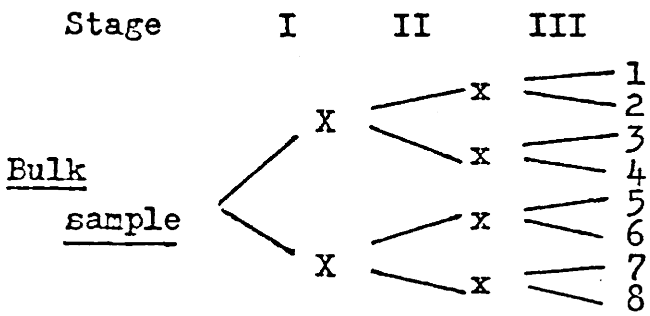
The analyses of all plant samples listed in the text were carried out in the Bedford College laboratory by the following method.

10 - 15 grams of air dried plant material were weighed into a 50 ml. beaker and placed in batches of 24 into an electric muffle furnace thermostatically controlled at 420 degrees centigrade. The samples in the centre of the furnace were completely reduced to ash during the 14 hour period from 6 pm. - 8 am. and the samples at the ends of the furnace were replaced for several hours to complete the ashing process. The percentage ash for the samples was then calculated from the dry weight of the plant sample and the weight of ash produced.

0.2 grams of plant ash were then weighed into a test-tube and 10 mls. of 1N HNO_3 were added. The ash was digested in the nitric acid for 1 hr. in a water bath at 95°C. The solution in the test-tube was allowed to cool and the copper content was determined by atomic absorption spectrophotometry. The copper content of the plant ash and the dry plant material could then be calculated.

Tests were carried out to determine the analytical accuracy and reproducability for plant samples using the above method.

Bulk samples, weighing approximately 100 grams, were collected for the leaves and twigs of ten common shrub species. The samples were thoroughly mixed and coned and quartered in three stages to give eight samples.



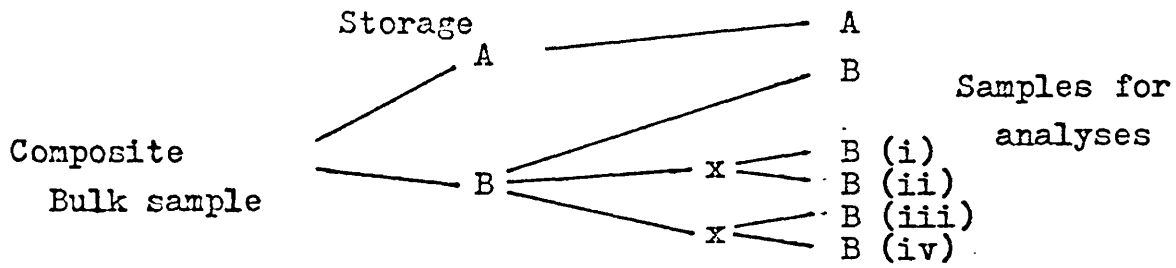
The eight samples were ashed and analysed and the results shown in Tables II. 5 - II. 14. The mean values and the standard deviation were calculated for the leaves and the twigs of the ten species.

The analytical precision for the leaves, (at the 95% confidence level (2 stds.)), varies from ± 4% for *Grewia flava*, *Catophractes alexandri* and *Boscia albitrunca* to ± 9% for *Tarchonanthus camphoratus*.

The range of analytical precision, at the 95% confidence level, for the twigs is from ± 4% for *Grewia flava* to ± 29% for *Ozoroa paniculosa*. The much lower level of analytical precision for the *Ozoroa paniculosa* twigs is most probably caused by incomplete ashing.

Four bulk samples of *Helichrysum leptolepis* were prepared by mixing individual samples collected at the Malachite Pan and Copper Causeway. The composite samples were thoroughly mixed and coned and quartered to give two samples A and B.

A grab sample was taken from A for analyses and the remainder retained for storage. One sample was taken from sample B and then the remainder of B was coned and quartered in two stages to give a further four samples for analyses.



Four groups of samples were prepared for the leaves and one group each for the stems and flowers. The results of analyses for these samples are shown in Table II.15. For the four groups of leaf samples the variation from the mean copper content is less than 10% and for the stems and flowers approximately 25% and 15% respectively.

Table II.5 Copper content of the 8 individual samples prepared from a bulk sample of Acacia hereroensis collected at the Copper Causeway. 5/7/70

	LEAVES			TWIGS		
	% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry
1	4.60	300	13.8	3.24	444	14.4
2	4.50	315	14.2	3.09	434	13.4
3	4.67	322	15.0	3.07	444	13.6
4	4.59	315	14.5	3.09	420	13.0
5	4.59	305	14.0	3.14	390	12.2
6	4.62	305	14.1	3.24	424	13.7
7	4.48	310	13.9	3.13	420	13.1
8	4.52	310	14.0	3.12	414	12.9
		Mean Value	14.2			13.3
		Std.	0.3			0.7
		Std%	2.1			5.3

Table II. 6. Copper content of the 8 individual samples prepared from a bulk sample of <u>Acacia mellifera</u> collected in the Pos Area. 5/7/70

	LEAVES			TWIGS		
	% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry
1	8.34	175	14.6	4.70	337	15.8
2	8.42	167	14.1	4.76	340	16.2
3	8.47	165	14.0	4.67	375	17.5
4	8.30	167	13.9	4.76	347	16.5
5	8.36	172	14.4	4.75	332	15.8
6	8.42	170	14.3	4.76	375	17.5
7	8.44	165	13.9	4.94	337	16.6
8	8.34	162	13.7	4.77	322	15.4
		Mean Value	14.1			16.3
		Std.	0.3			0.6
		Std.%	2.1			3.7

Table II. 7. Copper content of the 8 individual samples prepared from the sample of <u>Boscia albitrunca</u> collected at the Malachite Pan. 7/7/70

	LEAVES			TWIGS		
	% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry
1.	6.83	290	19.8	5.23	202	10.6
2.	7.06	295	20.8	5.29	200	10.6
3.	6.99	280	19.6	4.77	237	11.3
4.	7.02	280	19.7	5.09	212	10.8
5.	7.10	280	19.9	5.41	205	11.1
6.	7.00	285	20.0	5.48	205	11.2
7.	6.84	285	19.5	5.34	202	10.8
8.	6.84	282	19.3	5.33	197	10.5
		Mean value	19.8			10.9
		Std.	0.4			0.3
		Std.%	2.0			2.8

Table II. 8. Copper content of the 8 individual samples prepared from a bulk sample of <u>Catophractes alexandri</u> collected in the Pos Area. 5/7/70

	LEAVES			TWIGS		
	% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry
1.	5.70	267	15.2	3.53	380	13.4
2.	5.77	252	14.5	3.48	382	13.3
3.	5.69	257	14.6	3.54	350	12.4
4.	5.82	262	15.2	3.53	382	13.5
5.	5.72	262	15.0	3.43	397	13.6
6.	5.69	260	14.8	3.47	382	13.3
7.	5.77	250	14.4	3.46	375	13.0
8.	5.91	242	14.3	3.46	387	13.4
	Mean Value		14.8			13.2
	Std.		0.3			0.4
	Std.%		2.0			3.0

Table II.9. Copper content of the 8 individual samples prepared from a bulk samples of <u>Grewia flava</u> collected at the Malachite Pan. 5/7/70

	LEAVES			TWIGS		
	% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry
1.	8.74	360	31.5	3.64	285	10.4
2.	8.72	365	31.8	3.49	282	9.8
3.	8.93	362	32.3	3.73	285	10.6
4.	8.86	375	33.2	3.61	285	10.3
5.	8.73	360	31.4	3.65	282	10.3
6.	8.95	365	32.7	3.65	285	10.4
7.	8.99	365	32.8	3.70	280	10.4
8.	9.09	345	31.4	3.60	290	10.4
	Mean Value		32.1			10.3
	Std.		0.6			0.2
	Std.%		1.9			1.9

Table II. 10. Copper content of the 8 individual samples prepared from a bulk sample of <u>Ozoroa paniculosa</u> collected at the Malachite Pan. 5/7/70

	LEAVES			TWIGS		
	% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry
1.	7.33	170	12.5	3.13	195	6.1
2.	7.48	167	12.5	3.30	195	6.4
3.	7.53	170	12.8	3.76	202	7.6
4.	7.41	157	11.6	3.18	177	5.6
5.	7.48	170	12.7	3.73	195	7.3
6.	7.55	172	13.0	3.16	192	6.1
7.	7.44	160	11.9	3.07	185	5.7
8.	7.21	165	11.9	3.07	190	5.2
	Mean Value		12.4			6.3
	Std.		0.5			0.9
	Std.%		4.0			14.3

Table II. 11. Copper content of the 8 individual samples prepared from a bulk sample of <u>Phaeoptilum spinosum</u> collected at the Copper Causeway. 5/7/70

	LEAVES			TWIGS		
	% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry
1.	15.69	514	80.6	2.49	675	16.8
2.	15.90	505	80.3	2.61	655	17.1
3.	15.48	514	79.6	2.48	655	16.2
4.	15.45	534	82.5	2.56	635	16.3
5.	15.62	495	77.3	2.57	645	16.6
6.	15.60	540	84.2	2.56	635	16.3
7.	15.70	534	83.8	2.47	640	15.8
8.	15.73	490	77.1	2.62	610	16.0
	Mean Value		80.7			16.4
	Std.		2.5			0.4
	Std. %		3.1			2.4

Table II. 12. Copper content of the 8 individual samples prepared from a bulk sample of Rhus pyroides collected at the Malachite Pan. 7/7/70

	LEAVES			TWIGS		
	% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry
1.	5.90	265	15.6	2.96	322	9.5
2.	5.91	265	15.7	2.95	275	8.1
3.	5.95	262	15.6	3.06	285	8.7
4.	5.96	267	15.9	3.20	267	8.5
5.	5.93	270	16.0	3.18	275	8.5
6.	5.93	275	16.3	3.12	290	9.1
7.	6.07	275	16.7	2.95	275	8.1
8.	6.03	280	16.9	3.12	280	8.7
	Mean values		16.1			8.7
	Std.		0.5			0.4
	Std. %		3.1			5.2

Table II. 13. Copper content of the 8 individual samples prepared from a bulk sample of Tarchonanthus camphoratus collected at the Malachite Pan. 7/7/70

	LEAVES			TWIGS		
	% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry
1.	6.81	830	56.5	2.64	300	7.9
2.	6.72	830	55.8	2.71	285	7.7
3.	6.74	754	50.2	2.84	310	8.8
4.	6.53	765	50.0	2.77	300	8.3
5.	6.87	800	55.0	2.85	285	8.1
6.	6.69	820	54.9	2.76	300	8.0
7.	6.86	795	54.5	2.81	305	8.6
8.	6.90	820	56.6	2.90	290	8.4
	Mean Value		54.2			8.2
	Std.		2.4			0.4
	Std. %		4.4			4.3

Table II. 14. Copper content of the 8 individual samples prepared from a bulk sample of <u>Ziziphus mucronata</u> collected at the Malachite Pan. 7/7/70

	LEAVES			TWIGS		
	% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry
1.	8.23	87	7.2	2.56	262	6.7
2.	8.39	87	7.3	2.61	262	6.8
3.	8.30	92	7.6	2.64	250	6.6
4.	8.42	85	7.2	2.54	245	6.2
5.	8.24	87	7.2	2.72	262	7.1
6.	8.33	92	7.6	2.70	262	7.1
7.	8.29	90	7.5	2.75	265	7.3
8.	8.00	92	7.4	3.03	262	7.9
	Mean Value		7.4			7.0
	Std.		0.2			0.5
	Std. %		2.2			6.4

Table II. 15. Copper content of individual samples prepared from composite bulk samples of <u>Helichrysum leptolepis</u>.

Sample Composition	Part of Sample	% ash	ppm ash	ppm dry
Leaves 2080-2087	A	12.70	645	78
	B	11.73	700	82
	B(i)	11.04	690	76
	B(ii)	11.69	700	82
	B(iii)	11.29	690	80
	B(iv)	11.04	655	72
Leaves 2088-2092, 2100-2102	A	13.72	900	123
	B	13.87	855	119
	B(i)	13.25	1000	133
	B(ii)	13.73	910	125
	B(iii)	13.75	900	124
	B(iv)	13.67	890	122
Leaves 2107-2116	A	12.68	835	106
	B	13.59	755	105
	B(i)	13.60	845	115
	B(ii)	13.79	810	112
	B(iii)	13.90	790	110
	B(iv)	13.86	810	112
Leaves 3505-3517	A	9.13	600	55
	B(i)	9.57	635	61
	B(ii)	9.33	620	58
	B(iii)	10.47	610	64
	B(iv)	10.39	600	62
Stems 3505-3517	A	4.77	380	18
	B(i)	6.11	445	27
	B(ii)	5.36	390	21
	B(iii)	5.11	400	20
	B(iv)	4.72	380	18
Flowers 3505-3517	A	8.21	335	28
	B(i)	8.00	400	32
	B(ii)	7.85	335	26
	B(iii)	7.97	315	25
	B(iv)	8.07	345	28

APPENDIX III

List of plant Species Recorded in the Witvlei Area

ACANTHACEAE

2675. Barleria irritans Nees
2555. Barleria lanceolata (Schinz) Oberm.
2666. Barleria rigida Nees
2678. Blepharis leendertziae Oberm.
2620. Justicia guerkeana Schinz
2585. Monechma nepeta (S. Moore) C.B. Cl.
2660. Peristrophe grandibracteata Lindau

AIZOACEAE

2525. Gisekia pharnacioides L.

AMARANTHACEAE

2651. Aerva leucura Moq.
2573. Alternanthera pungens H.B. & K.
2684. Celosia linearis (Schinz) Schinz
2563. Cyphocarpa angustifolia Lopr.
2619. Leucosphaera bainsii (Hook. f.) Gilg
2574. Nelsia quadrangula (Engl.) Schinz
2575. Pupalia lappacea Juss.
2652. Sericorema remotiflora (Moq.) Lopr.

AMARYLLADACEAE

2610. Buphane disticha Herb.
2516. Crinum nerinoides Bak.
2627. Nerine laticoma (Ker) Dur. & Schinz
2634. Pancratium chapmannii Harv.

2542. Ozoroa paniculosa (Sond.) R. & A. Fernandes
2622. Rhus pyroides Burch.

ASCLEPIADACEAE

2579. Fockea augustifolia K. Schum.
2636. Gomphocarpus fruticosus L.

BIGNONIACEAE

2568. Catophractes alexandri D. Don
2696. Rhigozum brevispinosum Kuntze

BORAGINACEAE

2606. Ehretia rigida (Thunb.) Druce
2533. Heliotropium ovalifolium Hassler
2561. Heliotropium steudneri Vatke
2528. Heliotropium strigosum Willd.
2541. Trichodesma angustifolium Harv.

BURSERACEAE

2617. Commiphora pyracanthoides Engl. subsp. pyracanthoides

CAPPARIDACEAE

2598. Boscia albitrunca (Burch.) Gilg. et Binn.
2632. Cleome angustifolia Forsk.
2650. Cleome monophylla L.

CARYOPHYLLACEAE

2677. Pollichia campestris Soland. in Ait.

CHENOPODIACEAE

2509. Chenopodium album L.
2688. Lophiocarpus polystachyus Turcz.
2595. Selago albida Choisy

COMBRETACEAE

2645. Combretum apiculatum Sond.
2653. Terminalia sericea Burch. ex DC.

COMMELINACEAE

2562. Commelina benghalensis L.

COMPOSITAE

2682. Dicoma capensis Less.
2680. Dicoma schinzii O. Hoffm.
2671. Dicoma tormentosa Cass.
2567. Geigeria ornativa O. Hoffm.
2556. Helichrysum leptolepis DC.
2658. Hirpicium echinus Less
2693. Hirpicium gorterioides (Oliv. & Hiern) Roessler
2597. Launaea intybacea (Jacq.) Beauv.
2521. Nidorella resedifolia DC.
2581. Nolletia arenosa O. Hoffm.
2508. Nolletia gariepina (DC) Mattf.
2593. Pegolettia pinnatilobata (Klatt) O. Hoffm. ex Dinter
2594. Platycarpha carlinoides Oliv. & Hiern
2662. Tagetes minuta L.
2695. Tarchonanthus camphoratus L.
2511. Vernonia fastigiata Oliv. & Hiern

CONVOLVULACEAE

2514. Evolvulus alsinoides (L.) L.
2638. Ipomoea bolusiana Schinz
2685. Ipomoea sinensis Fisch.
2648. Ipomoea verbascoidea Choisy
2630. Seddera suffruticosa (Schinz) Hall. f.

CUCURBITACEAE

2571. Cucumis africanus L.f.

CYPERACEAE

2621. Cyperus esculentus L.
2646. Fimbristylis exilis Roem. & Schult. ex hispidula Kunth.
2615. Kyllinga alba Nees

EBENACEAE

2628. Diospyros lycioides Desf. subsp. lycioides

EUPHORBIACEAE

2640. Croton gratissimus Burch.
2578. Euphorbia inaequilatera Sond.
2566. Phyllanthus pentandrus Schum. & Thonn.

FICOIDACEAE

2505. Limeum argute-carinatum Wawra & Peyr.
2565. Limeum viscosum (Gay) Fenzl. subsp. viscosum
2558. Mollugo cerviana (L.) Ser.
2505. Tetragonia spicata L.f.

GRAMINEAE

2549. Anthephora pubescens Nees
2583. Aristida adscensionis L. subsp. guineensis (Trin. & Rupr.) Henr.
2529. Aristida congesta Roem. & Schult.
2584. Aristida effusa Henr.
2683. Aristida stipitata Hack. ex Schinz
2552. Aristida vestita Thunb.
2539. Brachiaria nigropedata (Munro) Stapf
2537. Cenchrus ciliaris L.
2548. Cymbopogon plurinodis Stapf ex Burtt-Davy
2642. Danthoniopis anomala (C.E. Hubb. & Schweick) Clayton
2544. Diandrochloa pusilla (Hack.) de Wint.
2582. Digitaria smutsii Stent
2624. Echinochloa holubii (Stapf) Stapf
2698. Enneapogon brachystachus (Jaub. & Spach.) Staph.

(cont. GRAMINEAE)

2546. Enneapogon cenchroides (Licht.) C.E. Hubb
2536. Eragrostis curvula (Schrad.) Nees
2659. Eragrostis denudata Hack. ex Schinz
2691. Eragrostis horizontalis Peter.
2654. Eragrostis pallens Hack.
2550. Eragrostis porosa Nees
2538. Eragrostis rigidior Pilg.
2527. Eragrostis superba Peyr.
2633. Fingerhuthia africana Lehm.
2547. Heteropogon contortus (L.) Beauv.
2551. Pogonarthria fleckii (Hack.) Hack.
2590. Pogonarthria squarrosa (Licht.) Pilg.
2545. Rhynchelytrum brevipilum (Hack.) Chiov.
2522. Schmidtia pappophoroides Steud.
2586. Sporobolus fimbriatus Nees var. latifolius Stent
2612. Stipagrostis ciliata (Desf.) de Wint. var. capensis (Trin. & Rupr.) de Wint.
2543. Stipagrostis uniplumis (Licht.) de Wint. var. uniplumis
2639. Tragus berteronianus Schult.
2679. Tricholaena monachne Stapf & C.E. Hubb.

IRIDACEAE

2596. Babiana hypogaea Burch.
2644. Lapeyrousia sandersonii Bak.

LABIATAE

2553. Acrotome inflata Benth.
2515. Leucas pechuellii (Kuntze) Guerke
2519. Ocimum americanum L.

LEGUMINOSAE

2697. Acacia giraffae Willd
2623. Acacia hebeclada DC. subsp. hebeclada
2626. Acacia hereroensis Engl.
2618. Acacia karroo Hayne

(cont. LEGUMINOSAE)

2600. Acacia mellifera (Vahl) Benth. subsp. detinens (Burch.) Brenan
2599. Albizia anthelmintica (A. Rich.) Brongn.
2518. Cassia italica (Mill.) Lam ex Steud. subsp. arachoides (Burch.) Brenan
2517. Crotalaria argyraea Welw. ex Bak.
2635. Crotalaria spartioides DC.
2614. Dichrostachys cinerea (L.) Wight & Arn subsp. africana Brenan & Brummitt var. africana sens. lat.
2670. Indigofera flavicans Bak
2690. Indigofera heterotricha DC.
2667. Listia heterophylla E. Mey.
2504. Melolobium candicans Eckl. & Zeyh.
2641. Mundulea sericea (Willd.) A. Chev.
2591. Neorautanenia amboensis Schinz
2524. Otoptera burchelli DC.
2580. Rhynchosia totta (Thunb.) DC.
2523. Sylitra biflora E. Mey.
2559. Tephrosia burchellii Burtt Davy

LILIACEAE

2502. Asparagus africanus Lam.
2643. Dipcadi bakerianum Bol.
2676. Dipcadi glaucum Bak.
2607. Eriospermum rautanenii Schinz
2530. Ornithogalum ornithogaloides (Kunth.) Oberm.
2602. Pseudogaltonia clavata (Bak.) Phill.
2605. Scilla sp. (genus under revision)
2656. Trachyandra laxa (N.E. Br.) Oberm.

LORANTHACEAE

2601. Loranthus oleaefolius Cham. & Schlecht.

LYTHRACEAE

2657. Nesaea rigidula (Sond.) Koehne.

MALVACEAE

2570. Hibiscus fleckii Gurke ex Schinz.
2689. Hibiscus micranthus L.
2616. Pavonia clathrata Mast.
2681. Sida chrysantha Ulbr.

MENISPERMACEAE

2668. Antizoma angustifolia (Burch.) Miers.

NYCTAGINACEAE

2611. Commicarpus pentandrus (Burch.) Heim.
2609. Phaeoptilum spinosum Radlk.

PAPAVERACEAE

2604. Argemone mexicana L.

PEDALIACEAE

2637. Dicerocaryum zanguebarium (Lour.) Merrill.
2669. Pterodiscus aurantiacus ~~aurantiacus~~ Welw.
2540. Sesamum triphyllum Welw. ex Asch.

POLYGONACEAE

2564. Oxygonum dregeanum Meissn.
2649. Polygonum hystriculum Schuster

PORTULACACEAE

2503. Portulaca grandiflora Hook.
2501. Talinum arnotii Hook.f.

RHAMNACEAE

2631. Helinus spartioides (Engl.) Schinz ex Engl.
2531. Ziziphus mucronata Willd.

RUBIACEAE

2587. Kohautia omahekensis (K. Krause) Bremek.

SCROPHULARIACEAE

2526. Aptosimum arenarium Engl.
2588. Aptosimum depressum (L.f.) Burch. var. depressum Hiern
2506. Aptosimum leucorrhizum (E. Mey.) Phill.
2535. Nemesia gracillima Dinter
2672. Selago minutissima Choisy
2613. Sutera atropurpurea Hiern
2532. Walafrida densiflora Rolfe

SOLANACEAE

2554. Datura stramonium L.
2569. Lycium lancifolium Damm.
2625. Solanum incanum L.
2520. Solanum rautanenii Schinz.

STERCULIACEAE

2513. Hermannia abrotanoides Schrad.
2507. Hermannia damarana Bak.f.
2674. Hermannia modesta Planch.
2687. Melhania didyma Eckl. & Zehy.

