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A STREAM SEDIMENT GEOCHEMICAL ORIENTATION SURVEY OF THE DAVENPORT PROVINCE, NORTHERN TERRITORY.

by

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ABSTRACT

A geochemical orientation survey of the Davenport Province in the Northern Territory, was undertaken in 1982. The aim was to develop an understanding of the mechanisms of secondary dispersion active in the area, and to determine which sampling media would be most effective in defining potential mineralisation. Soil profiles throughout the region are poorly developed and the immature skelatal soils and aeolian