THYMELAEACEAE

2592. Lasiosiphon microphyllus Meisn.

TILIACEAE

2577. Grewia bicolor Juss.
2603. Grewia flava DC.
2576. Grewia flavescens Juss.
2694. Grewia retinervis Burret

VAHLIACEAE

2534. Vahlia capensis Thunb

VELLOZIACEAE

2500. Vellozia humilis Bak.

VERBENACEAE

2692. Chascanum pinnatifidum E. Mey.
2560. Lantana mearnsii Moldenke var. latibracteolata Moldenke

ZYGOPHYLLACEAE

2572. Tribulus terrestris L.
2629. Tribulus zeyheri Sond.
2608. Zygophyllum suffruticosum Schinz.

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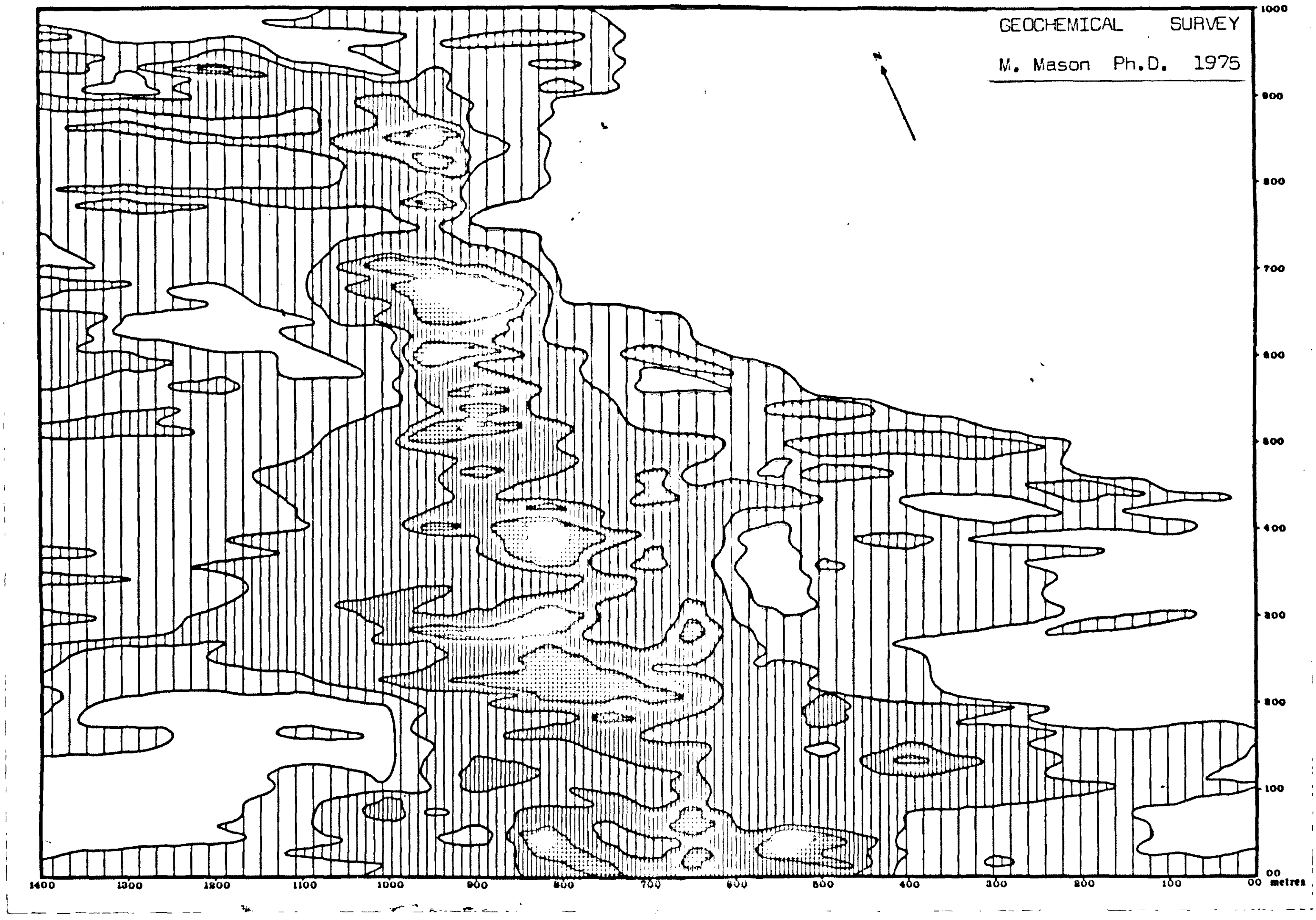
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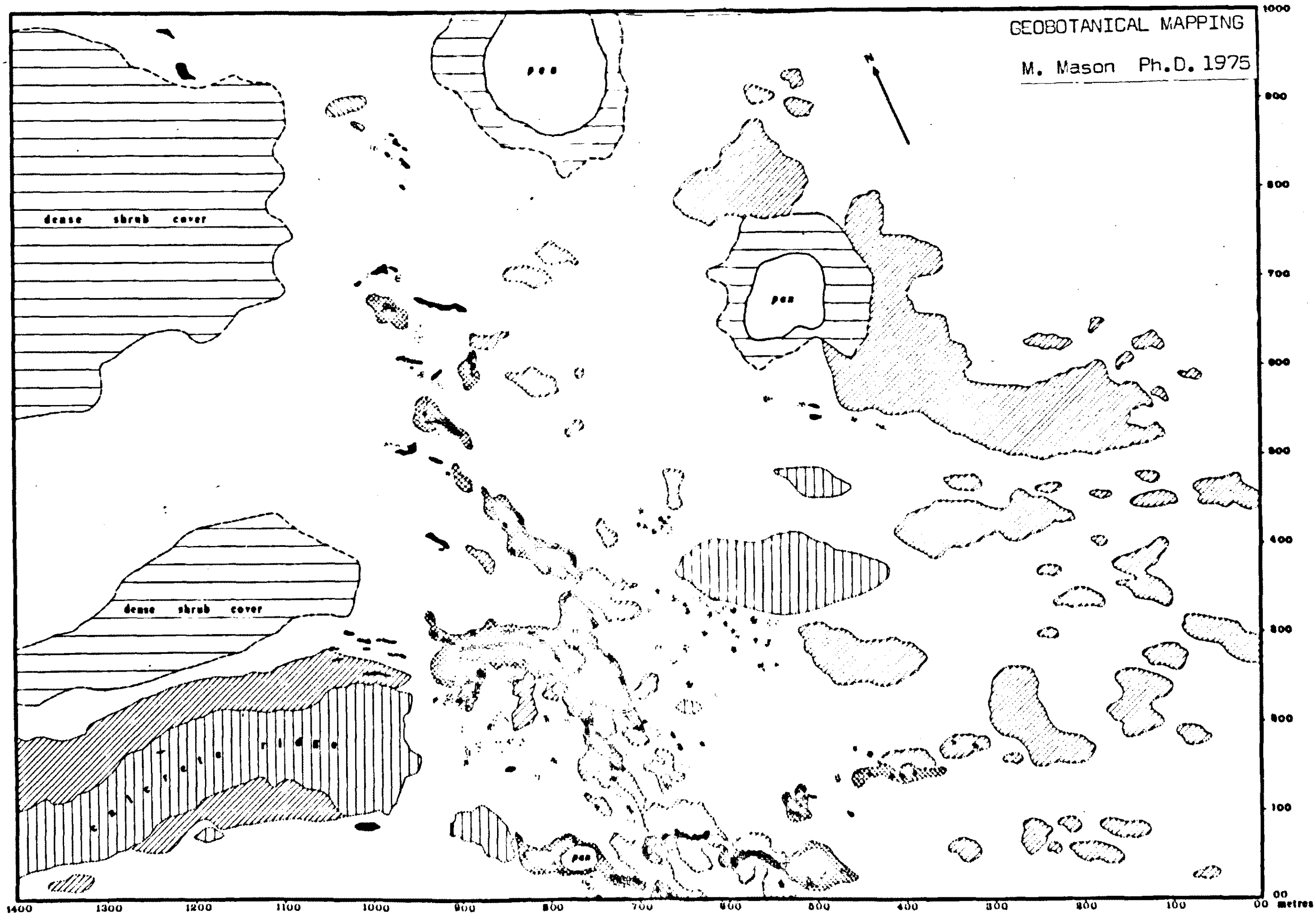
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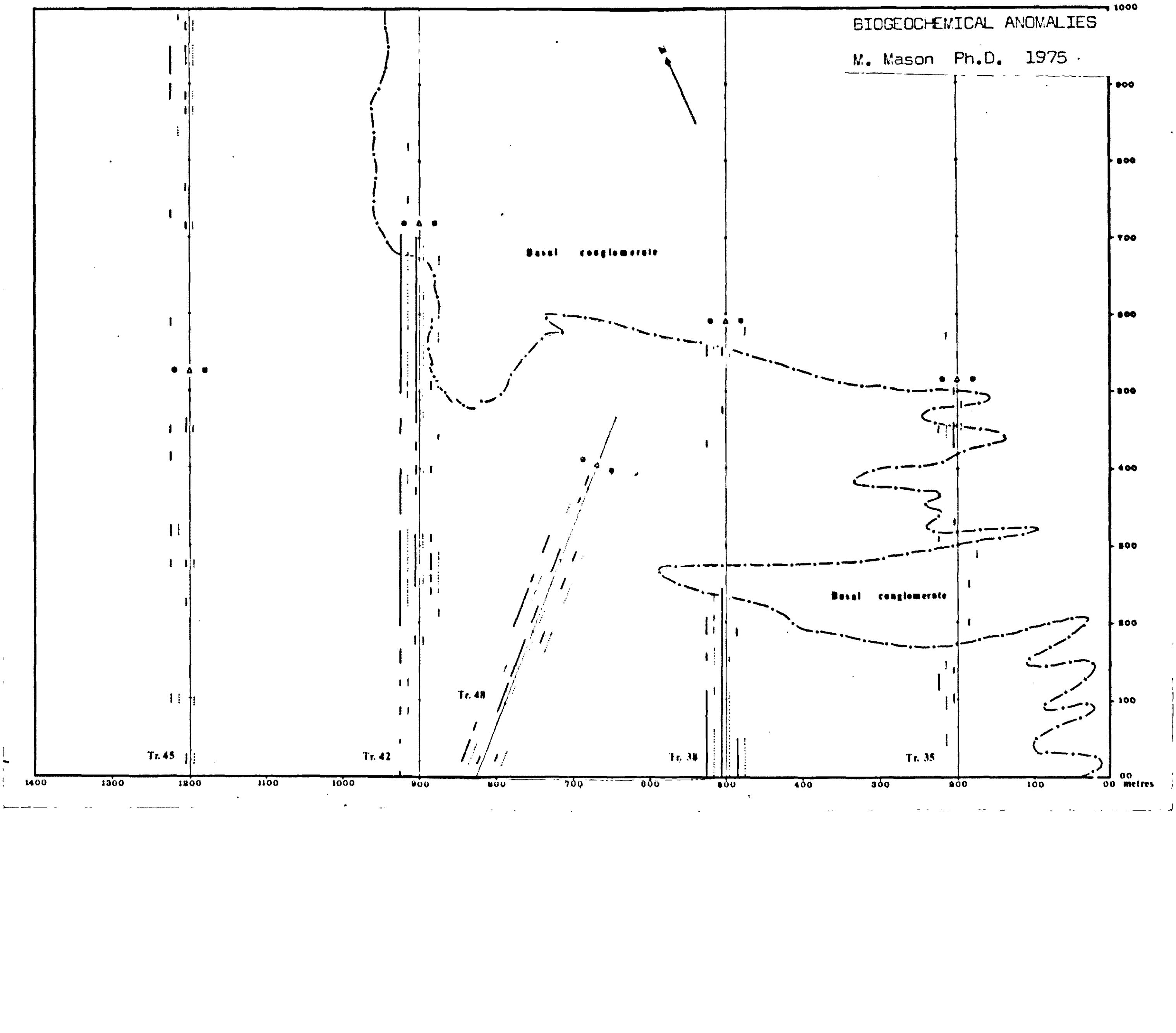
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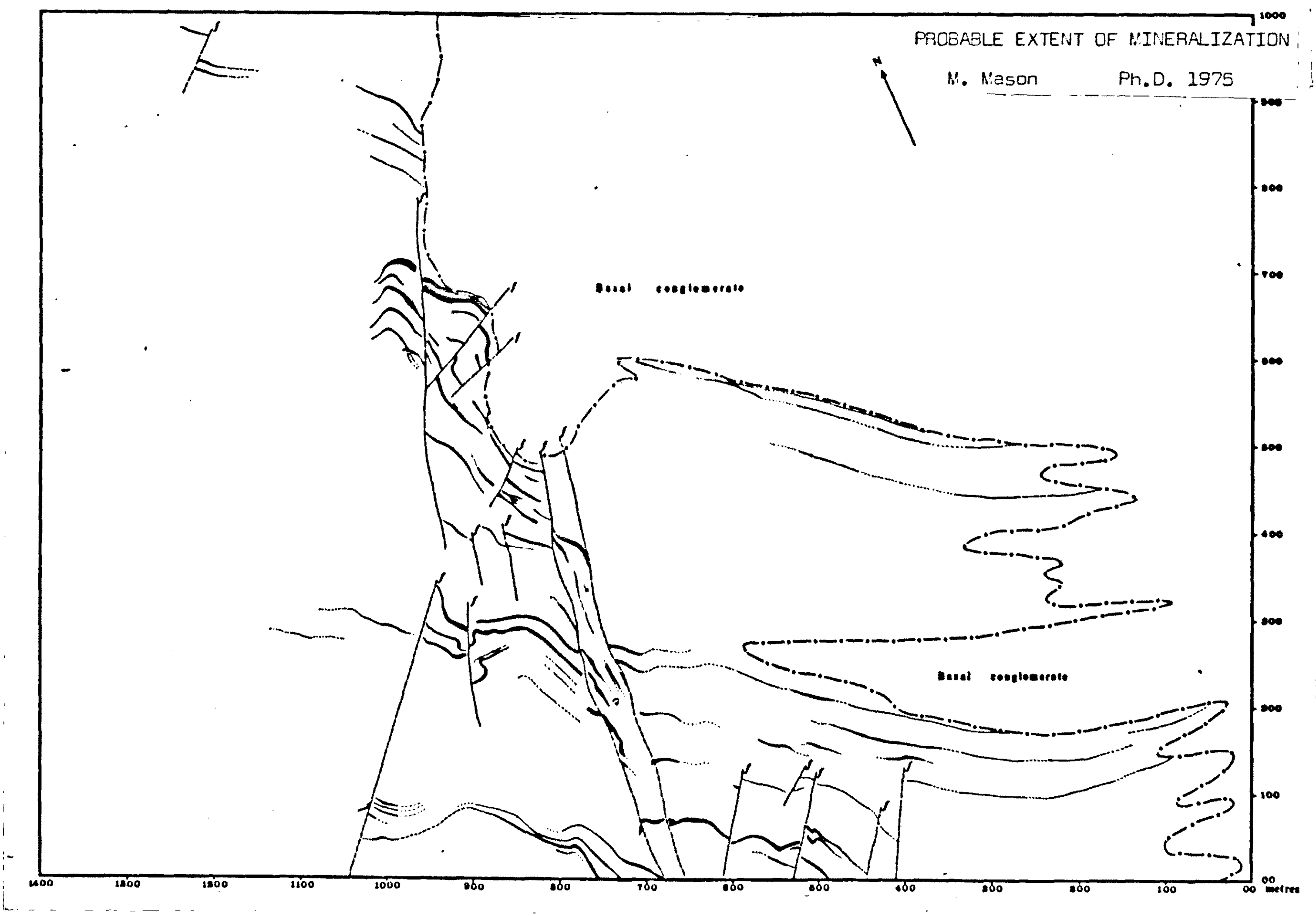

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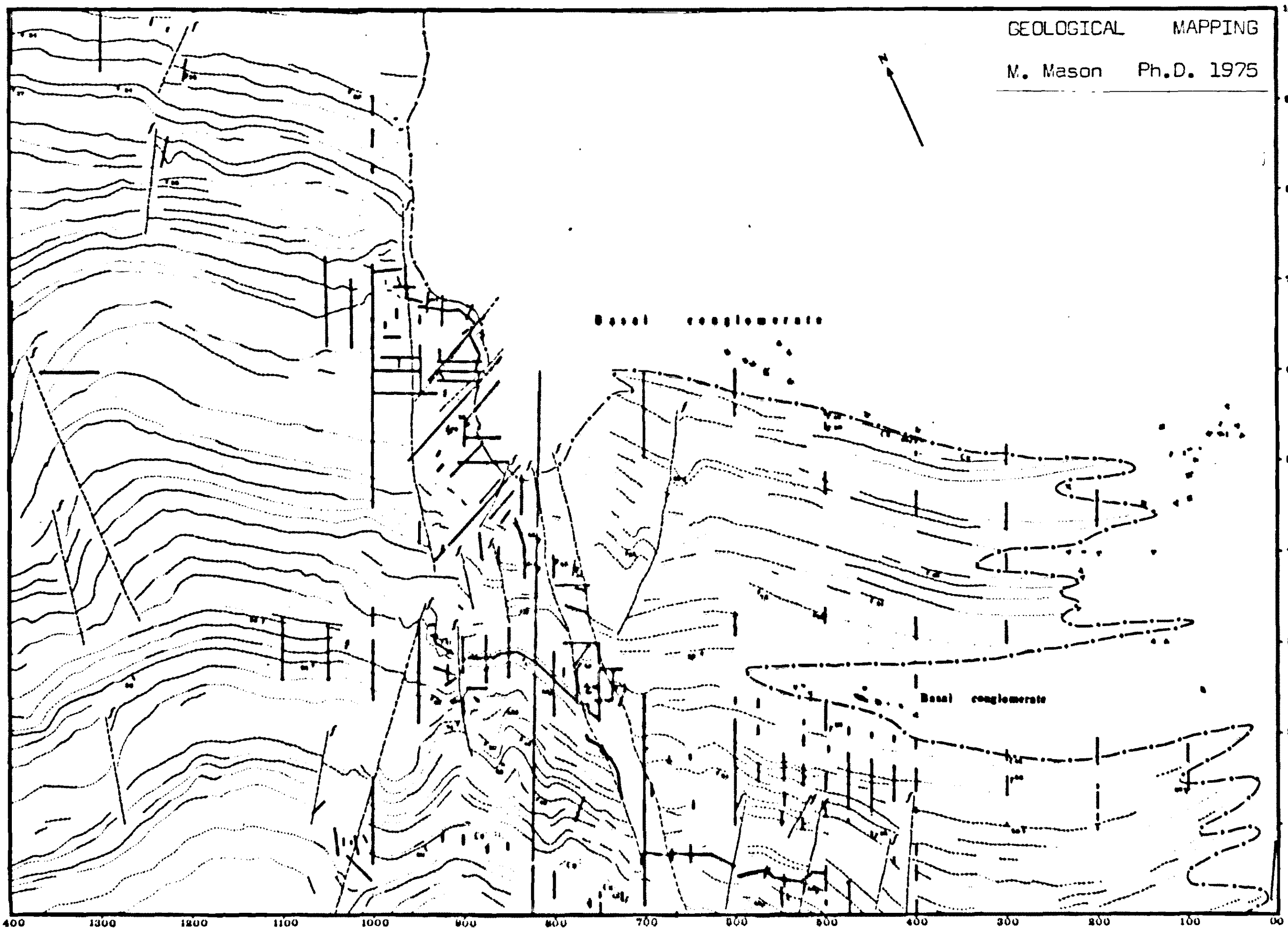

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ANALYTICAL TABLES

APPENDIX IV BIOGEOCHEMICAL RESULTS

APPENDIX IV (contd.)

APPENDIX IV (contd.)

Table IV.1

Copper content of *Grewia flava* samples, leaves and twigs, collected on Transect 30, Pos Area. 14/4/69.

Sample No.	Distance m.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
2840	100N	6.04	100	6.0	3.04	127	3.9	5
2841	79N	6.65	87	5.8	3.28	87	2.9	4
2842	57N	5.37	150	8.1	2.49	110	2.7	4
2843	44N	6.35	172	10.9	3.27	104	3.4	6
2844	18N	6.63	155	10.3	3.41	80	2.7	12
2845	00	7.27	143	10.4	3.61	107	3.9	30
2846	15S	7.30	143	10.4	3.66	110	4.2	25
2847	39S	7.95	227	18.0	2.98	155	4.6	147
2848	63S	6.52	182	11.9	2.73	145	4.0	45
2849	80S	6.92	218	15.2	2.63	110	2.9	30
2850	95S	6.97	107	7.5	4.45	147	6.5	38
2874	120S	6.90	207	14.3	3.83	110	4.2	32
2875	140S	6.64	120	8.0	2.87	165	4.7	18
2876	160S	6.88	205	14.1	3.80	173	6.6	5
2877	170S	7.68	132	10.1	5.53	62	3.4	10
2878	181S	8.50	115	9.8	4.19	127	5.3	30
2879	190S	6.87	257	17.7	5.74	152	8.7	72
2880	198S	6.53	345	22.5	3.92	197	7.7	240
2881	206S	7.15	405	29.0	3.25	167	6.0	325
2882	206S	6.09	395	24.1	3.64	167	6.1	325
2883	212S	6.18	452	27.9	4.22	127	5.4	330
2884	230S	6.50	453	29.4	3.25	155	5.0	237
2885	240S	6.59	360	23.7	3.56	110	3.9	222
2886	250S	5.81	375	21.8	3.34	112	3.7	277
2887	264S	6.91	377	26.1	3.82	200	7.6	310
2888	270S	7.05	288	20.3	3.88	145	5.6	355
2889	294S	6.70	152	10.2	3.41	138	4.7	100
2890	302S	6.45	212	13.7	3.52	152	5.4	52
2891	310S	7.26	135	9.8	2.95	165	4.9	40
2892	318S	7.02	147	10.3	3.67	127	4.7	36
2893	332S	6.89	150	10.3	4.02	125	5.0	40
2894	342S	7.53	142	10.7	4.71	112	5.3	39
2895	364S	6.07	180	10.9	2.95	117	3.5	68
2896	379S	6.82	107	7.3	3.54	75	2.7	26
2897	399S	6.91	132	9.1	4.20	82	3.4	25
2898	418S	7.01	100	7.0	2.65	102	2.7	40
2899	442S	7.32	127	9.3	2.98	190	5.7	175
2900	462S	6.45	190	12.3	3.05	120	3.7	88
2901	546S	5.49	265	14.5	2.81	165	4.6	40
2902	582S	7.22	132	9.5	3.83	132	5.1	50

Table IV.2

Copper content of *Acacia mellifera* samples, leaves and twigs, collected on Transect 30, Pos Area, 14/4/69.

Sample No.	Distance m.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
2851	103N	7.53	150	11.3	3.52	120	4.2	5
2852	65N	10.11	60	6.7	4.83	82	4.0	4
2853	44N	8.78	60	5.2	4.76	50	2.4	6
2854	20N	8.73	110	9.6	4.09	87	3.6	10
2855	00	7.54	102	7.7	3.59	72	2.6	30
2856	20S	8.66	92	8.0	4.16	92	3.8	24
2857	39S	8.81	137	12.1	4.79	120	5.7	150
2858	61S	10.98	137	15.0	3.34	132	4.4	48
2859	82S	10.86	127	13.8	4.24	127	5.4	32
2860	100S	7.77	110	8.5	4.21	152	6.4	35
2903	115S	9.10	102	9.3	4.59	110	5.0	54
2904	143S	9.56	78	7.5	2.65	80	2.1	15
2905	160S	9.02	82	7.4	4.16	113	4.7	5
2906	170S	7.48	135	10.0	3.46	95	3.3	8
2907	180S	7.84	135	9.9	3.27	92	3.0	13
2908	191S	9.97	175	17.4	4.27	147	6.3	115
2909	196S	9.60	125	12.0	4.87	115	5.6	140
2910	204S	9.54	147	14.0	3.38	97	3.3	276
2911	212S	9.04	240	22.7	2.99	252	7.5	320
2912	216S	8.84	255	22.5	4.49	250	11.2	225
2913	230S	7.83	272	21.3	4.13	180	7.4	237
2914	241S	8.86	127	12.5	3.31	210	7.0	220
2915	249S	9.34	160	14.9	4.02	210	8.4	204
2916	259S	8.77	145	12.7	3.39	162	5.5	270
2917	270S	9.58	152	14.6	4.77	162	7.7	355
2918	280S	9.82	100	9.8	3.82	122	4.7	140
2919	296S	8.46	110	9.3	4.44	117	5.2	90
2920	303S	8.68	110	9.5	6.25	67	4.2	52
2921	315S	5.20	110	5.7	4.36	122	5.3	38
2922	322S	9.24	97	9.0	4.86	135	6.5	36
2923	330S	9.03	90	8.1	4.02	120	4.8	35
2924	353S	7.39	97	7.2	5.60	100	5.6	22
2925	362S	9.10	72	6.6	5.46	75	4.1	22
2926	380S	7.94	125	9.9	3.31	128	4.2	29
2927	401S	10.08	87	8.8	4.84	137	6.6	27
2928	422S	5.88	95	5.6	4.17	155	6.5	51
2929	440S	8.86	82	7.3	5.23	132	6.9	155
2930	465S	9.52	90	10.4	4.29	117	5.0	84
2931	494S	8.93	128	11.4	3.62	105	3.8	271
2932	515S	8.64	87	7.5	6.81	127	8.6	60
2933	540S	9.54	87	8.3	3.64	105	3.8	43
2934	602S	10.28	77	7.9	5.40	82	4.4	18

Table IV.3

Copper content of Boscia albitunca samples, leaves and twigs collected on Transect 30. Pos Area. 15/4/69.

Sample No.	Distance m.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
2935	60N	13.68	40	5.5	3.46	102	3.5	4
2936	42N	4.66	42	4.1	3.58	60	2.1	7
2937	2S	6.69	72	4.8	4.25	47	2.0	29
2938	11S	10.29	70	7.2	3.13	162	5.1	26
2939	41S	6.69	82	5.5	3.81	92	3.5	108
2940	48S	9.13	60	5.5	4.10	92	3.8	85
2941	70S	8.09	60	4.9	3.94	152	6.0	35
2942	93S	7.02	157	11.0	3.48	70	2.4	36
2943	10S	8.41	70	5.9	3.21	172	5.5	75
2944	150S	9.08	57	5.2	3.69	92	3.4	10
2945	170S	11.30	65	7.3	3.05	185	5.6	8
2946	184S	8.21	72	5.9	3.20	110	3.5	60
2947	200S	11.94	92	11.0	4.85	110	5.3	216
2948	207S	10.84	202	21.9	3.85	132	5.1	350
2949	232S	7.84	110	8.6	2.72	155	4.2	230
2950	242S	9.26	117	10.9	3.91	137	5.4	220
2951	249S	10.17	73	9.4	3.54	92	3.3	206
2952	259S	11.16	82	9.2	4.07	127	5.2	272
2953	265S	10.00	142	14.0	5.10	42	2.1	311
2954	284S	8.66	90	7.8	3.51	110	3.9	138
2955	293S	10.23	72	7.4	4.27	55	2.3	112
2956	312S	10.28	52	5.3	5.13	42	2.2	38
2957	320S	9.56	40	3.8	4.16	70	2.9	37
2958	331S	10.70	33	3.5	4.27	92	3.9	36
2959	342S	8.26	45	3.7	5.01	52	2.6	43
2960	361S	7.67	100	7.7	3.10	195	6.0	22
2961	377S	7.66	80	6.1	4.87	87	4.2	27
2962	399S	10.45	60	6.3	7.68	33	2.5	26
2963	416S	7.99	82	6.6	6.32	40	2.5	42
2964	440S	9.31	75	7.0	7.24	45	3.3	155
2965	469S	7.38	72	6.1	2.86	210	6.2	65
2966	524S	7.79	45	3.5	5.57	50	2.8	55
2967	538S	6.90	70	4.8	9.15	25	2.3	41

Table IV.4

Copper content of Catophractes alexandri samples, leaves and twigs, collected on Transect 30, Pos Area. 16/4/69.

Sample No.	Distance m.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
2987	40N	5.45	120	6.5	3.10	187	5.7	7
2988	20N	7.00	115	8.0	2.84	185	5.3	10
2990	0	5.89	110	10.0	3.32	170	5.6	20
2991	20S	6.89	130	9.0	2.98	177	5.3	24
2992	39S	6.50	197	12.8	3.34	187	6.2	150
2993	50S	6.50	193	12.5	3.38	170	5.7	67
2994	85S	5.94	195	11.6	3.11	262	8.1	33
2995	100S	5.96	232	13.8	3.06	277	8.5	35
2996	120S	6.10	213	13.0	3.72	277	10.3	32
2997	160S	7.74	112	8.7	3.41	250	8.5	7
2998	169S	5.62	135	7.6	3.44	150	5.2	8
2999	184S	5.68	132	7.5	3.38	223	7.5	60
3000	190S	6.45	135	8.6	3.36	172	5.8	112
3001	200S	7.58	213	16.1	3.26	280	9.1	216
3002	204S	6.78	247	16.7	3.15	290	9.1	280
3003	220S	6.48	223	14.5	3.60	167	6.0	282
3004	240S	7.58	313	23.7	3.08	380	11.7	222
3005	252S	5.39	282	15.2	2.55	242	6.1	216
3006	272S	5.39	167	9.0	3.34	118	3.9	315
3007	314S	6.68	162	10.8	3.51	195	6.8	38
3008	322S	7.16	140	10.0	2.74	262	7.2	37
3009	330S	8.60	85	7.4	4.17	158	6.6	35
3010	340S	9.12	107	9.8	3.55	195	6.9	47
3011	355S	7.32	135	9.9	2.98	223	6.6	22
3012	372S	6.67	158	10.5	2.28	230	5.2	24
3013	398S	6.01	108	6.5	2.41	135	3.3	25
3014	419S	6.52	113	7.4	2.75	220	6.1	43
3015	442S	6.96	162	11.3	3.04	217	6.6	175
3016	443S	6.50	162	10.5	2.91	225	6.5	185
3017	452S	7.78	130	10.1	3.30	217	7.2	99
3018	497S	8.32	147	12.2	2.98	225	6.7	160
3019	503S	6.93	162	11.2	2.79	217	6.1	50
3020	520S	5.92	132	7.8	3.60	125	4.5	70
3021	540S	6.66	162	10.8	3.01	155	4.7	43
3022	558S	6.43	122	7.8	3.65	157	5.7	70
3023	578S	7.32	132	9.7	3.21	178	5.7	75
3024	600S	4.78	80	3.8	2.92	207	6.0	18

Table IV.5

Copper content of Phaeoptilum spinosum samples,leaves and twigs, collected from Transect 30, Pos Area. 16/4/69.

Sample No.	Distance m.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
2968	62N	10.03	47	4.7	2.59	40	1.0	4
2969	57N	10.04	40	4.0	3.51	162	5.7	5
2970	7N	8.25	60	5.0	2.90	115	3.3	27
2971	2S	8.90	120	10.7	5.49	100	5.5	29
2972	30S	5.78	92	5.3	3.80	177	6.7	42
2973	50S	13.13	138	18.1	2.58	295	7.6	67
2974	95S	12.28	75	9.2	3.95	150	5.9	36
2975	143S	12.83	42	5.4	4.87	110	5.4	16
2976	190S	12.01	210	25.2	3.41	290	9.9	112
2977	208S	11.15	490	54.5	3.77	352	13.3	400
2978	309S	10.29	115	11.8	3.57	255	9.1	41
2979	342S	10.28	70	7.2	5.79	115	6.7	43
2980	418S	16.27	60	9.8	5.30	125	6.6	43
2981	448S	16.62	145	23.8	4.07	275	11.2	120
2982	457S	10.51	272	28.6	6.33	167	10.6	99
2983	523S	9.98	135	13.5	3.74	197	7.4	58
2984	538S	11.28	190	21.4	3.79	250	9.5	40
2985	570S	14.57	67	9.8	3.45	190	6.6	102
2986	588S	8.99	102	9.2	5.96	100	6.0	30

Table IV.6

Copper content of Tarchonanthus camphoratus samples, leaves and twigs collected on Transect 30, Pos Area. 17/4/69.

Sample No.	Distance m.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
2865	80N	4.93	367	18.1	2.90	157	4.6	4
2866	55N	4.94	223	11.0	2.54	173	4.4	4
2867	34N	5.70	362	20.6	2.38	157	3.7	7
2868	12N	6.20	342	21.2	3.32	140	4.6	18
2869	3S	5.45	465	25.3	2.98	173	5.2	28
2870	54S	8.82	405	35.7	2.66	223	5.0	59
2871	65S	6.29	360	22.6	2.40	192	4.6	42
2872	82S	6.37	460	29.3	3.01	170	5.1	31
2873	94S	7.15	292	20.1	2.52	242	6.1	36
3025	120S	6.83	363	24.7	3.29	155	5.1	32
3026	124S	7.84	305	23.9	3.33	167	5.6	18
3027	153S	6.34	317	20.1	3.04	187	5.7	8
3028	165S	7.07	250	17.6	2.40	162	3.9	7
3029	182S	7.04	397	27.9	2.81	223	6.3	33
3030	201S	8.14	520	42.3	3.54	322	11.4	228
3031	206S	7.37	402	29.6	2.95	255	7.5	330
3032	261S	6.85	520	35.6	2.64	367	9.7	285
3033	308S	7.10	325	23.1	3.46	210	7.3	42
3034	317S	7.63	310	23.7	2.82	227	6.4	38
3035	349S	7.59	185	14.0	3.01	212	6.4	216
3036	420S	7.64	450	34.4	2.80	212	5.9	45

Table IV.7

Copper content of leaves and twigs for the less common trees and shrubs sampled on Transect 30, Pos Area. 17 - 24/4/69

Species	Sample Number	Dist. m.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
Acacia hereroensis	2861	88N	4.3	113	5	3.9	110	5	4
	2862	70N	4.9	132	7	3.8	117	5	4
	2863	9N	4.7	142	7	2.4	117	3	20
	2864	78S	4.7	162	8	4.9	132	6	30
	3037	130S	5.7	135	7	3.2	75	2	18
	3038	170S	6.3	105	7	4.6	75	4	10
	3039	211S	5.1	380	20	4.1	380	15	390
	3040	475S	5.2	110	6	2.4	95	2	58
	3041	485S	5.7	205	12	4.5	125	6	50
Albizia anthelmintica	3042	495S	6.7	300	20	3.4	125	4	271
	3043	496S	6.0	300	23	2.9	145	4	240
	3044	512S	8.2	135	11	5.5	90	5	60
	3045	533S	6.4	215	14	2.8	135	4	37
	3046	543S	6.0	165	10	3.3	95	3	44
	3047	479S	7.3	90	7	3.4	95	3	67
	3048	460S	6.7	115	8	2.5	135	3	104
Dichrostachys cinerea	3916	91N	5.2	135	7	2.3	133	3	5
	3921	59N	5.4	130	7	3.0	128	4	4
	3924	20S	6.1	150	9	3.3	148	5	24
	3940	485S	5.8	213	12	2.9	250	7	50
Ehretia rigida	3917	90N	11.0	78	9	3.7	190	7	5
	3927	140S	11.4	113	13	3.5	223	8	18
	3929	215S	13.8	140	19	4.6	255	12	212
	3931	250S	10.1	168	17	3.6	308	11	202
	3936	443S	11.0	135	15	3.4	285	10	185
Rhigosum brevispinosum	3918	85N	6.0	95	6	2.9	250	7	4
	3920	63N	6.0	108	7	3.5	170	6	4
	3923	20N	5.1	93	5	3.5	210	7	10
	3933	325S	6.1	100	6	3.2	195	6	36
Grewia flavescens	3919	70N	8.8	115	10	3.6	105	4	4
	3925	95S	9.3	185	17	3.3	213	7	36
	3928	215S	9.6	260	25	4.8	283	14	212
	3932	265S	8.3	228	19	4.3	265	11	320
	3935	400S	8.9	123	11	4.2	165	7	26
	3938	480S	8.3	185	15	3.9	223	9	57
Grewia bicolor	3926	120S	7.4	243	18	4.6	135	6	32
	3930	230S	7.7	270	21	5.3	200	11	237
	3934	370S	7.5	230	17	4.1	153	6	22
	3939	480S	6.6	263	17	3.9	173	7	57
Commiphora pyrocanthoides	3937	465S	9.0	130	12	5.0	185	9	82
	3943	500S	9.5	113	11	5.9	173	10	50
	3944	525S	8.8	105	9	4.3	183	8	52
	3945	590S	9.1	123	11	5.3	123	7	23
Combretum apiculatum	3941	485S	6.9	145	10	4.1	128	5	50
	3942	495S	5.9	165	11	3.7	113	6	220
Ziziphus mucronata	3922	20N	7.7	105	8	3.5	210	7	10

Table IV.8

Copper content of the herb species Barleria lanceolata for samples of leaves and twigs collected on Transect 30, Pos Area. 22/4/69.

Sample No.	Distance m.s	LEAVES			TWIGS			SOIL
		% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry	-80 mesh
3049	156	15.6	75	12	2.8	170	5	7
3050	178	13.7	80	11	2.8	155	4	17
3051	195	13.2	105	14	3.3	150	5	188
3052	205	15.0	100	15	4.2	210	9	282
3053	216	16.0	95	15	2.7	175	5	212
3054	243	14.6	110	16	3.2	205	7	215
3055	255	15.0	105	16	3.6	186	7	240
3056	268	12.7	125	16	2.9	280	8	335

Table IV.9

Copper content of Grewia flava leaves collected on Transect 87, Pos Area. 4/2/70.

Sample No.	Dist. m.	% ash	ppm ash	ppm dry	Sample No.	Dist. m.	% ash	ppm ash	ppm dry
5181	514S	7.6	180	13.8	5231	30S	7.3	315	23.0
5182	510S	8.8	202	16.5	5232	20S	7.1	317	22.4
5183	499S	6.4	240	15.4	5233	8S	8.1	165	13.3
5184	490S	6.7	244	16.1	5234	1S	6.7	190	12.7
5185	477S	7.4	202	15.0	5235	13N	6.2	245	15.2
5186	470S	7.6	230	17.5	5236	18N	7.6	137	10.4
5187	460S	7.4	200	14.9	5237	30N	7.0	225	15.8
5188	449S	7.6	285	21.6	5238	40N	7.6	117	8.9
5189	437S	7.8	275	21.4	5239	50N	7.6	190	14.4
5190	430S	9.3	245	22.9	5240	60N	8.0	197	15.8
5191	420S	7.4	252	18.5	5241	72N	6.9	225	15.5
5192	410S	7.5	280	21.0	5242	80N	8.3	145	12.1
5193	400S	7.7	270	20.7	5243	92N	7.2	230	16.6
5194	391S	7.5	270	20.0	5244	100N	7.8	175	13.7
5195	378S	8.6	275	23.5	5245	144N	7.6	127	9.6
5196	371S	7.2	295	21.4	5246	120N	7.3	155	11.4
5197	357S	7.3	257	18.7	5247	130N	7.0	220	15.5
5198	350S	7.8	245	19.1	1548	140N	6.4	215	13.8
5199	342S	7.5	310	23.2	5249	155N	6.6	190	12.6
5200	331S	8.1	317	25.8	5250	160N	7.5	180	13.6
5201	320S	7.5	265	19.8	5251	165N	7.3	170	12.2
5202	311S	7.6	222	17.2	5252	180N	7.1	195	13.8
5203	299S	6.3	372	23.6	5253	530S	7.3	295	21.4
5204	289S	7.6	252	19.1	5254	540S	7.5	262	19.7
5205	278S	7.7	355	27.3	5255	549S	7.3	265	20.8
5206	269S	6.5	345	22.4	5256	560S	7.2	280	20.1
5207	267S	6.6	350	22.9	5257	570S	6.4	290	18.6
5208	260S	7.1	305	21.6	5258	580S	7.0	267	18.7
5209	251S	7.5	372	27.7	5259	590S	8.3	277	23.1
5210	241S	7.6	322	24.4	5260	600S	6.2	310	19.2
5211	230S	6.6	337	22.2	5261	613S	10.6	222	22.3
5212	222S	7.3	327	23.8	5262	623S	7.9	285	22.6
5213	207S	7.9	245	19.4	5263	630S	7.3	250	18.3
5214	199S	7.6	300	22.7	5264	640S	Sample	Missing	
5215	190S	7.1	475	33.8	5265	650S	7.7	167	12.9
5216	180S	6.8	262	17.8	5266	660S	7.1	262	18.5
5217	171S	7.8	337	26.4	5267	670S	7.0	257	18.0
5218	160S	7.4	265	19.6	5268	681S	7.8	240	18.7
5219	148S	8.9	252	22.3	5269	690S	7.9	222	17.6
5220	140S	8.2	260	21.3	5270	701S	7.3	257	18.7
5221	127S	7.1	372	26.4	5271	710S	7.9	265	20.8
5222	110S	6.6	270	17.9	5272	720S	8.1	210	17.0
5223	105S	7.2	172	12.5	5273	730S	7.3	275	20.0
5224	100S	7.3	212	15.5	5274	739S	7.5	235	17.6
5225	90S	6.7	212	14.3	5275	751S	7.7	185	14.2
5226	82S	8.1	142	11.6	5276	760S	7.7	207	16.0
5227	68S	7.4	217	16.1	5277	771S	8.6	190	16.4
5228	60S	6.8	207	14.1	5278	780S	8.4	237	19.6
5229	51S	7.1	260	18.6	5279	789S	8.0	210	16.8
5230	38S	7.6	200	15.2	5280	804S	7.3	240	17.5

Table IV.10

Copper content of Grewia flava, leaves and twigs, collected on Transect 55, Copper Causeway. 10/1/70.

Sample No.	Distance m.N	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
3060	10	8.0	160	12.8	3.3	105	3.5	5
3061	28	7.9	205	16.3	4.1	150	6.2	10
3062	49	7.8	210	16.5	3.8	130	5.0	10
3063	73	7.0	218	15.4	4.1	113	4.6	16
3064	93	7.9	335	18.6	4.4	140	6.2	19
3065	112	7.3	203	14.9	3.6	120	4.4	14
3066	127	7.5	223	16.8	3.8	158	6.0	16
3067	140	8.3	195	16.4	3.8	123	4.7	40
3068	159	8.2	175	14.4	3.5	140	5.0	19
3069	179	7.2	190	13.7	3.7	138	5.1	28
3070	191	7.7	175	13.6	3.2	150	4.9	71
3071	200	7.7	255	19.4	3.5	205	7.2	70
3072	209	7.6	218	16.7	3.7	170	6.4	136
3073	223	7.7	288	22.3	2.9	235	7.0	240
3074	230	6.9	375	26.1	3.8	210	8.2	272
3075	243	8.2	283	23.2	5.4	180	9.8	215
3076	260	7.9	235	18.6	3.5	145	5.1	222
3077	270	7.9	260	20.7	3.6	175	6.3	195
3078	285	7.8	278	21.9	2.7	285	7.9	114
3079	292	7.1	250	17.6	3.2	118	3.8	106
3080	301	6.5	345	22.7	3.3	188	6.3	106
3081	316	8.3	278	23.3	4.6	185	8.7	210
3082	320	8.7	360	31.5	4.6	190	8.8	182
3083	340	8.3	273	22.7	3.8	205	7.9	150
3084	345	8.2	365	30.0	4.1	328	13.6	224
3085	358	7.4	300	22.4	3.5	195	6.8	250
3086	372	7.7	248	19.3	3.7	180	6.8	85
3087	398	9.0	278	25.3	3.9	210	8.4	180
3088	418	7.8	173	13.6	4.0	118	4.8	42
3089	430	8.1	185	15.2	3.5	145	5.2	7
3090	443	7.7	218	17.0	3.5	163	5.8	5
3091	454	7.8	168	13.2	3.3	113	3.6	5
3092	473	7.4	225	16.8	4.0	108	4.4	7
3093	488	8.5	150	12.8	3.9	130	5.1	7
3094	510	7.2	123	9.0	3.8	120	4.7	7
3095	530	7.6	150	11.5	2.9	113	3.3	7
3096	555	7.0	225	15.9	3.8	123	4.7	10
3097	573	7.2	205	14.8	2.9	118	3.5	5
3098	590	7.0	173	12.1	3.9	98	3.9	7
3099	599	7.1	185	13.2	2.9	100	3.0	5

Table lV.11

Copper content of Acacia hebeclada, leaves and twigs, collected on Transect 55, Copper Causeway. 11/1/70.

		LEAVES			TWIGS			SOIL
Sample No.	Distance m.N	% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry	-80 mesh
3232	10	7.2	25	1.8	6.9	33	2.3	5
3233	30	5.4	28	1.5	5.3	28	1.5	10
3234	63	6.2	28	1.7	7.1	25	1.8	15
3235	82	6.8	28	1.9	6.5	28	1.8	18
3236	100	7.5	25	1.9	6.8	28	1.9	22
3237	134	6.2	18	1.1	7.3	25	1.8	30
3238	152	6.5	30	2.0	6.3	38	2.4	21
3239	161	6.3	30	1.9	5.6	50	2.8	18
3240	190	6.6	18	1.2	7.7	23	1.8	77
3241	200	6.6	38	2.5	7.3	25	1.8	70
3243	236	6.3	30	1.9	6.7	40	2.7	230
3244	254	6.4	58	3.7	5.2	75	3.9	215
3245	267	5.6	50	2.8	4.7	68	3.2	205
3246	275	7.2	65	4.7	5.9	138	8.2	150
3247	292	7.7	40	3.1	5.2	40	2.1	110
3248	302	7.8	30	2.4	7.4	35	2.6	110
3249	316	6.6	48	3.2	6.4	58	3.7	210
3250	324	5.7	55	3.1	5.9	75	4.4	147
3251	333	5.6	58	3.3	5.0	80	4.0	190
3252	343	6.5	110	7.2	7.3	195	14.3	175
3253	346	7.3	53	3.9	5.8	95	5.5	230
3254	369	5.4	58	3.2	7.1	58	4.2	80
3255	387	5.9	113	6.7	4.1	193	7.9	172
3256	394	6.0	115	7.0	5.5	193	10.8	215
3257	418	6.6	30	2.0	7.2	25	1.8	40
3258	463	5.7	25	1.4	5.1	35	1.8	5
3259	478	6.9	25	1.7	6.2	33	2.1	7
3260	515	5.8	28	1.6	6.5	18	1.2	6
3261	535	6.6	30	2.0	7.3	25	1.8	8
3262	578	5.4	33	1.8	4.3	35	1.5	5
3263	598	7.8	18	1.4	7.1	18	1.3	6

Table lV.12

Copper content of Acacia hereroensis, leaves and twigs, collected on Transect 55, Copper Causeway. 11/1/70.

Sample No.	Distance m.N.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
3189	44	4.3	160	7.0	3.0	290	8.9	10
3190	46	4.9	118	5.9	3.6	113	4.1	10
3191	70	4.4	135	6.0	3.1	103	3.3	15
3192	115	5.1	108	5.6	2.6	180	4.7	12
3193	153	4.9	113	5.6	3.7	135	5.0	20
3194	172	4.9	113	5.6	3.5	130	4.7	22
3195	201	5.2	148	7.7	4.5	110	5.0	80
3196	210	5.1	130	6.7	5.7	123	7.1	143
3197	220	3.9	230	9.1	6.3	165	10.5	227
3198	220	5.3	143	7.6	5.5	125	6.9	227
3199	232	5.1	210	10.7	3.5	260	9.2	265
3200	250	5.5	145	8.1	4.2	148	6.3	210
3201	276	5.8	113	6.6	4.3	135	5.8	140
3202	299	4.7	170	8.1	3.9	170	6.7	102
3203	317	5.5	133	7.4	3.7	133	5.0	232
3204	332	4.9	220	10.8	2.8	293	8.5	190
3205	355	6.1	130	8.0	3.4	163	5.5	137
3206	361	5.2	148	7.8	3.8	185	7.0	300
3207	393	4.4	140	6.3	3.6	165	6.0	210
3208	395	5.3	173	9.3	4.0	300	12.1	220
3209	397	6.2	293	18.2	4.4	815	34.0	180
3210	403	5.1	120	6.2	4.1	273	11.4	110
3211	450	5.8	113	6.6	5.4	113	6.1	5
3212	472	5.4	158	8.6	3.7	193	7.2	7
3213	482	5.1	113	5.8	3.4	125	4.4	7
3214	503	4.7	135	6.3	3.2	125	3.9	7
3215	520	6.0	65	4.0	4.0	205	8.2	5
3216	552	5.6	130	7.3	4.5	85	3.9	10
3217	562	4.6	113	5.2	3.0	103	3.2	10
3218	585	5.1	125	6.4	3.6	83	3.0	5
3219	600	5.4	125	6.9	3.8	120	6.9	5

Table lV.13

Copper content of *Acacia mellifera* and *Boscia albitrunca*, leaves and twigs, collected on Transect 55, Copper Causeway. 10/1/70.

Acacia mellifera		LEAVES			TWIGS			SOIL
Sample No.	Distance m.N	% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry	-80 mesh
3168	26	7.8	78	6.2	6.1	105	6.5	10
3169	45	7.0	78	5.5	3.3	83	2.7	10
3170	57	6.8	78	5.4	4.6	88	4.1	14
3171	74	8.1	103	8.4	4.1	95	3.9	16
3172	105	8.7	100	8.7	5.3	95	5.1	20
3173	155	8.6	78	6.7	3.9	98	3.9	20
3174	168	7.0	63	4.4	5.2	63	3.3	18
3175	210	8.7	78	6.8	4.2	88	3.7	143
3176	220	8.3	100	8.3	5.5	168	9.2	227
3177	249	8.4	55	4.6	4.1	60	2.5	210
3178	281	8.0	85	6.8	4.3	90	3.9	120
3179	290	7.1	115	8.3	4.1	165	6.9	107
3180	305	7.7	110	8.5	3.8	145	5.6	120
3181	317	8.7	95	8.3	3.9	93	3.7	232
3182	333	6.9	143	10.0	3.7	230	8.7	170
3183	370	7.3	98	7.2	4.3	153	6.7	80
3184	405	7.6	80	6.1	5.0	215	10.8	95
3185	419	8.1	78	6.3	4.9	108	5.4	37
3186	448	9.3	78	7.3	4.7	135	6.4	5
3187	458	8.7	120	10.5	4.5	130	6.0	5
3188	593	5.4	80	4.1	3.9	98	3.8	5
Boscia albitrunca								
3220	14	7.0	78	5.5	4.0	58	2.4	10
3221	70	9.6	85	8.2	4.3	93	4.0	15
3222	108	9.0	85	7.7	3.4	128	4.4	17
3223	111	10.6	90	9.5	3.8	135	5.2	15
3224	146	7.8	120	9.4	3.4	95	3.3	30
3225	202	8.0	125	10.1	3.7	125	4.7	84
3226	226	7.6	175	13.4	3.1	268	8.3	250
3227	331	8.0	113	9.1	3.3	148	5.0	250
3228	376	8.9	130	11.6	4.0	135	5.4	92
3229	402	8.7	120	10.4	4.2	125	5.3	120
3230	420	9.3	93	8.7	2.8	108	3.1	37
3231	435	8.2	85	7.0	3.3	95	3.2	6

Table lV.14

Copper content of Tarchonanthus camphoratus, leaves and twigs, collected on Transect 55, Copper Causeway. 11/1/70.

Sample No.	Distance m.N.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
3100	30	7.7	230	17.7	3.7	195	7.4	10
3101	45	6.9	328	22.8	2.6	198	5.3	10
3102	60	6.7	290	19.6	3.3	180	6.0	15
3103	154	7.6	218	16.7	3.6	190	6.8	21
3104	176	7.8	305	23.9	4.1	168	7.0	26
3105	204	9.0	205	18.6	3.6	163	5.9	105
3106	240	8.4	278	23.4	4.1	305	12.6	217
3107	246	7.8	310	24.4	3.2	278	9.2	212
3108	252	8.3	315	26.4	4.0	253	10.2	212
3109	260	7.6	223	17.2	3.5	260	9.2	222
3110	268	7.1	340	24.3	2.8	260	7.4	200
3111	279	8.4	210	17.8	3.4	210	7.3	130
3112	314	7.6	328	25.2	3.1	210	6.7	190
3113	319	8.7	295	25.8	3.4	273	9.4	200
3114	330	8.8	410	36.5	3.1	350	10.9	260
3115	339	6.9	365	25.5	3.1	260	8.2	150
3116	349	7.1	275	19.8	3.0	250	7.7	250
3117	362	8.1	175	14.2	3.1	150	4.8	200
3118	392	7.7	388	30.2	3.5	168	6.0	210
3119	401	8.2	365	29.9	3.7	238	9.0	125
3120	411	7.5	223	16.8	3.5	155	5.5	52
3121	436	8.2	195	16.1	3.9	173	6.8	6
3122	450	6.7	228	15.3	2.8	190	5.4	5
3123	464	7.7	200	15.6	4.3	130	5.6	6
3124	476	7.1	115	8.3	3.7	115	4.3	7
3125	490	7.6	180	13.8	3.4	120	4.1	7
3126	516	7.9	208	16.6	3.6	163	6.0	6
3127	552	7.5	200	15.1	3.3	155	5.2	10
3128	573	7.4	190	14.1	3.2	120	3.9	5
3129	584	7.6	185	14.1	4.0	130	5.2	6

Table lV.15

Copper content of Phaeoptilum spinosum, leaves and twigs, collected on Transect 55, Copper Causeway. 12/1/70.

		LEAVES			TWIGS			SOIL
Sample No.	Distance m.N	% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry	-80 mesh
3130	10	9.1	45	4.1	5.6	35	2.0	5
3131	27	10.7	40	4.3	3.7	55	2.0	10
3132	50	15.7	50	7.9	4.7	95	4.5	10
3133	70	11.1	65	7.2	3.8	118	4.6	15
3134	102	10.0	80	8.0	4.6	75	3.5	20
3135	114	13.8	35	4.8	4.5	83	3.8	12
3136	130	10.2	65	6.6	3.6	120	4.4	18
3137	143	11.3	43	4.8	4.0	115	4.7	35
3138	159	8.5	100	8.5	3.2	145	4.8	18
3139	182	12.8	190	11.7	4.5	150	6.9	40
3140	195	10.4	82	8.7	3.9	237	9.3	72
3141	210	10.9	160	17.5	3.4	270	9.2	143
3142	218	10.9	150	16.4	3.9	300	11.8	205
3143	228	13.6	140	19.1	3.7	233	8.8	262
3144	243	11.1	213	23.7	4.6	275	12.8	215
3145	255	10.3	288	29.7	3.3	293	9.8	216
3146	264	13.3	225	30.0	4.0	293	11.8	210
3147	278	15.2	243	37.1	4.2	410	17.4	130
3148	294	9.5	310	29.6	3.8	270	10.3	105
3149	320	11.0	158	17.4	4.2	273	11.7	182
3150	320	10.8	183	19.8	3.2	340	11.0	182
3151	342	10.3	240	24.8	2.9	343	10.0	180
3152	349	11.6	293	34.1	3.2	350	11.4	250
3153	375	8.9	158	14.1	3.6	275	10.0	90
3154	385	11.1	198	22.1	1.9	300	6.0	150
3155	401	11.3	215	24.4	4.5	225	10.2	130
3156	410	11.1	155	17.5	3.9	265	10.4	57
3157	426	12.5	80	10.1	3.5	165	5.9	15
3158	449	12.8	78	10.0	4.2	215	9.1	5
3159	459	12.3	43	5.2	5.3	43	2.3	7
3160	477	13.1	35	4.6	6.5	55	3.6	7
3161	487	11.0	50	5.5	5.2	55	2.9	7
3162	503	13.3	63	8.4	5.1	78	4.0	7
3163	538	11.9	70	8.4	5.3	133	7.0	8
3164	549	12.8	120	15.4	6.2	83	5.2	10
3165	575	10.7	80	8.6	4.5	100	4.5	5
3166	587	11.8	83	9.9	4.9	100	4.9	6
3167	597	11.0	95	10.5	3.5	178	6.4	5

Table lV.16

Copper content of the shrub species Dichrostachys cinerea, Ziziphus mucronata, Lycium lancifolium, Rhus pyroides and Ehretia rigida, for samples collected on Transect 55, Copper Causeway. 16/1/70.

Species	Sample No.	Distance m.N	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
Dichrostachys cinerea	3264	47	5.1	178	9.0	3.2	103	3.3	10
	3265	66	7.3	93	6.8	4.0	93	3.7	15
	3266	257	6.0	175	10.6	3.6	125	4.5	215
	3267	263	5.6	220	12.4	3.0	175	5.3	210
	3269	311	6.1	170	10.3	3.5	165	5.7	155
	3270	314	5.0	195	9.8	2.7	160	4.2	190
	3271	398	6.2	210	13.1	3.7	250	9.1	169
	3272	408	6.6	153	10.1	3.2	148	4.7	70
	3273	447	6.3	143	9.0	4.4	122	5.4	5
	3274	458	6.3	128	8.1	4.7	85	4.0	5
Ziziphus mucronata	3275	557	12.4	45	5.6	3.6	78	2.8	10
	3276	540	9.8	60	5.9	4.3	103	4.4	10
	3277	463	8.4	53	4.5	3.8	93	3.5	6
	3278	381	8.6	60	5.1	3.8	95	3.6	120
	3279	290	9.4	70	6.6	4.3	83	3.5	107
	3280	256	8.8	60	5.3	2.9	95	2.8	215
	3281	218	8.8	70	6.2	2.5	108	2.7	200
	3282	158	8.4	65	5.5	4.5	45	3.0	19
	3283	101	10.9	45	4.9	6.6	48	3.2	20
	3284	70	9.7	55	5.3	4.8	58	2.8	15
	3285	38	8.3	70	5.8	3.2	138	4.4	10
Lycium lancifolium	4835	590	14.6	97	14.2	4.6	187	8.5	7
	4836	480	14.9	100	14.9	4.3	162	7.0	7
	4841	320	19.3	125	24.2	4.5	240	10.8	182
	4844	250	17.6	182	32.0	3.7	265	9.9	210
	4847	190	17.5	145	25.3	5.9	187	11.0	77
	4849	102	17.7	75	13.3	4.9	205	10.1	20
	4850	85	13.2	102	13.5	5.5	145	7.9	18
	4851	70	17.1	95	16.3	4.7	172	8.0	15
	4852	20	19.7	65	12.8	4.7	205	9.7	10
Rhus pyroides	4836	560	7.3	110	8.0	4.1	100	4.1	10
	4837	490	9.3	130	12.0	4.1	97	4.0	7
	4840	350	7.9	247	19.5	4.7	115	5.3	225
	4842	322	8.5	295	25.2	5.0	192	9.6	160
	4843	280	11.2	155	17.1	5.0	130	6.4	120
Ehretia rigida	4839	375	10.2	140	14.3	5.4	182	9.8	90
	4845	226	9.8	247	24.2	4.1	285	11.5	240
	4846	220	10.9	178	19.3	4.5	215	9.6	277
	4848	103	8.4	125	10.4	4.2	265	11.2	20

Table lV.17

Copper content of Stipagrostis uniplumis samples collected on Transect 55, Copper Causeway. 14/1/70

Sample No	Distance m.N	% ash	ppm ash	ppm dry	Sample No.	Distance m.N	% ash	ppm ash	ppm dry
3395	0	5.7	55	3.2	3433	315	6.1	138	8.5
3396	10	6.6	35	2.3	3434	317	5.6	185	10 4
3397	20	7.8	38	3.0	3435	320	5.9	143	8.5
3398	28	7.4	35	2.6	3436	325	5.9	80	4.8
3399	32	5.6	43	2.4	3437	330	5.9	135	8.1
3400	52	7.6	33	2.5	3438	335	5.7	148	8.5
3401	62	6.1	68	4.2	3439	340	6.3	178	11.4
3402	71	6.7	65	4.4	3440	347	6.3	215	13.7
3403	80	6.5	58	3.8	3441	351	6.2	185	11.5
3404	90	5.9	45	2.7	3442	355	6.4	288	18.6
3405	99	7.9	48	3.8	3443	362	5.3	165	8.9
3406	110	6.2	55	3.4	3444	365	5.3	118	6.3
3407	118	6.0	43	2.6	3445	370	5.1	123	6.4
3408	130	7.0	50	3.5	3446	375	5.4	140	7.7
3409	140	6.7	60	4.0	3447	385	6.0	153	9.3
3410	150	6.3	65	4.1	3448	390	5.7	148	8.6
3411	160	5.0	90	4.5	3449	395	6.2	170	10.6
3412	170	4.5	70	3.2	3450	400	4.3	180	7.8
3413	180	5.9	75	4.5	3451	410	6.7	78	5.2
3414	190	8.6	65	5.6	3452	420	6.9	80	5.6
3415	200	5.6	85	4.8	3453	430	5.8	70	4.1
3416	212	10.7	90	9.7	3454	440	5.8	50	2.9
3417	222	7.1	218	15.6	3455	450	6.5	35	2.3
3418	225	8.9	103	9.2	3456	460	5.9	25	1.5
3419	230	8.3	248	20.8	3457	470	6.2	25	1.6
3420	235	6.6	138	9.2	3458	480	6.1	35	2 2
3421	240	7.5	120	9.0	3459	490	5 8	35	2.0
3422	245	5 9	180	10.6	3460	500	4.8	55	2.6
3423	248	7.6	215	16.5	3461	510	6.0	53	3.2
3424	257	6.4	130	8.4	3462	520	5.4	63	3 5
3425	259	6.0	130	7.8	3463	530	5.9	38	2.2
3426	265	7.1	115	8.2	3464	540	5.3	40	2.1
3427	270	8.5	110	9.4	3465	550	5.9	53	3.1
3428	274	5.4	133	7.2	3466	560	4.7	53	2.5
3429	280	5.5	138	7.6	3467	570	6.2	48	3.0
3430	290	7.0	128	9.0	3468	580	6.0	55	3.3
3431	300	5 6	75	4.3	3469	590	6.2	48	3.0
3432	310	5.4	103	5.6	3470	600	5.9	58	3.4

Table lV.18

Copper content of *Aristida congesta* samples collected on Transect 55, Copper Causeway. 14/1/70.

Sample No.	Distance m.N	% ash	ppm ash	ppm dry	SOIL -80 mesh
3471	591	7.3	20	1.5	7
3472	584	5.0	35	1.8	5
3473	571	4.9	35	1 7	5
3474	560	4 2	35	1.5	10
3475	545	4.0	37	1.5	10
3476	495	5 4	28	1.5	7
3477	385	5.2	117	6.2	150
3478	355	5 7	77	4.4	135
3479	348	4.0	77	3.1	235
3480	342	4.0	135	5.4	235
3481	335	4.7	60	2.9	122
3482	330	4.0	111	4.5	260
3483	317	5.2	65	3.4	232
3484	280	5.3	49	2.6	120
3485	275	5.4	72	3.9	152
3486	270	5.3	55	3.0	195
3487	265	5.6	46	2.6	205
3488	260	6.0	43	2.6	222
3489	255	6.3	37	2.4	215
3490	250	6.4	43	2.8	210
3491	245	6.0	43	2.6	215
3492	240	6.1	43	2.7	217
3493	235	5.4	67	3.6	240
3494	230	4.5	82	3.7	272
3495	215	6.4	49	3.1	180
3496	210	4.6	28	1.3	143
3497	138	7.6	28	2.1	36
3498	100	6.9	25	1.7	22
3499	80	5.1	37	1.9	18
3500	70	5.2	32	1.7	15
3501	63	5.9	35	2.1	15
3502	50	5.8	28	1.6	10
3503	42	5.5	35	1.9	10
3504	20	8.0	25	2.0	10

Table lV.19

Copper content of Stipagrostis uniplumis samples collected on Transect 74, Copper Causeway. 3/2/70.

Sample No.	Distance m.N	% ash	ppm ash	ppm dry	Sample No.	Distance m N	% ash	ppm ash	ppm dry
5001	0	25	2.1	8.5	5033	320	92	8.2	8.9
5002	8	35	2.3	6.5	5034	330	65	4.2	6.3
5003	30	32	3.6	11.2	5035	340	37	2.6	6.9
5004	50	35	2.6	7.5	5036	350	55	3.7	6.8
5005	60	22	1.9	8.6	5037	360	62	4.6	7.3
5006	70	15	1.2	7.7	5038	370	62	4.0	6.4
5007	80	25	2.2	8.7	5039	380	75	5.5	7.3
5008	90	25	2.1	8.5	5040	390	47	3.2	6.7
5009	100	32	2.1	6.6	5041	400	80	9.2	11.5
5010	110	27	2.3	8.3	5042	410	67	4.8	7.1
5011	120	18	1.8	10.4	5043	415	67	4.5	6.7
5012	130	25	2.6	10.3	5044	420	117	6.7	5.7
5013	140	25	2.2	8.7	5045	425	57	3.3	7.5
5014	150	32	2.4	7.5	5046	430	87	6.3	7.2
5015	160	27	2.6	9.5	5047	440	25	2.7	10.9
5016	170	20	2.6	13.2	5048	450	37	3.0	8.1
5017	180	25	2.0	8.0	5049	460	25	1.8	7.2
5018	190	42	2.7	6.0	5050	470	57	3.4	6.0
5019	200	35	3.5	9.9	5051	480	32	2.2	6.9
5020	210	62	7.0	11.3	5052	490	57	2.9	5.0
5021	220	82	7.0	8.5	5053	500	47	3.2	6.7
5022	230	70	5.8	8.3	5054	510	72	4.1	5.6
5023	240	125	7.2	5.7	5055	520	50	2.9	5.8
5024	245	125	6.4	5.1	5056	530	62	3.6	5.7
5025	250	137	8.3	6.0	5057	590	35	2.2	6.3
5026	260	120	6.8	5.6	5058	550	32	1.8	5.1
5027	265	142	10.3	7.2	5059	560	18	1.1	6.1
5028	270	220	14.8	6.7	5060	570	22	1.6	7.2
5029	280	105	6.8	6.4	5061	580	15	1.0	6.9
5030	290	125	12.6	10.0	5062	590	20	1.3	6.3
5031	300	110	11.1	10.0	5063	600	28	2.4	8.5
5032	310	60	14.1	6.9					

Table lV.20

Copper content of <u>Stipagrostis uniplumis</u> collected on Transect 76, Copper Causeway, 3/2/70.

Sample No.	Distance m.N	% ash	ppm ash	ppm dry	Sample No.	Distance m.N	% ash	ppm ash	ppm dry
5065	590	7.5	40	3.0	5095	273	9.2	18	1.7
5066	580	6.5	42	2.7	5096	268	7.1	32	2.3
5067	570	7.7	95	7.4	5097	260	5.7	35	2.0
5068	560	6.2	102	6.4	5098	250	8.3	18	1.5
5069	550	6.4	75	4.8	5099	240	7.0	35	2.5
5070	540	6.3	60	3.8	5100	230	8.1	20	1.6
5071	530	5.8	60	3.5	5101	225	7.1	18	1.3
5072	520	5.2	62	3.4	5102	215	7.7	28	2.2
5073	510	5.6	47	2.7	5103	210	6.4	35	2.3
5074	500	7.2	37	2.7	5104	200	7.8	20	1.6
5075	490	6.8	42	2.9	5105	190	6.5	47	3.1
5076	480	6.0	60	3.6	5106	180	7.2	27	2.0
5077	470	7.0	42	2.9	5107	170	8.0	42	3.4
5078	460	9.0	25	2.3	5108	160	5.8	42	2.5
5079	450	6.3	35	2.2	5109	150	7.1	32	2.3
5080	440	6.4	102	6.6	5110	140	7.2	47	3.4
5081	430	6.8	55	3.8	5111	130	6.0	67	4.0
5082	420	6.9	55	3.8	5112	120	6.9	32	2.2
5083	410	6.5	47	3.1	5113	110	8.0	50	4.0
5084	400	5.6	45	2.5	5114	100	6.2	35	2.2
5085	390	7.3	65	4.8	5115	90	5.9	47	2.8
5086	380	6.9	25	1.7	5116	80	5.9	50	3.0
5087	370	7.7	47	3.6	5117	70	6.3	75	4.8
5088	360	7.2	47	3.4	5118	60	6.9	82	5.7
5089	350	6.8	92	6.3	5119	50	5.7	32	1.8
5090	340	6.9	62	4.3	5120	40	5.8	35	2.0
5091	330	7.3	42	3.1	5121	30	8.1	35	2.8
5092	320	7.4	57	4.3	5122	20	7.8	47	3.4
5093	310	8.1	35	2.8	5123	0	7.7	32	2.7
5094	300	6.3	25	1.6					

Table 1V.21

Copper content of Grewia flava leaves collected on Transect 76, Copper Causeway 3/2/70.

Sample No.	Distance m.N	% ash	ppm ash	ppm dry	Sample No	Distance m N	% ash	ppm ash	ppm dry
5124	00	7.1	165	11.8	5153	300	6.7	212	14.3
5125	20	7.4	152	11.2	5154	305	7.5	307	23.0
5126	30	8.1	172	14.0	5155	315	7.5	175	13.3
5127	40	7.9	170	13.6	5156	330	7.4	242	18.0
5128	50	7.1	165	11.9	5157	345	7.3	140	10.3
5129	60	7.9	155	12.3	5158	360	6.4	247	15.9
5130	70	8.3	130	10.9	5159	375	6.5	220	14.4
5131	80	8.1	152	12.4	5160	390	6.9	197	13.6
5132	95	7.8	147	11.5	5161	410	6.1	212	13.0
5133	100	6.7	170	11.4	5162	415	7.5	217	16.4
5134	110	8.6	130	11.3	5163	430	6.5	165	10.7
5135	120	7.6	120	9.2	5164	440	7.5	240	18.1
5136	130	7.3	185	13.6	5165	450	8.1	175	14.2
5137	145	6.6	207	13.8	5166	460	7.6	240	18.4
5138	150	7.3	120	8.8	5167	470	7.1	257	18.2
5139	160	9.1	112	10.3	5168	480	7.4	202	15.0
5140	170	8.3	115	9.5	5169	495	6.5	287	18.8
5141	180	6.9	165	11.5	5170	500	8.1	202	16.4
5142	190	7.5	115	8.9	5171	508	7.0	310	21.7
5143	200	8.6	142	12.3	5172	520	7.1	240	17.2
5144	215	7.5	222	16.8	5173	540	7.2	207	14.9
5145	220	6.8	152	10.5	5174	547	6.2	230	14.4
5146	230	5.2	192	11.9	5175	555	7.3	325	23.7
5147	240	8.2	170	14.1	5176	560	5.9	267	15.9
5148	247	7.4	217	16.2	5177	565	6.3	337	21.3
5149	253	7.6	150	11.1	5178	580	6.5	227	18.2
5150	260	8.2	202	16.7	5179	600	9.0	220	19.9
5151	280	7.1	257	18.4	5180	575	6.9	400	27.8
5152	290	8.4	222	18.1					

Table 1V 22

Copper content of Stipagrostis uniplumis samples from Transect 56-59, Copper Causeway.

	Distance m.N	ppm Copper S.uniplumis Dry wt.	Soil -80 mesh
Tr. 56	0	8.6	140
	5	7.6	127
	10	5.8	110
	15	3.4	134
	20	7.2	164
	25	6.1	191
	30	16.1	366
	35	7.4	162
	40	9.5	117
	45	7.3	117
	50	5.7	107
Tr. 57	0	3.1	120
	5	5.8	89
	10	6.8	90
	15	7.8	66
	20	2.9	80
	25	8.4	96
	30	9.3	140
	35	5.3	92
	40	3.3	45
	45	4.4	29
	50	5.5	14
	55	4.3	10
	60	5.0	12
Tr. 58	0	3.6	32
	5	4.3	40
	10	6.1	67
	15	5.2	68
	20	6.7	96
	25	7.0	93
	30	8.3	152
	35	14.1	310
	40	16.1	313
	45	30.3	464
	57	3.3	88
	62	3.7	62
	77	2.0	40
	80	3.9	42
Tr. 59	0	6.5	39
	5	6.1	58
	10	5.0	90
	15	4.1	98
	20	5.2	96
	25	5.5	75
	30	8.0	90
	35	7.2	152
	40	13.5	210
	50	6.9	107
	55	8.2	192
	65	6.9	89
	70	5.1	91
	75	6.0	116

Table lV.23

Copper content of Grewia flava samples from Transect 57, 58 and 59 Copper Causeway.

	Distance m.N	ppm Copper Leaves Dry wt.	Twigs Dry wt.	Soil -80 mesh
Tr. 57	6	20.1	5.8	90
	10	20.0	8.6	90
	22	16.0	7.5	85
	30	16.7	6.5	140
	33	24.9	6.6	112
	40	12.7	5.8	45
	47	14.9	5.3	24
	50	17.0	5.2	14
	59	11.4	5.3	12
Tr. 58	0	16.6	4.7	32
	5	21.0	4.6	40
	10	21.3	7.7	67
	20	15.9	3.9	96
	30	21.1	5.5	152
	45	26.8	9.4	460
	48	21.2	5.0	200
	64	10.2	3.5	60
	78	16.4	5.4	41
Tr. 59	0	12.4	5.4	39
	5	12.3	4.9	58
	16	13.2	7.7	98
	26	15.7	6.3	80
	45	12.3	8.0	275
	49	39.7	10.7	150
	58	30.3	9.1	165
	71	29.5	11.5	95
	75	31.3	11.7	116
	79	31.0	12.6	200

Table lV.24

Copper contentof <u>Phaeoptilum spinosum</u> from Transects 57, 58 and 59, Copper Causeway.

	Distance m.N	ppm. Copper Leaves Dry wt.	Twigs Dry wt.	Soil -80 mesh
Tr. 57	0	31.8	16.9	120
	12	17.3	16.0	82
	22	40.1	16.8	88
	38	10.6	15.1	62
	48	7.8	10.1	20
	60	3.4	6.0	12
Tr. 58	2	5.6	7.0	34
	14	11.4	10.2	67
	32	39.1	18.1	205
	42	38.6	18.1	350
	48	25.4	9.7	212
	63	21.0	8.7	60
	70	19.2	11.9	46
Tr. 59	0	10.3	8.8	39
	6	10.0	9.5	65
	16	10.8	9.7	98
	25	24.7	12.3	75
	80	110.4	21.0	205

Table lV.25

Copper content of <u>Acacia hereroensis</u> from Transects 57, 58 and 59 Copper Causeway

	Distance m N.	ppm Copper Leaves Dry wt.	Twigs Dry wt.	Soil -80 mesh
Tr. 57	30	11.5	11.4	147
	40	5.0	2.9	45
	59	5.5	5.3	59
Tr. 58	35	7.8	8.5	306
	41	16.5	16.5	350
	48	7.3	5.1	250
	63	7.0	6.1	58
	80	5.0	3.6	42
Tr. 59	0	6.3	5.0	39
	38	10.6	8.9	180
	45	6.5	9.0	275
	58	16.3	12.8	165
	68	30.3	16.3	90
	80	15.3	11.2	205

Table 1V.26

Copper content of the shrub species Acacia mellifera, Boscia albitrunca, Lycium lancifolium, Rhus pyroides, Tarchonanthus camphoratus, Ziziphus mucronata for samples collected on Transects 57, 58 and 59 Copper Causeway.

	Distance m.N	ppm. Copper Leaves Dry wt.	Twigs Dry wt.	Soil -80 mesh
A. mellifera				
Tr. 57	4	15.6	7.8	89
	15	7.1	3.4	66
	25	7.1	4.6	96
	29	9.3	4.1	140
	30	13.6	8.4	140
	50	7.8	3.3	14
B. albitrunca				
Tr. 59	59	11.6	7.2	155
L. lancifolium				
Tr. 57	40	27.8	10.0	45
Tr. 58	14	12.0	8.2	65
	51	26.0	4.0	140
	57	34.8	3.9	85
R. pyroides				
Tr. 58	44	21.0	4.6	400
	70	9.2	5.5	46
T. camphoratus				
Tr. 57	10	17.3	6.1	90
	17	15.8	7.8	70
	27	27.2	8.8	120
	32	24.9	5.5	125
	41	17.9	6.1	42
	47	18.6	6.1	22
	60	18.4	5.7	12
Tr. 59	0	15.1	6.2	39
	45	31.9	6.3	275
	75	32.7	6.8	116
Z. mucronata				
Tr. 57	37	4.7	2.7	84
Tr. 58	30	5.8	6.2	152
Tr. 59	21	5.3	3.6	90

Table IV.27

Copper content of Acacia hereroensis, leaves and twigs collected on Transect 48, Malachite Pan. 29/1/70

Sample No.	Distance m.N/m.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
4651	7	6.3	95	6.0	3.7	120	4.5	155
4652	7	5.8	136	8.0	5.0	151	7.6	155
4653	33	5.4	197	10.6	3.8	202	7.7	300
4654	36	6.0	141	8.6	4.9	156	7.8	215
4655	42	5.4	130	7.1	3.3	151	5.0	200
4656	100	5.3	125	6.7	2.6	166	4.4	100
4657	108	4.9	125	6.2	3.4	156	5.3	130
4658	134	7.0	125	8.8	4.9	136	7.0	94
4659	146	6.0	89	5.4	3.7	120	4.5	110
4660	155	6.4	125	8.0	4.3	156	6.7	130
4661	180	6.3	146	9.2	4.1	251	10.3	195
4662	182	4.8	161	7.8	4.5	173	7.8	180
4663	190	5.1	238	12.2	3.9	213	8.4	115
4664	195	6.3	156	9.9	4.1	187	7.7	195
4665	200	5.3	278	14.8	4.3	343	18.6	260
4666	205	5.6	187	10.5	3.3	173	5.7	155
4667	233	6.0	156	9.5	3.5	208	7.3	190
4668	240	4.5	182	8.2	3.2	125	4.0	155
4669	253	4.9	187	9.2	3.2	242	7.8	260
4670	258	4.8	141	6.8	2.6	166	4.4	210
4671	270	6.1	365	22.3	4.2	438	18.5	180
4672	275	5.0	338	16.9	2.6	431	11.3	215
4673	290	5.2	110	5.8	3.4	182	6.2	150
4674	306	5.3	348	18.5	3.8	256	9.8	75
4675	317	4.8	125	6.0	3.5	125	4.4	90
4676	330	5.8	78	4.5	4.0	74	3.0	65
4677	340	5.0	156	7.8	4.2	105	4.4	65
4678	365	5.9	110	6.5	4.1	125	5.2	100
4679	380	6.3	90	5.7	4.5	185	8.4	170
4580	393	6.1	87	5.4	4.7	90	4.3	105
4681	403	7.1	97	7.0	4.9	90	4.5	110
4682	415	5.2	77	4.1	3.4	82	2.8	110
4683	425	6.0	117	7.0	3.6	205	7.4	110
4684	440	6.1	115	7.0	4.3	157	6.9	90
4685	452	5.3	117	6.2	3.4	145	5.0	102
4686	462	6.3	137	8.7	5.2	42	2.2	120
4687	483	6.7	82	5.6	4.3	120	5.2	116
4688	500	7.3	120	8.9	4.3	195	8.4	70

Table IV.28

Copper content of *Grewia flava*, leaves and twigs collected on Transect 48, Malachite Pan. 29/1/70.

Sample No.	Distance m.N./m.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
4689	498	8.3	152	12.6	4.2	157	6.8	75
4690	488	8.4	185	15.6	3.5	145	5.1	105
4691	475	8.9	172	15.3	4.9	147	7.3	130
4692	460	7.8	232	18.1	4.4	130	5.7	115
4693	440	8.1	220	17.9	3.9	170	6.7	90
4694	425	8.1	177	14.4	4.2	165	7.1	110
4695	415	8.8	182	16.0	3.6	117	4.3	110
4696	405	9.2	190	17.6	3.7	155	5.7	110
4697	395	8.9	130	11.6	4.3	145	6.3	107
4698	380	8.5	187	16.0	3.6	125	4.5	170
4699	365	8.7	160	14.0	4.5	187	8.4	100
4700	353	8.2	235	19.3	3.9	102	4.0	85
4701	340	7.5	215	16.1	3.4	160	5.5	65
4702	330	7.7	295	22.8	3.5	195	7.0	65
4703	317	7.8	280	22.0	4.0	130	5.3	84
4704	306	8.2	160	13.2	3.7	137	5.1	80
4705	290	9.0	217	19.7	3.8	112	4.3	150
4706	276	9.5	247	23.5	5.0	190	9.5	225
4707	245	8.4	320	26.9	3.3	317	9.6	185
4708	240	8.5	437	37.1	4.5	345	15.6	155
4709	230	8.4	500	42.1	3.6	235	8.5	210
4710	216	7.8	290	22.7	3.8	200	7.7	145
4711	207	8.2	287	23.6	3.9	190	7.5	146
4712		No Sample						
4713	166	8.6	225	19.5	3.9	130	5.2	160
4714	142	7.7	262	20.4	4.1	262	10.9	103
4715	95	8.3	237	19.7	3.7	130	4.8	102
4716	60	7.7	410	31.6	3.8	190	7.4	300
4717	35	9.7	375	36.4	5.2	280	14.7	205
4718	30	10.0	277	27.7	3.9	245	9.6	300
4719	15	9.2	370	34.0	4.5	332	15.1	163

Table IV.29

Copper content of *Rhus pyroides*, leaves and twigs collected on Transect 48, Malachite Pan. 29/1/70.

Sample	Distance	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
4720	3	8.6	147	12.7	4.9	77	3.8	152
4721	12	7.6	197	15.0	4.4	165	7.3	162
4722		No Sample						
4723	55	11.0	190	20.9	5.1	180	9.3	300
4724	70	8.0	275	22.1	5.0	222	11.2	237
4725	85	8.5	155	13.2	6.1	142	8.8	130
4726	102	8.5	157	13.4	4.5	95	4.3	112
4727	112	7.6	110	8.4	3.7	92	3.5	130
4728	120	9.1	117	10.7	4.7	87	4.2	100
4729	132	6.6	110	7.4	5.0	60	3.1	92
4730	146	7.7	147	11.4	3.9	120	4.7	111
4731	153	7.3	165	12.2	5.0	87	4.4	125
4732	164	7.7	157	12.2	4.1	157	6.5	162
4733	180	7.6	185	14.1	4.5	175	7.9	195
4734	190	6.6	230	15.3	3.1	207	6.4	115
4735	200	9.3	320	30.0	3.5	170	6.0	260
4736	206	8.2	290	24.0	4.2	235	9.9	150
4737	222	6.2	212	13.3	3.3	247	8.3	165
4738	242	6.5	310	20.3	2.9	147	4.0	172
4739	246	5.4	340	18.5	3.0	110	3.3	190
4740	260	7.3	267	19.7	3.3	122	4.0	180
4741	276	5.7	232	13.4	3.6	190	6.9	220
4742	285	6.4	157	10.1	4.4	112	5.0	200
4743	294	7.5	175	13.0	4.6	137	6.3	135
4744	305	6.5	140	9.1	4.4	97	4.4	85
4745		No Sample						
4746	330	8.3	190	15.8	5.1	157	8.1	65
4747	340	8.0	157	12.7	5.8	82	4.8	65
4748	350	7.7	157	12.1	5.6	130	7.3	80
4749	360	7.9	182	14.5	5.4	112	6.1	90
4750		No Sample						
4751	380	6.0	175	10.6	3.6	142	9.0	170
4752	395	7.0	90	6.3	4.8	105	5.1	108
4753	405	7.6	152	11.5	5.7	77	4.5	108
4754	410	7.3	97	7.1	5.2	65	3.4	100
4755	420	9.6	122	11.7	5.9	97	4.9	115
4756	440	6.9	142	9.9	5.1	55	2.9	90
4757	450	7.1	152	10.8	4.2	157	6.6	100
4758	462	7.6	90	6.9	4.6	75	3.5	120
4759	480	6.9	115	8.0	4.3	115	5.0	125
4760	500	6.4	132	8.4	3.4	110	3.8	70

Table IV.30

Copper content of *Phaeoptilum spinosum*, leaves and twigs, collected on Transect 48, Malachite Pan. 2/2/70.

Sample No.	Distance m.N/m.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
4761	500	13.7	62	8.5	3.8	275	10.7	70
4762	492	18.2	32	5.8	3.8	165	6.4	95
4763	475	13.5	70	9.5	4.1	217	8.9	130
4764	465	13.3	65	8.7	3.1	345	10.8	125
4765	425	16.5	47	7.8	3.7	145	5.4	110
4766	420	15.4	32	4.9	4.1	265	10.9	115
4767	415	14.8	97	14.3	5.4	235	10.1	108
4768	400	13.8	102	14.1	3.9	320	12.7	115
4769	390	13.9	70	9.7	3.5	320	11.4	100
4770	380	12.0	115	13.9	3.6	247	9.1	170
4771	365	15.5	62	9.4	3.6	350	12.6	100
4772	350	15.7	65	10.2	2.8	427	12.1	80
4773	340	18.4	55	10.1	3.8	220	8.6	65
4474	310	17.2	82	14.2	3.7	180	6.8	65
4475	290	15.3	122	18.8	4.6	245	11.4	150
4476	285	11.8	230	27.3	3.6	380	13.8	200
4477	225	13.3	217	29.0	3.7	457	17.1	280
4478	215	11.9	257	30.8	3.3	462	15.4	142
4479	180	12.0	217	26.2	4.0	292	13.7	195
4780	160	18.5	120	22.2	4.6	280	13.0	140
4781	145	16.9	110	18.6	4.4	300	13.2	108
4782	122	25.7	60	15.4	5.2	307	16.0	98
4783	110	14.2	97	13.9	6.6	202	13.4	135
4784	90	15.6	190	29.5	4.1	300	12.3	105
4785	15	13.8	115	15.9	4.8	290	13.9	163

Table IV.30 A

Copper content of the shrub species Tarchonanthus camphoratus, Ehretia rigida, Lycium lancifolium, Ozoroa paniculosa and Ziziphus mucronata for samples collected on Transect 48, Malachite Pan. 20/2/70.

		LEAVES			TWIGS			SOIL
Sample No.	Distance m.N	% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry	-80 mesh
Tarchonanthus camphoratus								
4786	35	8.17	442	34.4	3.92	300	11.8	205
4788	85	6.06	410	24.6	3.41	300	10.2	130
4790	160	7.11	490	34.8	3.61	180	6.5	140
4791	175	7.22	202	14.6	2.85	375	10.1	190
4792	200	8.63	395	33.4	3.36	395	13.3	200
4794	215	7.66	322	25.8	3.84	217	8.3	142
4796	235	6.92	420	29.2	3.12	290	9.0	180
4798	315	6.51	420	27.3	3.18	280	8.9	80
4799	330	7.12	400	28.5	3.41	212	7.2	65
4801	353	7.25	240	17.4	3.08	215	6.6	82
4802	385	7.62	245	18.7	2.86	255	7.3	135
4803	500	6.74	260	17.5	3.21	157	5.0	70
Ehretia rigida								
4787	80	12.44	130	16.2	5.49	210	11.1	130
4795	225	14.16	132	18.7	5.19	210	10.9	160
4800	335	10.04	92	9.2	5.54	217	9.9	70
Lycium lancifolium								
4789	135	14.95	245	36.6	3.80	265	10.1	140
4797	285	15.00	112	16.8	3.89	222	8.6	200
Ozoroa paniculosa								
4793	205	7.09	157	11.3	4.26	282	12.0	155
Ziziphus mucronata								
4804	500	8.88	45	4.0	3.23	105	3.4	70
4805	350	12.00	60	7.2	3.94	120	4.7	80
4806	290	9.35	57	5.3	3.08	165	5.1	150
4807	265	10.64	47	5.0	3.07	182	5.6	180

Table IV.31

Copper content of Grewia flava leaves and twigs, for samples collected on Transect 35, Malachite Pan. 20/1/70.

Sample No.	Location m.N/m.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
4019	19	8.8	177	10.4	4.3	165	7.1	15
3946	30	9.0	127	11.5	3.5	180	6.3	17
3947	37	8.4	177	14.9	4.0	180	7.3	16
3948	43	7.7	180	14.0	3.9	222	8.7	17
3949	52	9.5	167	15.9	4.3	250	10.9	16
3950	70	7.6	230	17.6	3.4	177	6.1	12
3951	79	8.4	250	21.1	4.6	162	7.6	32
3952	90	9.5	175	16.6	3.7	230	8.6	25
3953	100	8.8	165	14.6	5.2	165	8.7	37
3954	111	9.9	262	25.9	4.2	175	7.4	42
3955	133	8.8	255	22.6	4.1	165	6.8	32
3956	140	8.7	195	17.1	4.0	187	7.5	47
3957	145	8.3	195	16.3	4.8	195	9.5	41
3958	152	7.3	187	13.7	3.5	155	5.5	30
3959	170	8.9	175	15.6	5.0	132	6.6	17
3960	181	9.5	182	17.4	4.3	165	7.1	14
3961	192	7.3	165	12.1	3.3	152	5.1	10
3962	199	7.2	157	11.3	3.6	127	4.6	10
3963	215	8.9	190	16.9	3.8	105	4.0	10
3964	226	7.2	202	14.7	3.2	187	3.5	10
3965	240	7.2	182	13.2	3.7	162	6.1	10
3966	261	7.7	170	13.2	3.2	165	5.4	15
3967	282	7.1	197	14.0	3.0	187	5.8	19
3968	294	7.6	240	18.4	4.1	182	7.5	16
3969	308	8.1	280	22.9	3.8	157	6.1	17
3970	322	7.5	190	14.3	3.4	187	6.4	14
3971	340	8.3	142	11.8	3.9	117	4.6	10
3972	360	8.0	152	12.2	3.4	187	6.5	12
3973	370	7.8	215	16.9	3.3	157	5.2	15
3974	376	8.6	160	13.9	4.9	140	6.9	15
3975	390	8.7	242	21.1	3.4	210	7.3	12
3976	400	7.6	157	12.0	3.6	132	4.5	20
3977	412	7.9	167	13.2	3.2	155	5.1	28
3978	421	8.0	155	12.5	4.5	110	5.0	35
3979	433	8.0	177	14.3	4.7	142	6.8	62
3980	445	8.8	227	20.0	4.1	212	8.8	123
3981	450	8.8	305	26.9	4.1	222	9.1	170
3982	463	7.6	222	17.0	3.8	200	7.7	38
3983	470	8.2	177	14.6	3.9	155	6.1	22
3984	485	6.4	295	19.1	4.9	160	7.8	18
3985	502	7.5	215	16.3	4.2	132	5.6	7
3986	517	7.6	155	12.0	3.8	155	5.9	10
3987	528	7.9	157	12.4	3.5	170	6.1	5
3988	540	8.5	125	10.7	4.1	155	6.4	7
3989	550	9.4	120	11.4	3.6	185	6.8	5
3990	570	7.5	210	15.9	3.9	214	8.3	6
3991	584	7.1	262	18.8	3.9	117	4.4	10
3992	598	8.4	137	11.6	4.3	150	6.5	8
3993	614	8.4	100	8.4	4.3	100	4.3	7
3994	630	7.3	167	12.3	3.8	135	5.1	7
3995	648	8.1	180	14.7	3.5	167	6.0	7

Cont'd.

Table IV.31 cont'd

Sample No.	Location m.N/m.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
3996	660	7.8	187	14.8	4.0	105	4.3	7
3997	680	8.0	142	11.5	3.5	165	4.0	8
3998	695	8.4	117	9.9	3.8	135	5.2	7
3999	708	7.4	150	11.2	3.8	122	4.7	7
4000	722	6.7	220	14.8	3.1	155	4.9	5
4001	736	8.9	145	12.9	4.6	127	5.9	
4002	750	8.3	130	10.8	No	Sample		5
4003	767	7.2	165	12.0	3.5	105	3.7	
4004	778	7.0	170	12.0	3.1	122	3.8	5
4005	797	7.7	145	11.3	4.1	125	5.1	5
4006	812	7.6	150	11.5	2.9	145	4.3	5
4007	828	7.1	192	13.8	No	Sample		
4008	841	7.0	127	8.9	3.6	150	5.4	4
4009	862	8.2	150	12.3	3.9	130	5.1	4
4010	877	7.3	205	15.1	3.8	135	5.2	5
4011	894	7.7	167	12.6	3.7	125	4.7	8
4012	907	7.4	127	9.5	3.8	117	4.6	5
4013	926	7.7	167	12.9	3.9	150	5.9	5
4014	945	8.8	97	8.5	3.6	122	4.5	5
4015	960	7.0	175	12.3	3.6	130	4.8	5
4016	975	8.1	145	11.8	3.3	132	4.5	6
4017	990	7.2	180	13.0	3.4	182	6.2	5
4018	1000	8.5	117	9.9	4.4	102	4.6	5

Table IV.32

Copper content of *Phaeoptilon spinosum* leaves and twigs collected on Transect 35 Malachite Pan 20 /1/70

Sample No.	Location m.N/m.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
4233	7	12.3	42	5.2	3.0	140	4.3	25
4234	26	16.3	47	7.7	5.2	237	12.4	16
4235	46	17.3	37	6.4	4.0	147	6.0	18
4236	49	16.7	65	10.9	4.2	197	8.4	20
4237	73	13.2	75	9.9	3.6	235	8.6	20
4238	79	14.7	57	8.4	4.1	235	9.6	32
4239	90	18.9	82	15.5	3.6	302	10.9	25
4290	100	14.2	117	16.6	3.5	217	7.7	37
4291	116	13.4	97	13.0	3.3	260	8.7	40
4292	140	14.8	95	14.1	2.5	355	9.0	47
4293	145	14.5	72	10.4	4.4	185	8.3	40
4294	156	14.2	42	6.0	4.8	92	4.4	16
4295	168	14.9	35	5.2	4.6	147	6.8	17
4296	180	18.1	47	8.5	5.5	175	9.7	15
4297	190	13.3	60	8.0	4.1	215	8.9	10
4298	200	15.1	32	4.8	3.4	202	6.9	10
4299	212	13.4	47	6.3	4.2	120	5.1	10
4250	222	12.7	45	5.7	4.3	295	12.9	10
4251	232	14.5	35	5.1	3.6	175	6.4	10
4252	255	14.5	32	4.7	3.6	275	10.1	13
4253	270	12.6	37	4.7	3.8	182	7.0	10
4254	282	14.7	47	6.9	3.1	217	6.7	20
4255	300	11.5	110	12.8	4.0	337	13.8	17
4256	310	12.5	97	12.2	3.4	337	11.6	17
4257	329	12.7	132	16.8	3.4	130	4.4	10
4258	No Sample							
4259	355	10.7	62	6.7	6.3	137	8.7	12
4260	375	15.9	60	9.6	3.6	270	9.9	15
4261	387	14.1	55	7.8	5.1	180	9.2	14
4262	405	13.7	80	11.0	5.1	205	10.6	23
4263	414	12.7	60	7.6	3.5	235	8.3	29
4264	430	18.5	92	17.0	3.9	327	12.9	55
4265	454	17.0	105	17.9	4.9	405	20.0	116
4266	466	14.8	72	10.7	3.3	332	11.1	30
4267	479	16.3	60	9.8	5.8	262	15.4	25
4268	490	12.8	45	5.8	3.2	257	6.0	10
4269	500	15.9	105	16.7	4.0	290	11.7	7
4270	512	13.6	55	7.5	3.0	230	6.9	10
4271	530	16.2	47	7.6	4.6	202	9.5	7
4272	547	14.1	32	4.5	4.0	165	6.7	6
4273	567	19.3	20	3.9	3.4	195	6.7	7
4274	578	13.9	35	4.9	4.1	150	6.2	7
4275	592	12.2	32	3.9	3.0	140	4.3	7
4276	609	12.0	25	3.0	4.2	157	6.7	10
4277	632	13.0	30	3.9	3.1	185	5.8	7

Cont'd

Table IV.32 cont'd

Sample No.	Location m.N/m.	LEAVES			TWIGS			SOIL
		% ash	ppm dry	ppm ash	% ash	ppm ash	ppm dry	-80 mesh
4278	650	12.8	45	5.8	6.3	145	9.2	7
4279	660	15.5	57	8.9	3.8	230	8.8	7
4280	674	13.4	42	5.6	4.1	212	8.8	12
4281	688	12.3	60	7.4	4.6	212	9.8	10
4282	698	14.5	35	5.1	4.9	165	7.9	7
4283	725	14.3	50	7.2	4.1	167	6.9	6
4284	733	15.1	32	4.8	4.2	152	6.4	5
4285	750	11.8	42	5.9	4.6	185	8.5	5
4286	770	9.6	65	6.3	5.2	165	8.7	5
4287	785	14.0	35	4.9	4.5	152	6.8	5
4288	802	14.2	32	4.6	3.6	157	5.7	7
4289	812	12.2	42	5.2	3.9	197	7.9	5
4290	825	10.7	45	4.8	3.4	185	6.4	5
4291	842	13.1	47	6.2	3.8	170	6.5	5
4292	855	16.5	37	6.1	3.8	225	8.7	5
4293	872	14.3	55	7.9	4.8	127	6.2	5
4294	885	16.2	22	3.6	4.1	120	4.9	7
4295	898	15.8	47	7.4	3.4	295	10.0	5
4296	912	15.3	47	7.5	4.1	200	8.2	5
4297	930	13.5	45	6.1	4.6	180	8.3	7
4298	945	13.6	37	5.0	4.7	165	7.9	7
4299	970	13.1	45	5.9	3.6	117	4.2	5
4300	990	11.3	35	4.0	4.4	207	9.2	5

Table IV.33

Copper content of Acacia hereroensis leaves and twigs collected on Transect 35. 27/1/70

Sample No.	Location m.N/m.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
44448	11	7.2	120	8.7	4.3	195	8.4	25
4449	28	6.5	100	6.5	4.9	140	6.9	16
4450	50	5.5	150	8.4	4.9	125	6.1	20
4451	65	5.9	122	7.2	4.3	105	4.7	17
4452	80	6.9	70	4.9	4.5	120	5.4	32
4453	90	6.5	152	9.9	3.7	142	5.3	25
4454	111	6.7	97	6.5	4.1	120	4.9	37
4455	125	6.1	157	9.7	4.9	147	7.3	38
4456	142	6.7	92	6.2	4.1	145	6.0	45
4457	146	6.2	105	6.5	4.9	152	7.5	40
4458	170	5.7	110	6.3	3.8	112	4.3	17
4459	200	6.4	207	13.3	4.4	157	6.9	10
4460	220	7.4	117	8.7	4.0	150	6.0	10
4461	235	6.2	100	6.2	4.1	172	7.1	10
4462	250	7.2	175	12.7	4.0	120	4.9	10
4463	265	7.4	73	5.4	4.4	89	4.0	12
4464	270	6.1	100	6.2	3.4	110	3.8	10
4465	290	7.5	137	10.3	5.4	197	10.7	15
4466	315	6.2	120	7.5	3.9	120	4.7	17
4467	335	5.3	175	9.3	5.0	105	4.2	10
4468	360	4.4	110	4.9	3.9	120	4.7	12
4469	412	5.2	95	5.0	4.0	152	6.1	28
4470	440	6.1	78	4.8	3.0	83	2.5	70
4471	445	7.2	110	8.0	5.0	152	7.6	123
4472	460	5.7	105	6.0	4.7	95	4.5	45
4473	470	5.7	115	6.6	4.7	73	3.5	22
4474	500	4.7	95	4.5	4.0	135	5.5	7
4475	520	5.7	100	5.8	5.2	105	5.6	10
4476	530	6.1	115	7.0	3.3	95	3.2	7
4477	555	5.3	105	5.6	4.2	115	4.9	7
4478	580	5.6	73	4.1	4.4	110	4.9	5
4479	600	6.0	100	6.0	3.5	110	3.9	10
4480	630	5.5	89	4.9	4.4	110	4.9	7
4481	640	5.9	105	6.2	4.8	120	5.8	10
4482	665	5.3	115	6.1	3.5	140	4.9	10
4483	678	6.6	73	4.8	4.9	95	4.7	12
4484	700	5.9	89	5.3	4.7	105	5.0	7
4485	720	5.1	95	4.9	4.7	95	4.5	7
4486	750	4.8	89	4.3	3.2	105	3.4	5
4487	775	5.7	100	5.7	4.1	100	4.1	5
4488	795	6.7	78	5.3	4.4	120	5.3	7
4489	No Sample							
4490	860	5.8	120	7.0	4.7	83	3.9	4
4491	880	5.3	115	6.1	3.8	120	4.6	5
4492	896	5.0	95	4.8	4.4	78	3.5	6
4493	915	5.1	115	5.9	3.6	115	4.2	5
4494	945	5.1	120	6.2	4.4	89	3.9	7
4495	960	4.9	105	5.2	3.4	115	4.0	5
4496	980	6.0	83	5.0	5.7	52	3.0	7
4497	995	5.0	180	9.1	3.1	135	4.2	5

Table IV. 34

Copper content of Grewia flava, leaves and twigs, collected on Transect 38 at the Malachite Pan Eskadron. 21/1/70

Sample No.	Location M.S.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
4020	6	7.9	285	22.5	3.6	242	8.7	125
4021	16	8.8	295	26.0	3.7	215	8.1	128
4022	27	9.1	335	30.8	4.4	222	9.9	172
4023	60	6.9	377	26.9	3.6	245	9.0	55
4024	75	7.9	285	22.5	4.2	145	6.2	52
4025	90	8.7	372	32.4	4.4	167	7.3	45
4026	98	9.0	257	23.1	4.1	195	8.1	74
4027	111	7.5	340	25.6	4.4	205	9.2	65
4028	112	8.8	250	22.0	4.0	192	7.8	63
4029	138	8.0	227	18.4	3.7	192	7.3	68
4030	147	8.3	182	15.2	3.9	222	8.6	92
4031	150	9.0	212	19.2	4.2	190	8.2	105
4032	152	8.2	310	22.5	4.7	217	10.2	96
4033	159	8.1	245	20.1	3.9	212	8.5	64
4034	168	7.3	267	19.6	3.9	212	8.3	66
4035	179	8.9	217	19.3	4.0	157	6.4	85
4036	187	9.1	280	25.5	4.1	217	8.9	82
4037	195	7.7	300	23.3	4.2	185	7.8	76
4038	203	8.0	272	21.9	4.2	217	9.3	91
4039	221	8.0	155	12.5	3.9	132	5.2	70
4040	233	7.0	262	18.4	4.0	240	9.6	57
4041	245	8.6	112	9.7	3.7	190	7.1	30
4042	258	8.0	162	13.1	3.2	160	5.2	26
4043	270	8.6	182	15.7	4.6	145	6.7	25
4044	285	8.9	112	10.1	3.8	117	4.5	24
4045	313	9.1	177	16.1	4.2	137	5.9	20
4046	326	7.4	143	10.7	3.8	180	6.3	15
4047	340	7.5	177	13.3	3.6	185	6.8	20
4048	348	8.6	170	14.7	4.2	175	7.4	20
4049	361	7.9	172	13.7	3.0	210	6.3	31
4050	370	7.7	202	15.7	4.0	145	5.9	25
4051	396	8.0	180	14.4	4.6	180	8.4	23
4052	412	10.0	192	19.3	4.3	132	5.7	42
4053	431	7.8	265	20.7	4.0	172	7.0	55
4054	445	8.3	185	15.5	3.3	132	4.3	28
4055	463	8.2	175	14.5	4.7	162	7.7	16
4056	477	8.4	172	14.6	3.7	190	7.1	28
4057	490	9.1	200	18.4	3.3	117	3.9	35
4058	501	8.4	162	13.7	3.8	135	5.2	30
4059	509	8.5	157	13.5	3.1	127	4.0	18
4060	522	8.7	150	13.1	3.6	187	6.9	22
4061	544	7.1	225	15.8	3.8	162	6.3	93
4062	545	8.2	337	27.6	4.1	225	9.2	92
4063	550	8.0	267	21.4	4.5	190	8.7	87
4064	555	7.8	315	24.8	4.0	190	7.8	77
4065	564	6.9	200	14.0	3.4	215	7.4	47
4066	574	7.9	145	11.5	3.4	115	3.9	23
4067	590	7.4	147	10.9	3.2	145	4.7	22
4068	600	7.5	202	15.2	3.3	180	6.0	17
4069	619	8.2	157	13.0	3.3	150	5.1	15
4070	636	7.9	120	9.6	3.6	140	5.1	18
4071	660	7.3	182	13.4	3.7	125	4.6	25

Table IV. 34. (cont.)

Sample No.	Location M.S.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
4072	670	8.2	192	15.7	3.5	157	5.6	32
4073	740	7.9	162	12.9	4.3	120	5.2	5
4074	750	7.1	180	12.8	4.1	127	5.2	7
4075	760	7.4	102	7.6	3.7	110	4.1	7
4076	775	8.3	200	16.6	3.2	105	3.4	6
4077	788	7.9	170	13.4	3.4	170	5.8	5
4078	798	7.6	195	14.9	2.9	115	3.1	5
4079	818	6.7	222	15.0	3.7	147	5.5	7
4080	840	7.0	187	13.1	3.4	142	4.9	5
4081	854	8.0	140	11.2	4.1	130	5.4	5
4082	867	8.8	140	12.4	3.4	110	3.8	6
4083	886	8.1	145	11.9	4.7	120	5.7	7
4084	903	7.4	130	[illegible]	3.4	145	5.0	10
4085	918	7.0	152	10.6	3.1	177	5.6	8
4086	930	7.2	142	10.3	3.4	157	5.4	6
4087	950	7.7	175	13.6	3.3	112	3.8	7
4088	[illegible]	7.5	237	17.8	3.9	150	5.9	10
4089	998	7.4	[illegible]	18.6	3.4	[illegible]	4.2	10

Table IV. 3[illegible].

Copper content of *Phaeoptilum spinosum*, leaves and twigs, collected on Transect [illegible] at the Malachite Pan [illegible]. 23/1/70.

Sample No.	Location M.S.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
4301	11	15.0	235	35.3	4.5	505	22.8	135
4302	20	18.2	300	54.8	5.0	500	25.1	122
4303	30	14.0	442	62.0	4.1	410	17.0	202
4304	40	13.4	447	60.1	2.8	600	17.1	205
4305	45	15.4	267	41.2	4.5	515	23.4	189
4306	60	11.6	185	21.5	2.9	500	14.8	55
4307	80	15.0	125	18.8	5.4	260	14.1	62
4308	95	17.2	142	24.5	5.4	315	17.2	63
4309	112	17.3	142	24.6	6.0	262	15.8	64
4310	119	14.8	180	26.7	4.4	267	11.9	52
4311	122	12.7	195	24.9	2.7	327	10.6	54
4312	130	16.8	87	14.7	3.5	285	10.2	70
4313	144	11.3	115	13.1	3.8	305	11.7	80
4314	150	16.2	195	31.7	4.4	290	12.9	105
4315	161	17.0	102	17.4	5.7	300	17.3	61
4316	190	11.9	147	17.6	4.6	305	14.2	79
4317	200	13.9	222	31.0	4.6	305	14.2	75
4318	210	11.4	130	14.9	4.6	142	6.6	120
4319	219	22.3	130	26.5	6.1	165	10.1	74
4320	232	14.6	195	32.4	4.2	500	21.2	60
4321	240	13.9	122	16.9	3.0	350	10.5	32
4322	250	14.0	37	5.2	3.4	290	10.1	27
4323	260	13.7	55	7.5	3.9	260	10.1	25
4324	270	15.3	35	5.4	3.4	210	7.2	25
4325	290	19.6	35	6.9	4.6	185	8.6	27
4326	305	12.9	72	9.3	2.5	340	8.7	22
4327	331	17.5	32	5.6	2.7	295	8.2	16
4328	350	14.7	35	5.2	3.9	207	8.2	20
4329	365	15.4	50	7.7	6.7	142	9.5	28
4330	390	15.0	47	7.1	5.2	202	10.6	20
4331	410	18.7	55	10.3	3.3	257	8.6	42
4332	418	17.7	62	11.0	3.8	245	9.4	42
4333	430	13.8	65	9.0	4.8	212	10.3	60
4334	445	16.0	67	10.7	3.6	310	11.3	28
4335	460	13.0	45	5.9	4.4	175	7.8	15
4336	475	15.8	137	21.7	3.5	355	12.7	26
4337	500	13.5	65	8.8	4.1	222	9.2	32
4338	510	14.0	37	5.2	3.1	285	8.9	17
4339	550	16.1	97	15.6	5.5	310	17.1	87
4340	550	13.8	237	32.8	3.1	437	13.7	90
4341	560	15.4	60	9.2	4.1	285	11.8	67
4342	575	14.8	57	8.5	3.6	202	7.4	22
4343	596	15.8	32	5.1	4.3	167	7.2	18
4344	606	13.1	62	8.1	4.0	202	8.1	17
4345	615	11.0	55	6.1	3.5	157	5.6	16
4346	625	15.9	75	12.0	4.1	222	9.6	18
4347	635	14.1	50	7.1	5.0	257	12.9	18
4348	665	12.0	72	8.7	2.9	232	6.8	30
4349	680	12.6	62	7.8	4.8	195	9.4	32
4350	745	13.7	32	4.4	3.8	182	6.9	6
4351	755	12.7	62	7.9	4.2	187	7.9	7
4352	775	15.0	70	10.5	5.4	217	11.8	6
4353	790	15.5	47	7.3	4.7	165	7.8	5
4354	803	12.0	40	4.8	3.6	137	4.9	7

Table IV. 35. (cont.)

Sample No.	Location M.S.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
4355	818	12.4	42	5.2	3.1	327	10.4	7
4356	837	14.5	45	6.6	4.1	315	12.9	8
4357	860	10.9	35	3.9	4.1	125	5.2	5
4358	872	12.7	47	6.0	3.5	255	9.0	6
4359	885	13.0	35	4.7	3.5	235	8.3	6
4360	896	12.1	57	6.9	5.6	160	9.0	8
4361	915	11.9	57	6.8	3.9	232	9.1	7
4362	922	14.3	30	4.3	4.1	172	7.1	6
4363	940	15.7	30	4.7	4.9	95	4.7	7
4364	967	14.4	32	4.6	4.0	135	5.5	10
4365	980	13.2	35	4.6	3.5	140	4.9	7
4366	998	14.1	27	3.8	3.3	150	5.0	10

Table IV. 36.

Copper content of *Acacia hereroensis*, leaves and twigs, collected on Transect 38 at the Malachite Pan Eskadron. 27/1/70.

Sample No.	Location M.S.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
4498	5	5.7	241	13.8	4.4	258	11.4	126
4499	22	5.9	197	11.7	4.4	283	12.5	138
4500	33	5.8	208	12.2	5.0	298	15.0	204
4501	40	5.2	500	26.0	4.0	1050	42.0	205
4502	40	6.4	275	17.6	3.4	950	32.7	205
4503	48	4.8	343	16.5	3.0	488	14.8	185
4504	60	6.0	212	12.8	3.6	100	3.6	55
4505	78	5.5	110	6.1	3.4	140	4.8	57
4506	110	5.1	135	6.9	3.5	140	5.0	67
4507	120	5.0	105	5.3	3.1	135	4.3	50
4508	130	4.8	191	9.2	4.0	130	5.2	70
4509	140	6.1	105	6.4	3.5	130	4.6	60
4510	150	6.1	83	5.1	3.9	100	3.9	105
4511	170	10.3	83	8.6	3.5	115	4.1	67
4512	188	10.0	125	13.7	3.1	152	4.8	81
4513	193	5.5	135	7.5	3.5	162	5.7	77
4514	203	6.4	125	8.1	3.7	115	4.3	88
4515	210	5.2	89	4.7	4.3	135	5.8	120
4516	222	4.2	73	3.1	5.3	95	5.0	69
4517	238	4.2	120	5.1	4.1	105	4.3	39
4518	250	6.9	68	4.7	4.2	110	4.6	27
4519	270	6.2	120	7.5	4.2	146	6.1	25
4520	283	6.3	95	6.0	4.1	100	4.1	22
4521	306	6.2	125	7.8	4.5	169	7.7	22
4522	318	5.5	100	5.5	3.5	130	4.6	16
4523	340	5.7	120	6.9	3.1	125	3.9	20
4524	350	6.7	120	8.1	3.9	130	5.1	20
4525	360	6.5	115	7.4	4.1	120	5.0	32
4526	378	6.1	140	8.6	4.1	140	5.7	17
4527	415	5.7	125	7.1	3.7	146	5.5	42
4528	468	6.5	105	6.9	3.9	146	5.8	16
4529	475	6.2	95	5.9	4.0	115	4.6	25
4530	495	6.9	115	8.0	3.9	120	4.7	33
4531	504	5.5	78	4.3	3.2	89	2.9	26
4532	524	4.8	100	4.8	3.1	73	2.3	22
4533	537	6.1	105	6.4	4.4	146	6.5	75
4534	555	5.9	152	9.0	4.7	110	5.2	77
4535	575	6.5	115	7.5	5.3	208	11.0	22
4536	630	3.9	100	3.9	3.3	115	3.8	20
4537	655	4.7	110	5.2	2.4	83	2.0	23
4538	740	5.0	73	3.7	5.5	105	5.9	5
4539	745	4.9	68	3.4	3.9	73	2.9	6
4540	760	5.5	63	3.4	4.7	95	4.5	7
4541	770	5.6	120	6.8	3.2	100	3.2	7
4542	804	4.9	89	4.4	4.1	83	3.5	6
4543	810	6.0	115	6.9	3.4	89	3.1	7
4544	830	4.9	110	5.4	3.4	78	2.7	10
4545	850	6.1	89	5.5	4.3	100	4.3	5
4546	892	5.4	100	5.5	4.6	105	4.9	7
4547	905	5.6	120	6.7	3.8	105	4.0	10
4548	925	4.3	89	3.8	3.4	63	2.2	6
4549	950	4.8	169	8.2	2.9	110	3.2	7

Table IV. 36. (cont.)

Sample No.	Location M.S.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
4550	960	6.4	83	5.3	4.1	73	3.0	10
4551	995	6.0	89	5.3	4.5	95	4.3	10
4552	1000	5.9	68	4.0	3.7	56	2.1	10

Table IV. 37

Copper content of Grewia flava, leaves and twigs, collected on Transect 42 at the Malachite Pan Eskadron. 21/1/70.

		LEAVES			TWIGS			SOIL
Sample No.	Location M.S.	% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry	-80 mesh
Grewia flava								
4090	2	8.4	285	24.0	3.3	177	5.9	59
4091	16	8.6	240	20.6	3.7	110	4.1	50
4092	24	8.7	182	16.0	3.9	130	5.1	47
4093	41	7.1	232	16.5	2.9	185	5.4	60
4094	46	7.8	262	20.5	4.0	140	5.6	40
4095	55	9.1	185	17.0	5.2	85	4.5	37
4096	70	8.8	190	16.8	3.2	187	6.1	62
4097	77	8.2	215	17.8	3.4	200	6.9	80
4098	85	8.1	337	27.5	3.5	262	9.2	67
4099	86	9.3	290	27.2	4.2	152	6.4	62
4100	95	8.6	135	11.7	4.7	130	6.1	61
4101	107	7.9	225	17.9	4.0	160	6.4	101
4102	114	8.2	225	18.5	3.6	185	6.7	98
4103	121	8.1	290	25.3	3.9	210	8.3	79
4104	137	7.9	232	18.4	3.2	207	6.7	50
4105	151	7.4	287	24.4	3.5	175	6.1	60
4106	163	8.4	325	27.5	3.1	190	6.0	62
4107	177	7.6	250	19.1	3.6	200	7.2	72
4108	201	8.5	250	21.4	3.4	205	7.0	85
4109	214	7.5	410	30.8	2.9	240	7.0	120
4110	226	7.7	405	31.3	4.9	190	9.4	216
4111	229	7.3	510	37.6	3.4	295	10.2	264
4112	240	7.3	365	26.8	3.7	265	9.9	145
4113	252	8.0	322	25.8	3.5	290	10.4	197
4114	260	7.2	382	27.7	2.4	285	7.0	295
4115	270	7.9	382	30.3	3.4	275	9.5	212
4116	286	7.8	530	41.6	4.0	232	9.4	108
4117	301	8.2	290	23.8	3.7	267	10.0	130
4118	314	8.3	375	31.2	4.7	225	11.0	58
4119	335	7.0	275	19.4	4.1	125	5.2	52
4120	345	7.8	315	24.6	4.0	130	5.2	37
4121	360	7.0	360	25.3	3.1	217	6.8	50
4122	370	8.2	362	29.7	4.3	152	6.6	47
4123	385	9.1	375	34.4	4.2	290	12.4	72
4124	397	7.5	322	24.4	3.2	205	6.6	86
4125	418	9.7	195	19.1	3.7	190	7.1	96
4126	430	7.9	217	17.1	3.6	180	6.6	117
4127	450	7.8	387	30.3	3.7	140	5.3	70
4128	460	8.6	420	36.3	3.6	217	7.8	115
4129	487	8.8	217	19.1	3.1	220	6.9	95
4130	490	7.2	262	18.9	3.7	217	8.2	87
4131	500	7.9	425	33.7	3.5	245	8.8	97
4132	510	7.9	300	23.7	3.9	240	9.5	145
4133	518	7.1	395	28.4	4.1	257	10.7	149
4134	533	7.8	367	28.9	4.3	325	14.0	192
4135	540	8.6	345	29.7	4.2	255	10.8	187
4136	547	8.4	300	25.3	4.3	235	10.2	134
4137	554	8.3	315	26.2	3.0	240	7.3	107
4138	570	7.5	275	20.8	3.8	155	5.9	142

Table IV. 37 (cont.)

Sample No.	Location M.S.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
Grewia flava								
4139	584	9.6	300	28.8	4.6	230	10.7	108
4140	600	8.7	230	21.1	4.1	265	11.1	150
4141	602	8.7	395	34.5	4.0	305	12.2	155
4142	617	8.3	455	38.2	3.4	255	8.9	125
4143	630	7.8	462	36.4	4.0	295	11.9	127
4144	650	8.5	367	31.5	3.5	300	10.7	190
4145	657	8.4	360	30.3	3.9	385	15.2	188
4146	662	7.6	415	32.2	4.3	255	11.0	230
4147	670	8.3	345	28.9	3.5	270	9.5	300
4148	680	7.3	322	23.5	3.7	245	9.2	242
4149	693	7.4	352	25.6	2.9	235	6.9	159
4150	711	8.8	152	13.4	4.2	162	6.9	56
4151	747	7.2	145	10.5	5.1	180	9.3	34
4152	975	7.2	207	15.1	4.0	152	6.2	32
4153	790	7.9	165	13.2	4.8	152	7.4	42
4154	795	7.4	145	10.8	5.4	160	8.8	47
4155	805	8.3	157	13.2	4.0	115	4.6	44
4156	816	9.2	112	10.3	3.6	97	3.6	34
4157	830	7.3	195	14.3	3.1	197	6.1	70
4158	850	8.4	180	15.2	3.3	210	7.0	57
4159	865	9.0	190	17.3	3.8	155	5.9	43
4160	883	8.2	185	15.2	3.7	175	6.5	49
4161	896	8.4	142	12.0	3.8	145	5.6	43
4162	914	8.4	180	15.2	4.0	155	6.2	52
4163	930	9.2	152	14.1	4.3	147	6.4	42
4164	953	8.3	162	13.5	4.3	152	6.7	37
4165	972	8.0	147	11.9	3.8	165	6.4	50
4166	1000	8.5	175	15.0	3.9	162	6.5	35

Table IV. 38

Copper content of *Phaeoptilum spinosum*, leaves and twigs, (Transect 42) collected at the Malachite Fan Escadron. 23/1/70.

Sample No.	Location M.S.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
Phaeoptilum spinosum								
4367	175	11.6	262	30.5	4.1	550	22.8	72
4368	253	17.7	285	50.6	3.2	560	18.1	215
4369	257	16.3	360	58.8	4.9	575	28.3	255
4370	258	13.3	1000	133.2	4.3	535	23.3	290
4371	300	13.0	187	24.4	5.9	337	19.8	137
4372	311	13.4	140	18.8	4.3	345	14.9	52
4373	348	17.5	65	11.4	4.8	230	11.1	34
4374	360	19.0	35	6.7	3.7	267	9.9	50
4375	370	15.8	82	13.0	4.2	287	12.1	47
4376	400	14.4	167	24.1	4.3	370	16.1	87
4377	437	15.2	140	21.3	4.6	237	11.0	100
4378	468	14.4	270	39.0	3.8	440	17.1	147
4379	478	14.8	222	33.0	4.0	297	12.0	125
4380	490	14.5	262	38.1	4.1	385	15.9	87
4381	510	13.5	315	42.6	4.8	600	30.0	145
4382	532	13.8	500	69.4	3.8	465	17.9	192
4383	550	15.4	262	40.6	5.8	417	24.4	110
4384	565	18.0	217	39.1	3.9	620	24.5	120
4385	600	13.0	220	28.7	4.2	297	12.5	150
4386	610	13.8	172	23.9	5.5	230	12.7	157
4387	625	19.5	180	35.1	5.5	302	16.7	118
4388	675	17.0	630	107.2	3.5	525	18.5	325
4389	685	13.9	207	28.8	4.2	385	16.2	220
4390	696	15.0	97	14.6	4.4	280	12.5	138
4391	708	11.0	55	6.1	5.1	185	9.5	65
4392	720	17.7	20	3.5	5.0	130	6.5	60
4393	736	12.2	75	9.2	4.2	285	12.1	39
4394	758	9.7	50	4.9	3.1	267	8.4	26
4395	775	15.3	82	12.6	4.5	245	11.2	32
4396	790	17.6	47	8.3	4.3	202	8.8	42
4397	800	14.8	67	9.9	4.4	200	8.9	55
4398	810	15.4	40	6.2	3.9	175	6.9	32
4399	825	18.2	55	10.0	4.7	240	11.3	52
4400	850	17.3	50	8.7	4.1	290	11.9	57
4401	875	17.6	70	12.3	3.4	395	13.5	47
4402	890	13.3	35	4.7	3.8	177	6.8	47
4403	902	15.5	47	7.3	4.5	195	8.9	44
4404	910	13.6	57	7.8	2.4	397	9.6	55
4405	920	12.7	50	6.4	2.9	305	9.1	47
4406	940	19.3	57	11.0	4.3	245	10.6	50
4407	960	19.3	62	12.0	3.8	295	11.4	42
4408	980	14.2	47	6.7	4.2	170	7.2	50
4409	990	14.8	67	9.9	4.3	202	8.8	37

Table IV. 32

Copper content of *Acacia hereroensis*, leaves and twigs, (Transect 42) collected at the Malachite Pan Eskadron. 28/1/70.

Sample No.	Location M.S.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
Acacia hereroensis								
4553	1	5.3	130	6.9	3.0	162	4.9	60
4554	10	5.1	152	7.8	4.1	135	5.6	57
4555	25	5.8	120	7.0	4.1	110	4.5	47
4556	47	6.1	130	8.0	3.6	203	7.3	42
4557	60	6.1	110	6.7	4.3	105	5.0	45
4558	75	7.1	84	6.0	4.0	115	4.6	74
4559	80	6.7	110	7.4	4.1	130	5.4	87
4560	94	5.1	151	7.7	4.0	146	5.9	59
4561	115	7.1	84	6.0	3.8	115	4.4	98
4562	130	5.9	125	7.4	3.4	120	4.1	75
4563	146	5.2	120	6.3	4.8	141	6.8	56
4564	162	5.0	115	5.8	3.5	115	4.0	60
4565	208	5.7	209	12.1	3.3	246	8.2	92
4566	220	5.5	183	10.1	4.5	136	6.1	147
4567	242	4.2	382	16.1	3.2	530	17.2	151
4568	253	5.9	188	11.1	3.5	295	10.4	202
4569	254	6.7	240	16.2	3.1	530	16.5	220
4570	266	5.4	178	9.1	3.7	285	10.6	225
4571	268	6.0	253	15.2	3.2	258	8.3	214
4572	285	5.4	456	24.7	3.8	240	9.2	111
4573	298	6.0	193	11.6	4.5	130	5.9	132
4574	310	4.7	246	11.6	2.5	225	5.7	50
4575	320	5.1	125	6.4	3.8	125	4.8	70
4576	335	4.5	136	6.1	3.4	115	3.9	52
4577	353	6.0	130	7.8	3.9	146	5.7	39
4578	370	6.1	120	7.3	3.9	145	5.7	60
4579	388	4.7	130	6.1	3.4	100	3.4	81
4580	400	6.9	173	12.1	4.3	156	6.8	87
4581	440	6.5	130	8.5	4.9	166	8.2	90
4582	450	5.5	156	8.6	3.5	156	5.5	70
4583	470	6.2	161	10.0	5.2	156	8.2	152
4584	480	5.4	151	8.2	3.8	156	6.0	120
4585	500	6.7	151	10.1	4.4	146	6.5	97
4586	512	6.6	203	13.5	4.7	246	11.6	146
4587	534	6.4	156	10.0	4.1	178	7.4	192
4588	552	5.4	105	5.7	4.2	125	5.3	108
4589	570	6.6	125	8.3	4.5	188	8.5	142
4590	585	6.3	130	8.2	4.1	156	6.4	106
4591	600	6.1	141	8.7	4.0	219	8.8	150
4592	620	5.4	120	6.5	5.4	115	6.2	110
4593	670	5.7	188	10.8	3.7	225	8.4	300
4594	690	5.6	151	8.5	4.1	120	4.9	180
4595	760	4.3	166	7.2	6.0	120	7.2	27
4596	780	3.4	105	3.6	6.4	100	6.5	32
4597	790	5.3	105	5.6	3.3	105	3.5	42
4598	840	6.0	141	8.5	4.0	125	5.0	90
4599	850	6.0	146	8.8	3.8	156	6.0	57

Table IV. 40

Copper content of Grewia flava, leaves and twigs, collected on Transect 45 at the Malachite Pan Eskadron. 22/1/70.

Sample No.	Location M.S.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
Grewia flava								
4167	4	8.2	225	18.5	3.9	150	5.9	37
4168	16	8.6	82	7.1	5.5	90	5.0	45
4169	29	9.7	210	20.5	4.2	180	7.6	30
4170	50	8.1	175	14.2	3.9	157	6.1	25
4171	68	9.0	102	9.2	3.9	185	7.4	22
4172	80	8.5	162	13.9	3.8	182	7.0	17
4173	100	8.3	300	25.0	4.2	257	10.9	10
4174	110	7.4	190	14.2	2.9	175	5.2	15
4175	120	7.9	175	13.8	3.2	125	4.0	5
4176	133	8.0	175	14.0	3.5	180	6.3	6
4177	148	8.7	120	10.5	3.9	122	4.8	7
4178	161	8.1	137	11.2	3.4	170	5.9	7
4179	172	7.7	177	13.7	3.5	195	6.8	12
4180	186	9.2	87	7.5	4.0	92	3.8	14
4181	198	8.3	112	9.4	3.3	117	4.0	13
4182	210	7.3	120	8.8	4.0	137	5.6	20
4183	222	7.7	175	13.6	3.6	125	4.6	26
4184	238	7.8	180	14.1	2.9	150	4.4	43
4185	248	7.4	222	16.6	3.0	202	6.2	52
4186	275	7.3	375	27.7	3.9	147	5.8	46
4187	298	8.4	185	15.7	4.8	142	6.9	56
4188	313	8.4	257	21.8	4.5	185	8.4	52
4189	320	7.6	295	22.5	4.1	232	9.6	42
4190	345	7.4	155	12.0	3.4	150	5.2	36
4191	365	8.8	175	15.5	4.0	170	6.8	34
4192	380	7.4	155	11.5	5.3	80	4.3	32
4193	398	7.4	112	8.4	4.1	135	5.6	34
4194	414	7.5	275	20.8	3.8	190	7.3	45
4195	425	8.8	217	19.2	4.2	165	7.0	32
4196	440	7.7	172	13.3	2.7	202	5.6	55
4197	451	7.9	262	20.9	3.0	130	3.9	34
4198	462	7.9	240	19.2	4.2	147	6.2	40
4199	490	7.4	202	15.0	3.7	157	5.8	37
4200	502	8.1	157	12.8	3.2	207	6.8	32
4201	517	8.2	125	10.3	3.7	207	7.7	32
4202	530	7.1	217	15.6	3.1	175	5.4	45
4203	545	7.9	130	10.4	4.3	132	5.7	43
4204	550	6.9	222	15.5	3.5	175	6.2	42
4205	580	7.6	230	17.6	3.6	142	5.6	32
4206	590	9.3	230	21.5	3.9	180	7.1	32
4207	600	6.6	212	14.1	3.3	125	4.2	32
4208	617	8.4	175	14.7	4.5	142	6.5	24
4209	627	7.7	185	14.3	3.3	200	6.7	24
4210	639	6.7	257	17.3	3.3	147	4.9	20
4211	652	7.6	200	15.3	3.6	160	5.9	22
4212	672	8.5	182	15.5	3.3	152	5.1	24
4213	688	9.1	185	16.9	4.0	152	6.2	22
4214	704	9.[illegible]	115	10.7	5.7	117	6.7	22
4215	720	8.8	188	16.7	3.7	135	5.0	20

Table IV. 40 (cont.)

Sample No.	Location W.S.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
Grewia flava								
4216	731	8.5	250	21.5	4.2	177	7.5	20
4217	745	8.8	212	18.8	3.6	180	6.7	20
4218	780	8.5	212	18.1	4.9	142	7.0	21
4219	795	7.2	227	16.5	3.7	120	4.8	25
4220	810	7.7	157	12.2	no	sample		5
4221	822	8.2	137	11.3	4.8	105	5.1	15
4222	837	7.3	222	16.4	4.9	175	8.7	14
4223	857	7.1	207	14.8	3.2	140	4.5	13
4224	884	7.6	305	23.3	3.5	170	6.0	18
4225	896	9.2	245	22.7	3.9	137	5.4	36
4226	907	8.4	180	15.3	3.0	177	5.4	29
4227	920	7.5	332	25.0	3.4	222	7.7	65
4228	934	7.5	325	24.6	3.3	177	5.6	32
4229	943	7.6	432	33.1	3.5	217	7.7	28
4230	967	7.9	180	14.3	3.8	137	5.3	16
4231	980	9.8	172	15.4	3.7	172	6.4	22
4232	995	8.0	195	15.7	4.6	185	8.6	16

Table IV. 41.

Copper content of *Phaeoptilum spinosum*, leaves and twigs, (Transect 45) collected at the Malachite Pan Eskadron. 26/1/70.

Sample No.	Location M.S.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
Phaeoptilum spinosum								
4410	1000	13.0	67	8.8	5.0	245	12.3	12
4411	975	15.2	210	31.9	5.3	320	17.1	20
4412	945	15.4	192	29.7	5.3	475	25.6	28
4413	930	15.4	110	17.0	4.9	290	14.3	32
4414	920	14.6	80	11.7	4.7	255	12.1	65
4415	907	14.0	42	5.9	4.2	320	13.7	27
4416	887	17.3	120	20.8	4.6	340	15.6	20
4417	865	15.3	100	15.4	5.4	322	17.4	18
4418	855	16.8	70	11.8	4.2	365	15.6	14
4419	843	16.0	47	7.5	3.4	345	11.9	11
4420	810	14.8	37	5.5	3.1	320	10.2	15
4421	785	15.5	55	8.5	4.0	185	7.5	24
4422	765	16.7	95	15.9	4.5	257	11.7	18
4423	750	18.7	65	12.2	4.6	277	13.0	20
4424	715	15.0	160	24.1	5.5	280	15.5	21
4425	688	14.4	37	5.3	4.6	172	8.0	22
4426	625	16.4	45	7.4	4.4	175	7.8	22
4427	605	13.9	55	7.7	4.7	180	8.5	27
4428	585	16.0	37	5.9	5.0	115	5.8	32
4429	575	16.2	22	3.6	4.1	177	7.3	34
4430	560	15.9	85	13.5	5.9	212	12.5	37
4431	540	22.1	60	13.2	5.4	212	11.5	45
4432	515	15.6	42	6.6	5.1	195	10.1	32
4433	475	19.1	65	12.4	7.0	95	6.7	32
4434	450	15.2	130	19.8	4.8	327	16.0	32
4435	435	17.1	47	8.0	4.4	220	9.9	40
4436	410	15.4	77	11.9	4.5	240	10.8	47
4437	400	15.1	77	11.7	6.8	180	12.3	37
4438	388	20.1	47	10.2	6.4	150	9.6	32
4439	370	15.8	50	7.9	4.6	217	10.1	32
4440	330	14.3	77	11.0	5.6	212	12.0	35
4441	302	15.3	70	10.7	6.4	170	10.9	56
4442	290	13.7	42	5.8	5.8	202	11.8	55
4443	276	21.8	65	14.2	5.0	470	23.8	47
4444	225	13.3	180	24.0	5.3	175	9.3	26
4445	105	14.2	35	5.0	5.2	150	7.8	12
4446	95	15.8	35	5.6	6.1	232	14.2	15
4447	22	13.8	140	19.4	5.5	317	17.5	40

Table IV. 42

Copper content of *Acacia hereroensis*, leaves and twigs, collected on Transect 45 at the Malachite Pan Eskadron. 28/1/70.

Sample No.	Location M.S.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
4600	995	5.4	178	9.6	3.7	141	5.2	16
4601	985	6.5	95	6.2	4.8	130	6.3	21
4602	965	5.8	173	10.1	3.6	125	4.5	16
4603	945	6.4	130	8.4	3.4	156	5.4	23
4604	925	5.9	141	8.3	3.7	120	4.5	46
4607	890	6.2	53	3.3	3.9	125	4.9	25
4608	875	5.8	105	6.1	3.5	105	3.7	16
4609	850	5.8	120	7.0	3.7	120	4.5	12
4610	810	5.7	69	4.0	3.8	74	2.8	15
4611	795	5.9	78	4.7	4.3	74	3.2	25
4612	785	6.2	100	6.2	3.5	89	3.1	23
4613	770	5.0	95	4.8	3.2	110	3.5	20
4614	756	6.7	100	6.7	3.8	125	4.8	18
4615	740	6.2	100	6.2	3.5	95	3.4	20
4616	700	5.9	89	5.3	3.7	136	5.1	22
4617	690	5.8	78	4.5	4.1	125	5.2	22
4618	670	4.2	125	5.3	3.5	120	4.2	22
4619	665	6.5	78	5.1	4.6	105	4.9	25
4620	635	6.3	78	4.9	3.4	125	4.3	20
4621	615	5.5	120	6.7	4.2	130	5.5	24
4622	600	6.7	105	7.1	4.2	84	3.6	32
4623	585	5.6	146	8.2	3.6	105	3.8	32
4624	530	5.5	95	5.3	3.3	105	3.5	45
4625	520	5.7	100	5.8	3.8	95	3.6	32
4626	500	6.3	95	6.1	4.6	166	7.7	32
4627	470	5.6	130	7.3	4.0	105	4.2	32
4628	450	4.1	141	5.8	3.3	100	3.3	32
4629	440	5.5	78	4.3	4.1	125	5.2	55
4630	420	5.7	105	6.0	3.4	84	2.9	42
4631	405	4.9	125	6.2	3.9	105	4.1	42
4632	370	6.1	115	7.0	3.8	84	3.2	32
4633	350	4.8	74	3.6	4.1	125	5.2	37
4634	335	6.8	58	4.0	3.3	84	2.8	35
4635	325	6.0	95	5.7	4.4	146	6.5	42
4636	300	5.8	89	5.2	3.7	105	3.9	57
4637	280	5.9	89	5.3	3.6	125	4.5	45
4638	245	4.8	105	5.1	4.0	146	5.9	51
4639	205	5.6	105	5.9	4.3	130	5.6	16
4640	165	5.5	100	5.5	3.3	100	3.3	10
4641	148	5.8	115	6.7	4.1	105	4.3	7
4642	140	5.2	100	5.2	3.8	125	4.8	7
4643	130	5.8	89	5.2	4.1	110	4.5	5
4644	95	5.7	105	6.0	3.8	115	4.4	15
4645	75	6.5	89	5.8	3.9	120	4.7	18
4646	50	6.7	74	5.0	3.4	84	2.9	25
4647	25	7.0	115	8.1	3.9	136	5.4	37
4648	20	5.4	74	4.0	3.8	89	3.4	47
4649	12	5.6	74	4.2	3.9	95	3.7	40
4650	5	6.6	110	7.3	4.4	115	4.9	37

Table lV.43.

Copper content of Grewia flava and Acacia hereroensis leaves and twigs, for samples collected on Transect 67, Okatjirute West.

11/2/69

Sample No.	Location m.SE/m.	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
2800	0	8.5	115	9.8	4.08	85	3.5	10
2801	10	7.3	172	12.6	3.74	87	3.3	10
2802	22	8.5	127	10.8	3.82	127	4.9	10
2803	28	10.1	120	12.2	4.60	75	3.5	12
2804	40	8.3	167	13.9	4.22	72	3.0	14
2807	60	8.9	142	12.7	6.21	185	5.3	17
2808	78	7.7	180	13.9	5.71	78	4.5	14
2810	90	8.8	242	21.5	6.20	78	4.8	37
2811	103	7.7	142	11.0	4.01	82	3.3	14
2812	110	7.8	145	11.4	5.04	50	2.5	8
2813	119	7.9	132	10.5	4.81	55	2.6	8
2814	129	8.6	104	9.0	5.10	62	3.2	7
2815	140	7.8	120	9.4	4.56	55	2.5	6
2816	150	7.4	132	9.9	5.46	55	3.0	7
2817	169	7.6	160	12.3	4.34	65	2.8	8
2818	188	7.1	180	12.8	4.22	92	3.9	8
2819	210	6.7	195	13.3	5.04	68	3.4	8
2820	235	7.7	155	12.0	5.06	55	2.8	8
2821	252	8.2	124	8.5	6.25	60	3.8	8
2822	269	8.2	120	9.9	4.78	58	2.8	8
2823	289	7.6	150	11.5	4.70	62	2.9	6
2824	307	7.0	152	11.1	4.97	50	2.5	6
2825	334	6.4	132	8.5	4.33	65	2.8	8
2826	348	7.6	143	10.9	4.19	60	2.5	6
2827	375	7.7	160	12.4	5.33	57	3.0	10
2829	405	6.9	196	13.6	3.77	77	2.9	13
2831	454	7.7	177	13.6	3.33	82	2.7	27
2832	462	8.1	182	14.8	4.80	85	4.1	30
2833	470	8.3	132	10.9	4.63	72	3.3	30
2834	480	6.9	162	11.2	6.29	75	4.7	25
2836	500	7.8	140	10.9	4.72	60	2.8	17
2837	508	7.5	157	11.8	4.39	60	2.6	17
2838	520	8.1	160	13.0	4.15	87	3.9	17
2839	530	6.7	135	9.1	2.80	78	2.2	17
Acacia hereroensis								
2805	50	6.6	60	4.0	4.61	130	6.0	18
2806	60	5.3	98	5.4	4.17	100	4.2	17
2830	430	8.2	205	16.9	3.46	110	3.8	17
2835	480	7.5	120	9.0	4.46	82	3.6	25

Table lV.44.

Copper content of Acacia giraffae, Tarchonanthus camphoratus and Ozoroa paniculosa, leaves and twigs for samples collected on the Daheim Grid.

24/4/70

Sample No.	Location m.E/m.S	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
Acacia giraffae								
4915	580/30	6.2	37	2.3	4.30	62	2.7	32
4917	570/15	6.2	57	3.6	5.20	50	2.6	42
4918	560/5	6.0	50	3.0	4.35	50	2.2	22
4919	545/5	5.8	62	3.6	5.00	60	3.0	35
4920	505/5	5.5	37	2.0	5.40	45	2.4	37
4921	485/0	5.5	82	4.6	3.75	92	3.5	65
4923	485/10	5.9	65	3.8	5.20	82	4.3	62
4925	470/20	7.1	62	4.4	5.70	25	1.4	15
4927	420/15	5.8	72	4.2	4.28	82	3.5	5
4929	380/5	6.3	55	3.5	3.84	47	1.8	7
4930	360/25	7.0	45	3.2	6.25	17	1.1	15
4931	340/20	10.2	22	2.2	7.72	22	1.7	5
4932	320/10	7.0	75	5.3	5.76	50	2.9	5
4933	295/10	5.7	55	3.2	4.05	20	0.8	7
4934	260/15	6.1	60	3.7	5.49	50	2.7	10
4935	250/10	9.4	45	4.3	3.49	50	1.7	10
Tarchonanthus camphoratus								
4914	600/10	6.0	187	11.3	3.43	253	8.6	35
4916	580/10	7.2	247	17.8	2.96	295	8.7	35
4922	485/0	7.4	345	25.8	3.14	217	6.8	60
4924	470/10	6.1	360	22.2	3.36	282	9.5	10
4926	425/5	6.3	347	24.2	3.28	215	5.1	10
4928	395/15	6.8	270	18.6	2.79	255	7.1	5
4939	375/10	7.2	245	17.7	2.77	247	6.8	15
4938	360/25	8.7	155	12.6	2.98	210	6.1	12
4937	350/30	6.9	310	21.4	2.75	230	6.3	15
4936	260/15	6.5	400	26.6	2.36	240	5.6	15
Ozoroa paniculosa								
4946	405/15	6.0	107	6.5	3.76	215	8.1	5
4950	300/30	6.5	70	5.2	4.23	175	7.4	10
4952	260/30	6.3	60	3.8	4.72	177	8.4	5
4953	220/20	5.8	60	3.5	3.31	132	4.4	5
4954	200/25	6.1	57	3.5	3.59	162	5.8	5
4956	160/10	7.8	55	4.3	3.17	157	5.0	5
4959	230/100	6.2	52	3.3	4.17	222	9.3	4
4963	345/110	7.3	60	4.4	3.30	180	5.9	18

Table lV. 45

Copper content of <u>Rhus pyroides</u> and <u>Ziziphus mucronata</u> leaves and twigs, for samples collected on the Daheim Grid. 24/4/70

Sample No.	Location m.E/m.S	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
Rhus pyroides								
4940	540/20	7.5	162	12.2	4.80	182	8.7	55
4941	520/15	8.0	125	10.0	4.43	150	6.6	47
4942	510/10	7.4	170	12.6	4.23	230	5.6	57
4943	470/20	8.5	142	12.0	4.64	232	10.8	20
4944	450/10	9.4	120	11.3	4.56	187	7.6	20
4945	435/10	10.1	103	10.4	4.20	165	6.9	20
4947	360/10	8.2	132	10.9	4.37	125	5.5	5
4949	335/5	8.1	122	9.9	4.61	145	6.7	5
4957	180/100	5.3	72	3.9	3.81	100	3.8	5
4958	215/100	7.6	132	10.1	4.25	107	4.5	7
4960	260/100	5.8	137	8.0	3.83	110	4.2	5
4961	300/100	7.1	177	8.4	3.74	142	5.3	10
4962	335/100	6.1	137	8.4	3.20	177	5.7	10
4965	445/105	7.0	145	10.2	4.58	155	7.1	7
4966	490/100	6.5	162	10.6	4.55	192	8.7	35
4967	515/100	6.7	205	13.8	4.20	200	8.4	35
4968	580/95	6.3	130	8.3	5.57	162	9.0	35
Ziziphus mucronata								
4948	350/15	9.7	90	8.8	3.91	170	6.6	5
4955	200/40	9.7	50	4.9	3.41	157	5.4	10
4951	270/30	7.9	45	3.6	3.12	150	4.7	10
4969	800/10	8.9	55	4.9	4.04	150	6.1	25
4970	805/15	9.4	40	3.8	2.62	112	2.9	5

Table IV.46

Copper content of <u>Grewia flava</u> leaf samples collected on Transect 99, Daheim Grid.

6/2/70

Sample No.	Dist. m.SE	ppm ash	ppm dry	% ash	Sample No.	Dist. m.SE	ppm ash	ppm dry	% ash
5283	6	165	9.3	5.6	5321	582	177	13.6	7.7
5284	23	165	12.6	7.6	5322	590	87	6.7	7.7
5285	56	185	14.1	7.6	5323	605	147	9.5	6.4
5286	102	147	11.0	7.4	5324	617	157	13.1	8.3
5287	152	191	12.4	6.4	5325	626	147	13.4	9.1
5288	195	125	9.2	7.4	5326	637	147	11.1	7.5
5289	205	145	11.1	7.6	5327	656	165	11.9	7.2
5290	220	92	7.4	8.0	5328	675	167	11.8	7.0
5291	275	195	12.9	6.6	5329	680	165	10.8	6.5
5292	304	137	10.7	7.8	5330	700	160	10.9	6.8
5293	317	215	15.8	7.3	5331	725	202	12.7	6.3
5294	324	207	15.9	7.6	5332	733	157	10.3	6.5
5295	340	175	13.5	7.7	5333	760	182	12.0	6.5
5296	370	202	15.4	7.6	5334	777	170	10.3	6.0
5297	379	195	12.4	6.3	5335	783	170	11.7	6.8
5298	390	240	17.2	7.1	5336	800	170	11.2	6.5
5299	398	237	17.5	7.3	5337	814	112	8.4	7.4
5300	403	267	17.0	6.3	5338	826	120	9.2	7.6
5301	413	260	20.6	7.9	5339	837	155	12.8	8.2
5302	423	337	26.5	7.8	5340	860	110	8.7	7.9
5303	430	240	18.0	7.5	5341	870	87	5.7	6.5
5304	437	240	20.9	8.7	5342	880	165	10.9	6.6
5305	440	245	16.1	6.5	5343	890	170	12.6	7.3
5306	443	275	20.5	7.4	5344	909	95	7.0	7.4
5307	460	275	20.3	7.3	5345	916	160	11.2	7.0
5308	465	280	20.4	7.3	5346	930	132	8.3	6.3
5309	469	410	30.1	7.3	5347	950	115	8.9	7.7
5310	475	390	29.0	7.4	5348	955	87	6.4	7.4
5311	480	157	14.2	9.0	5349	990	177	11.8	6.6
5312	495	280	20.0	7.0	5350	1000	137	10.1	7.4
5313	505	262	20.9	7.9					
5314	513	202	14.3	7.0					
5315	519	165	12.0	7.2					
5316	529	242	20.1	8.3					
5317	540	195	14.0	7.1					
5318	551	157	12.0	7.6					
5319	560	152	12.6	8.3					
5320	570	247	17.1	6.9					

Table lV. 47

Copper content of Grewia flava leaf samples collected on Transect 100, Daheim Grid. 9/4/70

Sample No.	Dist. m.SE	ppm ash	ppm dry	% ash	Sample No.	Dist m.SE	ppm ash	ppm dry	% ash
5607	995	87	7.0	7.9	5641	540	262	19.0	7.2
5608	984	142	11.1	7.8	5642	530	337	24.2	7.1
5609	973	130	9.2	7.0	5643	520	327	23.8	7.3
5610	963	145	11.4	7.8	5644	508	195	15.6	8.0
5611	956	102	7.3	7.1	5645	500	310	23.0	7.4
5612	940	110	9.0	8.1	5646	485	262	18.4	7.0
5613	933	97	6.8	7.0	5647	477	155	10.9	7.0
5614	915	120	9.6	8.0	5648	468	127	9.3	7.3
5615	900	120	8.8	7.3	5649	450	142	10.9	7.6
5616	870	167	13.0	7.8	5650	435	267	18.9	7.0
5617	847	170	12.8	7.5	5651	427	290	18.9	6.5
5618	815	100	7.4	7.4	5652	405	322	21.3	6.6
5619	800	115	9.2	8.0	5653	393	217	16.7	7.6
5620	783	147	10.7	7.2	5654	380	222	15.1	6.8
5621	767	92	7.1	7.6	5655	370	302	18.1	6.0
5622	756	92	7.4	8.0	5656	332	172	11.5	6.6
5623	730	130	9.3	7.1	5657	285	225	15.6	6.9
5624	717	137	10.8	7.8	5658	250	185	12.6	6.8
5625	710	122	8.5	6.9	5659	240	122	9.1	7.4
5626	700	97	7.7	7.8	5660	210	170	10.5	6.1
5627	695	142	9.2	6.5	5661	200	260	15.8	6.0
5628	685	127	9.4	7.4	5662	190	212	13.9	6.5
5629	674	140	8.8	6.3	5663	150	217	13.9	6.4
5630	665	102	7.4	7.2	5664	30	157	12.3	7.8
5631	642	152	10.8	7.1	5665	20	137	9.3	6.7
5632	622	160	11.9	7.4	5666	15	150	10.4	6.9
5633	615	122	9.1	7.4	5667	5	112	8.3	7.4
5634	595	170	11.7	6.8	5668	0	137	9.4	6.8
5635	586	185	13.5	7.2					
5636	582	185	14.1	7.6					
5637	578	267	19.0	7.1					
5638	563	195	15.1	7.7					
5639	557	280	22.4	8.0					
5640	550	730	70.1	9.6					

Table 1V.48

Copper content of Grewia flava leaf samples collected on Transect 101, Daheim Grid. 6/2/70

Sample No.	Dist m.SE	ppm ash	ppm dry	% ash	Sample No.	Dist m.SE	ppm ash	ppm dry	% ash
5351	1000	137	9.3	6.8	5381	600	180	12.4	6.9
5352	993	115	8.4	7.3	5382	575	222	15.7	7.0
5353	981	152	10.1	6.5	5383	565	237	14.4	6.0
5354	973	120	10.0	8.3	5384	558	187	13.5	7.2
5355	960	200	12.4	6.2	5385	542	145	10.3	7.1
5356	950	120	8.1	6.7	5386	530	142	9.2	6.5
5357	930	105	8.3	7.9	5387	520	187	14.4	7.7
5358	920	75	5.3	7.0	5388	510	192	13.7	7.1
5359	906	125	10.0	8.0	5389	470	170	11.9	7.0
5360	898	137	13.1	9.5	5390	460	180	13.6	7.5
5361	885	137	9.5	6.9	5391	452	157	12.5	7.1
5362	870	137	9.9	7.2	5392	425	195	13.4	6.8
5363	850	127	9.8	7.7	5393	380	267	16.7	6.2
5364	840	105	7.6	7.2	5394	370	217	13.8	6.3
5365	830	97	7.3	7.6	5395	360	170	9.9	5.8
5366	818	110	7.1	6.4	5396	350	185	12.3	6.6
5367	808	147	10.4	7.0	5397	310	180	11.4	6.3
5368	782	210	14.1	6.7	5398	300	187	11.9	6.3
5369	770	160	8.8	5.4	5399	290	170	11.4	6.7
5370	759	152	9.9	6.5	5400	160	127	9.3	7.3
5371	745	142	9.3	6.5	5401	145	145	8.9	6.1
5372	733	115	8.5	7.4	5402	120	190	10.8	5.7
5373	720	155	11.2	7.2	5403	110	222	13.5	6.0
5374	706	120	8.8	7.3	5404	93	130	9.7	7.4
5375	690	190	12.0	6.3	5405	72	142	9.5	6.7
5376	680	137	8.4	6.1	5406	60	165	12.2	7.4
5377	665	167	10.4	6.2	5407	40	185	13.1	7.0
5378	650	150	10.7	7.1	5408	25	195	12.1	6.2
5379	627	140	8.9	6.3	5409	5	187	11.9	6.3
5380	610	167	11.0	6.6					

Table lV.49

Copper content of Stipagrostis uniplumis samples collected on Transect 99, Daheim Grid. 9/4/70

Sample No.	Dist. m.SE	ppm ash	ppm dry	% ash	Sample No.	Dist. m.SE	ppm ash	ppm dry	% ash
5410	1000	50	2.9	5.7	5461	450	32	2.0	6.2
5411	990	60	4.1	6.8	5462	440	20	1.1	5.4
5412	980	42	2.4	5.7	5463	430	42	2.3	5.3
5413	970	37	1.9	5.0	5464	420	87	4.1	4.7
5414	960	42	3.4	8.0	5465	410	60	3.0	5.0
5415	950	42	2.4	5.6	5466	400	50	2.1	4.2
5416	940	45	2.5	5.4	5467	390	60	2.6	4.3
5417	930	32	2.0	6.2	5468	380	-	-	4.8
5418	920	57	3.9	6.7	5469	370	65	3.6	5.6
5419	910	37	1.8	4.9	5470	360	67	2.5	5.2
5420	900	37	2.1	5.7	5471	350	75	2.8	3.6
5421	890	50	2.6	5.1	5472	340	70	3.1	4.0
5422	880	45	2.3	5.1	5473	330	115	4.3	3.7
5423	870	47	2.3	4.9	5474	320	105	3.5	3.8
5424	820	50	3.8	7.5	5475	310	105	3.8	3.6
5425	810	57	3.7	6.5	5476	300	82	3.2	3.9
5426	800	42	2.0	4.6	5477	290	112	4.2	3.7
5427	790	55	3.0	5.4	5478	280	100	3.6	3.6
5428	780	57	3.3	5.7	5479	270	57	1.9	3.2
5429	770	32	2.1	6.4	5480	260	72	3.5	4.9
5430	760	37	2.2	5.9	5481	250	70	3.5	4.9
5431	750	20	1.1	5.5	5482	240	42	1.7	4.0
5432	740	25	1.3	5.1	5483	230	27	1.0	3.6
5433	730	32	2.0	6.2	5484	220	45	1.5	3.4
5434	720	20	1.3	6.4	5485	210	67	2.4	3.5
5435	710	20	1.0	4.9	5486	200	25	1.0	3.8
5436	700	32	1.6	5.0	5487	190	22	1.1	4.9
5437	690	27	1.5	5.4	5488	180	32	1.1	3.4
5438	680	60	3.1	5.1	5489	170	37	1.5	3.9
5439	670	45	2.2	4.9	5490	160	55	2.0	3.5
5440	660	32	2.0	6.2	5491	150	32	1.3	4.0
5441	650	22	1.3	5.8	5492	140	32	1.5	4.5
5442	640	32	1.6	5.0	5493	130	37	1.7	4.7
5443	630	42	2.4	5.8	5494	120	65	2.6	3.9
5444	620	65	3.6	5.5	5495	110	62	2.2	3.6
5445	610	70	4.2	5.9	5496	100	57	2.4	4.1
5446	600	77	3.9	5.1	5497	90	57	2.1	3.7
5447	590	70	3.9	5.6	5498	80	67	2.9	4.3
5448	580	65	3.9	6.0	5499	70	55	2.9	5.2
5449	570	55	3.1	5.6	5500	60	55	3.0	5.5
5450	560	47	2.4	5.1	5501	50	32	1.8	5.5
5451	550	50	2.8	5.5	5502	40	50	2.4	4.8
5452	540	65	4.1	6.2	5503	30	60	2.8	4.6
5453	530	60	3.2	5.3	5504	20	45	1.5	3.2
5454	520	57	3.1	5.5	5505	10	20	0.7	3.7
5455	510	42	2.5	5.9	5506	00	35	1.5	4.2
5456	500	32	1.8	5.9					
5457	490	117	8.1	6.9					
5458	480	92	5.7	6.1					
5459	470	32	1.7	5.2					
5460	460	25	1.5	5.9					

Table lV. 50

Copper content of Stipagrostis uniplumis samples collected on Transect 100, Daheim Grid. 9/4/70

Sample No.	Dist m.SE	ppm ash	ppm dry	% ash	Sample No.	Dist m.SE	ppm ash	ppm dry	% ash
5507	00	32	1.5	4.6	5560	530	102	5.6	5.4
5508	10	27	2.0	7.3	5561	540	92	5.6	6.0
5509	20	32	2.0	6.1	5562	550	67	3.6	5.3
5510	30	37	2.0	5.4	5563	560	125	6.6	5.2
5511	40	15	0.7	4.9	5564	570	115	5.7	4.9
5512	50	35	1.7	4.9	5565	580	197	10.0	6.0
5513	60	32	1.2	3.6	5566	590	92	4.5	4.8
5514	70	22	0.8	3.6	5567	600	65	3.7	5.6
5515	80	77	3.6	4.6	5568	610	60	3.7	6.1
5516	90	47	1.7	3.5	5569	620	42	2.4	5.7
5517	100	35	1.7	4.8	5570	630	55	3.2	5.8
5518	110	60	2.5	4.1	5571	640	50	3.1	6.2
5519	120	45	1.9	4.1	5572	650	82	4.1	5.0
5520	130	55	2.2	3.9	5573	660	55	2.0	5.6
5521	140	37	1.8	4.8	5574	670	60	2.6	4.3
5522	150	32	1.8	5.5	5575	680	75	3.3	4.4
5523	160	32	1.8	5.6	5576	690	47	2.3	4.7
5524	170	50	2.7	5.3	5577	700	50	2.8	5.5
5525	180	47	2.0	4.3	5578	710	55	2.8	5.1
5526	190	65	2.7	4.2	5579	720	47	2.6	5.4
5527	200	42	2.2	5.3	5580	730	42	2.3	5.4
5528	210	77	2.9	3.7	5581	740	35	1.7	4.7
5529	220	50	1.9	3.7	5582	750	37	2.4	6.4
5530	230	70	2.8	4.0	5583	760	37	2.2	5.9
5531	240	67	2.5	3.7	5584	770	32	2.4	7.6
5532	250	60	2.8	4.5	5585	780	32	2.0	6.8
5533	260	37	1.6	3.9	5586	790	55	3.3	6.0
5534	270	110	4.4	4.0	5587	800	35	2.0	5.8
5535	280	50	2.0	3.9	5588	810	42	2.2	5.2
5536	290	65	3.2	4.9	5589	820	32	2.0	6.4
5537	300	47	2.3	4.9	5590	830	47	2.0	4.2
5538	310	35	2.4	6.9	5591	840	45	2.8	6.2
5539	320	32	1.9	5.8	5592	850	50	2.4	4.8
5540	330	35	1.8	5.1	5593	860	42	2.3	5.4
5541	340	25	1.5	5.8	5594	870	57	2.9	5.0
5542	350	45	2.3	5.2	5595	880	47	2.8	5.8
5543	360	45	2.6	5.7	5596	890	37	1.6	4.4
5544	370	45	2.7	5.9	5597	900	45	2.1	4.5
5545	380	50	2.5	5.0	5598	910	32	1.7	5.2
5546	390	65	3.3	5.0	5599	920	32	2.0	6.1
5547	400	92	2.9	3.1	5600	930	42	2.7	6.4
5548	410	77	3.6	4.6	5601	940	25	1.6	6.3
5549	420	47	2.0	4.2	5602	950	37	2.3	6.1
5550	430	75	3.5	4.7	5603	960	25	1.5	6.0
5551	440	65	3.4	5.1	5604	970	57	4.5	7.9
5552	450	50	2.7	5.4	5605	980	32	1.9	6.0
5553	460	82	4.0	4.9	5606	990	32	1.8	5.7
5554	470	47	2.5	5.2					
5555	480	65	3.0	4.6					
5556	490	70	2.6	3.6					
5557	500	45	1.9	4.3					
5558	510	57	2.0	3.4					
5559	520	60	2.6	4.3					

Table lV. 51

Copper content of Stipagrostis uniplumis samples collected on Transect 101, Daheim Grid. 9/4/70

Sample No.	Dist. m.SE	ppm ash	ppm dry	% ash	Sample No.	Dist. m.SE	ppm ash	ppm dry	% ash
5669	1000	42	2.2	5.3	5721	490	87	3.9	4.5
5670	990	35	2.1	6.1	5722	480	72	3.3	4.6
5671	980	32	1.8	5.4	5723	470	37	1.5	3.9
5672	970	60	2.9	4.8	5724	460	35	1.5	4.2
5673	960	37	2.1	5.6	5725	450	35	1.5	4.2
5674	950	42	2.1	5.0	5726	440	45	2.1	4.7
5675	940	32	2.1	6.6	5727	430	32	1.4	4.2
5676	930	55	3.7	6.7	5728	420	35	1.7	4.8
5677	920	55	3.7	6.7	5729	410	32	1.6	5.0
5678	910	60	3.1	5.0	5730	400	35	1.6	4.5
5679	900	50	2.4	4.8	5731	390	32	1.5	4.8
5680	890	42	2.5	5.9	5732	380	35	1.7	4.8
5681	880	28	1.4	4.9	5733	370	47	2.3	4.8
5682	870	35	2.2	6.4	5734	360	70	2.9	4.1
5683	860	25	1.3	5.1	5735	350	60	3.0	5.1
5684	850	25	1.4	5.7	5736	340	45	2.4	5.3
5685	840	25	1.4	5.7	5737	330	70	4.0	5.7
5686	830	40	2.8	6.9	5738	320	35	1.4	4.1
5687	820	27	1.4	5.3	5739	310	55	2.5	4.4
5688	810	35	2.4	6.8	5740	300	25	1.2	4.9
5689	800	45	2.7	6.0	5741	290	42	2.4	5.7
5690	790	37	2.2	5.9	5742	280	32	1.6	5.1
5691	780	55	2.9	5.2	5743	270	22	1.1	4.9
5692	770	50	2.3	4.5	5744	260	22	1.3	5.7
5693	760	35	1.6	4.6	5745	250	25	1.3	5.2
5694	750			3.8	5746	240	25	1.4	5.7
5695	740	22	1.0	4.6	5747	230	32	1.6	5.1
5696	730	20	0.8	4.0	5748	220	25	1.3	5.2
5697	720	25	0.8	3.3	5749	210	32	1.9	5.8
5698	710	37	1.6	4.3	5750	200	20	1.1	5.4
5699	700	32	1.3	3.9	5751	190	25	1.4	5.6
5700	690	22	0.7	3.2	5752	180	32	1.5	4.6
5701	680	20	1.0	4.9	5753	170	32	1.2	3.8
5702	670	27	1.5	5.4	5754	160	25	0.9	3.7
5703	660	42	2.3	5.4	5755	150			
5704	650	25	1.0	3.8	5756	140	50	2.0	3.9
5705	640	27	1.4	5.0	5757	130	35	1.6	4.6
5706	630	42	2.0	4.6	5758	120	37	1.5	4.1
5707	620	35	1.6	4.5	5759	110	57	2.7	4.7
5708	610	60	2.3	3.9	5760	100	47	2.3	4.8
5709	600	57	1.9	3.3	5761	90	55	2.4	4.3
5711	590	35	1.4	3.8	5762	80	57	2.8	4.9
5712	580	55	2.4	4.3	5763	70	62	2.4	3.9
5713	570	55	2.9	5.2	5764	60	42	1.0	2.4
5714	560	72	3.4	4.7	5765	50	60	1.7	2.9
5715	550	32	1.6	4.9	5766	40	42	2.1	4.8
5716	540	47	2.0	4.2	5767	30	67	2.1	3.2
5717	530	25	1.4	5.4	5768	20	57	1.2	2.0
5718	520	55	3.1	5.6	5769	10	50	1.4	2.8
5719	510	42	2.3	5.4	5770	0	35	1.1	3.2
5720	500	82	4.1	4.9					

Table IV.52

Copper content of <u>Acacia mellifera</u>, <u>Phaeoptilum spinosum</u> and <u>Grewia flava</u> leaves and twigs collected on Transect 84, Eskadron Homestead Area. 25/11/69.

Sample No.	Distance m.E	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
Acacia mellifera								
3623	2	7.74	92	7.1	4.70	102	4.8	10
3624	23	7.96	90	7.2	4.40	95	4.2	11
3625	40	6.96	72	5.0	3.57	90	3.2	11
3626	60	7.91	75	5.9	5.67	62	3.5	7
3627	78	8.91	67	5.9	4.69	72	3.4	7
3628	100	7.80	60	4.7	6.89	40	2.8	6
3629	118	8.33	60	5.0	6.97	40	2.8	6
3630	132	7.86	50	3.9	5.38	62	3.3	18
3631	147	8.18	112	10.0	7.13	90	6.4	65
3632	150	9.19	100	9.2	6.55	75	4.9	73
3633	153	9.62	72	6.9	4.90	80	3.9	64
3634	150	8.68	95	8.2	5.17	105	5.4	73
3635	158	8.42	102	8.6	6.68	92	6.3	48
3636	170	8.79	67	5.9	5.32	60	3.2	19
3637	182	9.29	60	5.6	6.30	100	6.3	23
Phaeoptilum spinosum								
3638	185	12.05	60	7.2	3.52	105	3.7	30
3640	150	16.00	182	29.1	4.39	335	14.9	73
3643	78	6.89	87	6.1	4.77	240	11.4	7
3645	41	13.40	52	7.0	3.28	275	9.0	11
Grewia flava								
3639	185	8.53	185	15.8	4.25	87	3.7	30
3641	150	8.52	205	17.5	3.90	187	7.3	73
3642	115	9.02	107	9.7	4.56	67	3.1	10
3644	50	9.22	142	13.1	3.77	127	4.8	10

Table IV.53

Copper content of <u>Grewia flava</u> and <u>Phaeoptilum spinosum</u> samples, leaves and twigs, collected on Transect 85, Okatjirute West. 11/12/69.

Sample No.	Location m.S	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
<u>Grewia flava</u>								
3646	0	8.2	240	20.4	3.9	197	7.8	37
3647	22	9.3	225	21.0	4.8	195	9.4	41
3648	41	7.8	270	21.0	3.8	155	5.9	40
3649	60	7.8	215	16.9	3.7	117	4.3	31
3650	80	9.4	187	17.6	4.6	170	7.8	36
3651	95	8.7	197	17.3	3.3	175	5.9	31
3652	107	7.1	243	17.4	3.4	162	5.6	42
3653	120	7.8	260	20.4	3.8	192	7.3	46
3654	135	8.5	170	14.4	3.2	145	4.6	30
3655	149	8.4	162	13.6	3.4	182	6.3	141
3656	151	7.3	244	17.7	3.0	205	6.2	130
3657	150	8.5	225	19.1	4.1	147	6.1	150
3658	150	8.7	250	21.9	4.4	217	9.6	150
3659	157	8.9	142	12.6	4.5	142	6.5	43
3660	172	8.2	265	21.9	4.0	202	8.1	69
3661	191	8.3	222	18.5	4.4	105	4.6	100
3662	202	9.4	210	19.7	3.8	157	5.9	64
3663	210	8.2	212	17.4	3.7	222	8.3	56
3664	223	8.3	192	18.8	3.7	170	6.4	72
3665	227	7.7	217	16.8	4.0	150	6.0	56
3666	242	8.0	257	20.5	3.5	182	6.4	50
3667	260	8.5	177	15.1	4.0	135	5.4	44
3668	278	8.0	207	16.9	3.9	117	4.6	38
3669	290	7.8	192	15.1	3.0	175	5.2	31
3670	310	7.8	182	14.2	4.0	150	6.0	20
3671	323	7.0	202	14.2	3.4	135	4.6	17
3672	341	7.4	172	12.7	3.8	137	5.2	20
3673	350	8.6	182	15.7	4.6	135	6.2	12
<u>Phaeoptilum spinosum</u>								
3674	350	15.8	102	16.1	2.8	307	8.8	12
3675	325	13.5	85	11.5	3.5	202	7.1	17
3676	310	15.6	110	17.2	5.5	182	10.0	20
3677	277	10.0	192	19.2	4.2	275	11.5	38
3678	249	12.6	215	27.2	4.8	355	16.9	80
3679	203	11.3	175	19.8	3.4	315	9.9	61
3680	180	11.3	165	18.6	4.3	217	9.2	65
3681	155	9.6	282	27.1	3.2	315	10.1	44
3682	151	11.8	185	21.9	5.1	257	13.2	132
3683	143	11.4	100	11.4	4.9	145	7.1	40
3684	130	13.6	95	12.9	4.3	187	8.2	35
3685	107	11.5	80	9.2	4.3	150	6.5	48
3686	80	10.5	97	10.2	3.5	177	6.4	36
3687	64	11.4	77	8.8	4.4	180	7.9	32
3688	45	10.6	65	6.9	3.7	162	6.1	40
3689	30	12.4	57	7.1	3.8	165	6.2	47
3690	12	12.6	90	11.4	3.9	245	9.6	40

Table IV.54

Copper content of <u>Acacia hebeclada</u> leaves collected on Transect 86, Okatjirute West. 11/12/69.

Sample No.	Distance m.SE	% ash	ppm ash	ppm dry	-80 mesh
3691	9	5.6	40	2.3	18
3692	22	6.2	40	2.5	16
3693	31	7.3	37	2.7	16
3694	42	6.3	40	2.5	19
3695	55	6.9	28	1.9	20
3696	62	4.9	37	1.8	17
3697	70	6.6	40	2.7	14
3698	81	6.1	47	2.9	14
3699	90	7.4	47	3.5	14
3700	100	6.6	40	2.6	10
3701	110	7.5	42	3.2	10
3702	120	6.4	45	2.9	10
3703	133	6.8	32	2.2	17
3704	141	6.6	32	2.1	14
3705	152	7.1	40	2.8	21
3706	161	6.2	40	2.5	25
3707	170	5.8	40	2.4	24
3708	180	7.0	45	3.2	24
3709	190	7.6	28	2.1	18
3710	200	8.3	25	2.1	19
3711	210	7.0	32	2.3	14
3712	220	6.9	40	2.8	13
3713	230	6.7	50	3.5	14
3714	240	6.7	22	1.7	14
3715	252	6.8	45	3.1	24
3716	253	7.5	32	2.4	28
3717	260	7.3	42	3.1	15
3718	272	7.1	35	2.5	10
3719	280	7.0	35	2.5	9
3720	290	6.5	32	2.1	9
3721	300	7.2	32	2.3	7
3722	310	5.6	42	2.3	6
3723	320	6.0	40	2.4	9
3724	330	7.1	55	3.9	10
3725	340	7.5	45	3.4	28
3726	350	6.9	40	2.8	15
3727	360	7.8	35	2.7	18
3728	370	6.4	32	2.1	18
3729	381	6.4	40	2.6	24
3730	392	7.2	35	2.5	29
3731	401	6.7	50	3.5	25
3732	410	6.4	47	3.0	25
3733	420	6.5	45	2.9	25
3734	430	8.7	47	4.1	16
3735	440	7.5	47	3.5	13
3736	450	7.2	45	3.3	9
3737	460	8.0	37	3.0	8
3738	470	8.1	37	3.0	5
3739	480	7.4	40	3.0	8
3740	490	7.9	40	3.2	8
3741	500	6.6	30	2.0	8

Table IV.55

Copper content of the leaves, stems and flowers for Helichrysum leptolepis samples collected at the Copper Causeway. 20/5/68.

Sample No.	CO.Grid Coords.	LEAVES			STEMS			FLOWERS			SOIL
		% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry	% ash	ppm ash	ppm dry	mesh -80
2117	215.210E	16.6	830	138.4	8.6	975	84.5	20.3	775	157.5	240
2118	220.215E	19.4	626	121.3	7.8	660	51.7	14.0	330	46.2	510
2119	395.5W	23.9	320	76.5	9.1	365	33.4	14.2	300	42.9	308
2120	370.50E	18.6	655	122.3	8.5	655	56.3	16.2	400	64.8	460
2131	220.0	16.2	350	56.7	8.9	275	24.6	17.2	420	72.2	280
2132	317.5E	19.3	535	103.3	7.7	494	38.5	15.5	300	46.5	350
2133	360.0	21.6	300	65.0	9.9	420	41.6	16.7	240	40.3	280
2134	262.62W	17.4	715	125.0	9.4	680	64.3	13.5	375	50.9	432
2135	260.50W	16.9	785	132.9	7.4	770	57.4	12.4	465	58.0	294
2136	257.58W	24.6	750	185.2	10.0	885	89.1	18.7	545	102.3	360
2138	250.53W	16.7	580	97.2	12.5	635	79.4	13.6	420	57.4	480
2139	242.42W	20.4	695	141.8	9.1	795	73.1	14.5	445	64.9	528
2140	230.25W	21.8	525	114.9	10.5	660	69.8	16.4	205	33.7	504
Minimum value				56.7			24.6			33.7	
Maximum value				185.2			89.1			157.5	
MEAN VALUES				113.9			58.7			64.0	

Table IV.56

Copper content of the leaves, stems and flowers of Helichrysum leptolepis samples collected at the Malachite Pan Area. 20/5/68.

Sample No.	MP.Grid m.NW.NE	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	STEMS % ash	STEMS ppm ash	STEMS ppm dry	FLOWERS % ash	FLOWERS ppm ash	FLOWERS ppm dry	SOIL ppm -80
2080	738.235	11.5	795	91.6	8.3	770	64.6	7.5	515	38.6	335
2081	730.230	9.6	515	49.5	7.9	505	40.0	7.0	400	28.2	310
2082	734.167	11.2	675	75.9	7.9	565	45.1	7.6	515	39.1	265
2083	740.142	12.3	550	67.8	7.9	580	45.4	8.7	525	46.0	290
2084	780.238	11.1	515	57.3	9.1	535	48.9	8.3	385	32.1	352
2085	830.286	13.8	1240	171.2	9.7	445	43.2	8.2	300	24.5	275
2086	732.270	12.2	605	74.2	8.1	580	47.3	8.0	450	36.1	240
2087	776.332	15.5	415	64.6	8.6	410	35.5	9.8	320	31.6	285
2088	788.380	13.0	980	127.9	8.3	795	65.9	8.5	605	52.3	320
2089	796.388	14.6	900	131.7	8.7	665	58.2	10.1	590	58.7	410
2090	813.390	13.3	965	128.9	9.6	840	80.7	8.7	700	61.2	270
2091	900.664	17.4	705	123.1	9.6	465	45.1	9.9	465	46.2	580
2092	948.675	9.1	1060	97.0	8.8	785	69.2	11.8	625	74.9	620
2100	987.710	26.7	490	131.1	7.5	330	25.0	16.0	425	68.2	310
2101	887.606	17.6	505	89.1	8.9	590	52.8	10.5	300	31.7	195
2102	918.535	20.1	785	158.3	10.4	365	38.1	11.7	330	38.6	420
2107	912.250	15.6	1400	218.9	9.8	885	86.9	9.1	705	64.3	280
2108	913.270	15.3	705	107.1	8.8	555	48.9	12.1	470	57.2	295
2109	815.45	18.1	705	127.8	8.3	635	53.2	12.3	350	43.2	300
2110	802.45	14.4	910	131.3	7.8	785	61.5	14.3	535	76.6	335
2111	715.22	16.6	660	109.7	7.5	545	41.3	13.4	495	66.5	270
2112	691.55	17.5	680	119.0	10.2	575	58.6	13.6	430	58.5	265
2113	667.70	16.4	645	105.9	8.7	635	55.2	13.9	510	71.3	310
2114	550.42	15.1	545	82.7	9.8	545	53.6	13.8	405	56.0	360
2115	505.48	17.7	555	98.2	8.4	505	42.7	12.2	475	58.1	320
2116	626.73	23.9	625	149.8	11.0	785	86.8	18.5	475	88.3	295
Minimum value				49.5			25.0			24.5	
Maximum value				218.9			86.9			88.3	
MEAN VALUES				111.1			53.6			51.8	

Table IV.57

Copper content of *Fimbristylis exilis* collected at the Pos and Copper Causeway Areas.

Sample No.	Location	% Ash	ppm Ash	ppm Dry	-80 Mesh
4902	Tr.30,208m.S	15.3	345	53.1	325
4903	Tr.30,208.10W	15.5	362	40.7	290
4904	Tr.30,208.15E	11.9	335	40.1	275
4905	Tr.30,443m.S	10.5	217	22.9	185
4906	Tr.30,495m.S	12.6	225	28.4	225
4907	Tr.30,265m.S	14.6	262	38.2	280
4908	Tr.30,39m.S	15.1	168	25.5	120
4909	C.C,266.50W	11.8	252	29.8	294
4910	C.C,257.58W	16.4	325	53.3	360
4911	C.C,242.42W	17.7	222	38.4	528
5816	Tr.30,208.20W	17.7	262	43.8	360
5817	Tr.30,208.25E	15.2	312	47.6	310

Table IV.58

Copper content of spot samples of Acacia giraffae, Acacia hereroensis, Albizia anthelmintica, Barleria lanceolata and Boscia albitrunca.

Sample No.	Location	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
Acacia giraffae								
4912	Okj.W	6.8	37	2.5	4.5	57	2.6	4
5798	MP. 960.150	5.5	77	4.3	7.5	55	4.1	15
5799	MP. 990.130	6.3	60	3.8	6.0	27	1.6	10
5800	MP. 995.160	8.9	37	3.3	9.9	27	2.7	15
5777	MP. 900.650	6.5	54	3.5	5.6	60	3.4	130
5782	MP. 980.850	4.8	38	1.9	7.1	44	3.1	315
Acacia hereroensis								
3518	MP. 826.40	5.8	157	9.1	3.6	260	9.5	210
3519	MP. 831.49	6.8	116	7.9	3.9	137	5.3	185
3520	MP. 830.53	7.3	140	10.2	4.6	170	7.7	190
Albizia anthelmintica								
3785	Esk. ridge	6.3	103	6.5	4.7	45	2.1	4
3786	" "	5.7	143	8.3	5.5	55	3.0	4
3787	" "	6.1	120	7.3	3.2	110	3.6	4
3788	" "	6.6	130	8.6	3.8	78	3.0	4
3789	" "	6.0	128	7.7	4.7	73	3.4	4
4860	Okj.W-Esk.B.	5.7	80	4.6	3.1	130	4.0	4
4861	" "	5.1	168	8.6	3.7	60	2.2	4
Barleria lanceolata								
4996	MP. 930.330	16.9	95	16.0	5.7	162	9.3	55
4997	MP. 925.335	16.0	105	16.8	6.9	162	11.2	35
4998	MP. 915.350	17.0	70	12.0	7.7	142	11.0	57
4999	MP. 940.365	19.7	77	15.1	9.7	130	12.1	42
5787	MP. 710.295	19.2	81	15.5	8.5	144	12.2	65
5788	MP. 705.290	18.6	81	15.1	8.1	123	10.0	50
4853	CC. area	17.6	55	9.7	3.8	162	6.3	7
4854	CC. area	14.0	75	10.5	3.7	145	5.4	7
4862	Okj.W-Esk.B	13.7	68	9.3	3.9	115	4.5	4
4863	Okj.W-Esk.B	15.3	55	8.4	2.3	182	4.7	4
Boscia albitrunca								
4979	MP.635.60	6.9	275	18.9	5.1	215	11.0	92
4980	MP.650.60	7.2	230	16.3	7.0	107	7.3	230
4981	MP. 650.70	10.5	72	7.6	3.9	295	11.4	180
4984	MP. 650.50	8.4	122	11.2	3.4	275	9.2	217
4985	MP. 690.70	7.7	157	13.1	5.0	130	6.6	142
4995	MP. 875.175	10.7	105	11.2	8.4	197	16.5	35
5790	MP.1110.820	12.7	185	23.5	5.8	115	6.7	28
5791	MP.1300.180	7.4	195	14.4	7.9	87	6.8	32
5792	MP.1300.200	10.4	67	7.0	6.4	72	4.6	35

Table IV.59

Copper content of spot samples of Catophractes alexandri, Combretum apiculatum, Commiphora pyracanthoides, Dichrostachys cinerea, Grewia bicolor and Grewia flavescens.

Sample No.	Location	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
Catophractes alexandri								
5793	MP. 180.145	8.3	142	11.8	3.7	400	14.8	20
5794	175.145	6.8	142	10.0	3.0	315	9.5	32
5795	160.140	5.9	157	9.3	3.4	295	9.9	25
5797	200.190	7.6	112	8.5	3.6	280	10.4	40
4986	770.60	9.7	162	16.2	3.2	275	8.7	175
5779	950.710	7.2	144	10.3	3.5	208	7.2	110
5780	960.730	6.4	160	10.2	3.9	160	6.2	77
5781	960.810	7.2	150	10.8	2.7	160	4.2	77
5783	988.860	7.0	202	14.1	2.9	265	7.6	220
Combretum apiculatum								
5820	Wtv.Berg	8.2	42	3.5	8.9	92	4.5	5
5823	" "	7.9	70	5.4	4.1	90	3.6	5
5824	" "	8.0	42	3.5	3.7	95	3.5	5
3790	Esk.ridge	7.3	113	8.2	4.9	100	4.9	4
3791	" "	6.2	102	6.4	3.7	98	3.6	4
3792	" "	6.4	88	5.6	4.3	85	3.6	4
3793	" "	6.1	105	6.4	5.6	80	4.6	4
3794	" "	6.2	78	4.8	6.2	60	3.7	4
Commiphora pyracanthoides								
4855	Okj.W-Esk.B	11.2	50	5.6	3.3	82	2.7	4
4856	" "	14.4	37	5.3	3.6	172	6.2	4
Dichrostachys cinerea								
4988	MP. 540.45	5.0	307	15.5	2.8	310	9.0	152
4989	MP. 740.290	6.4	223	14.3	3.2	259	7.9	82
3799	Esk.ridge	5.6	78	4.3	3.5	75	2.6	4
3800	" "	7.1	80	5.7	3.3	100	3.3	4
3801	" "	6.3	70	4.4	3.5	85	3.0	4
3802	" "	6.6	108	7.1	4.2	65	2.7	4
3803	" "	5.7	103	5.9	3.1	92	2.9	4
Grewia bicolor								
3795	Esk.ridge	7.8	90	7.2	4.6	85	3.9	4
3796	" "	7.6	80	6.0	4.7	74	3.5	4
3797	" "	7.6	95	7.3	3.6	110	4.0	4
3798	" "	8.3	70	5.8	5.3	48	2.5	4
4860	Okj.W-Esk.B	7.6	87	6.6	4.0	102	4.1	32
Grewia flavescens								
4857	Okj.W-Esk.B	7.4	120	8.8	3.3	140	4.5	25

Table IV.60

Copper content of spot samples of Ozoroa paniculosa, Rhigosum brevispinosum, Rhus pyroides, Terminalia sericea and Ziziphus mucronata.

Sample No.	Location	LEAVES % ash	LEAVES ppm ash	LEAVES ppm dry	TWIGS % ash	TWIGS ppm ash	TWIGS ppm dry	SOIL -80 mesh
Ozoroa paniculosa								
3531	MP. 507.56	9.8	80	7.5	3.8	140	5.4	185
4982	MP. 650.70	7.3	180	11.3	2.3	187	5.6	195
4989	MP. 520.50	7.8	175	13.6	4.5	242	10.8	360
4990	MP. 510.50	7.2	120	8.6	3.7	200	7.4	157
4991	MP. 505.55	9.9	92	9.1	3.1	120	3.7	315
4992	MP. 501.52	7.7	200	15.4	3.5	227	9.6	190
4993	MP. 485.50	6.7	90	6.0	5.1	165	8.5	70
4994	MP. 780.250	10.5	242	25.5	4.3	255	11.1	125
Rhigosum brevispinosum								
5819	Wtv. Berg	7.8	55	4.3	2.8	190	5.3	4
5820	" "	6.1	42	2.6	2.5	102	2.5	4
Rhus pyroides								
3524	MP. 725.30	5.8	260	15.1	2.4	253	7.3	265
3526	MP. 750.195	5.8	220	12.7	2.9	247	7.0	192
3527	MP. 755.186	5.4	117	6.4	3.0	117	5.3	155
3528	MP. 730.182	6.0	252	15.1	3.4	207	7.1	212
3529	MP. 780.195	5.1	315	16.0	3.0	165	4.9	245
3530	MP. 720.265	5.6	315	17.7	3.2	167	5.3	185
Terminalia sericea								
4971	Daheim	6.4	100	6.4	3.8	85	3.3	4
4972	"	6.3	80	5.0	7.4	95	7.1	4
4973	"	5.1	107	5.5	6.7	85	5.7	4
4974	"	9.5	47	4.4	7.4	95	7.0	4
4975	"	5.9	107	6.3	5.5	85	4.7	4
4976	"	6.3	85	5.4	4.0	82	3.3	4
4977	"	6.6	80	5.3	7.1	105	7.5	4
4978	"	5.5	117	6.4	7.1	112	7.9	4
5818	Western Okj.	4.9	70	3.4	6.7	110	7.0	4
5822	" "	4.9	65	3.2	6.9	32	2.2	4
5814	Wtv. Berg	5.5	87	4.8	8.1	87	7.0	4
5815	" "	5.6	75	4.2	6.2	102	6.4	4
5816	Okatjepuiko	5.2	118	6.1	5.8	107	6.2	4
Ziziphus mucronata								
3522	MP. 810.51	9.0	63	5.6	2.7	103	2.9	185
3523	MP. 775.75	8.5	130	7.2	2.6	654	17.2	245
5796	MP. 130.150	9.0	47	4.2	3.5	190	6.4	20
4983	MP. 650.50	9.2	122	11.2	3.4	275	9.2	190
5000	MP. 890.650	8.9	77	6.9	3.7	202	7.4	185
5778	MP. 990.705	10.5	60	6.3	2.9	223	6.5	365
5784	MP. 870.910	10.8	54	5.8	3.7	139	5.2	45
5786	MP. 740.420	11.0	65	7.2	4.3	175	7.5	110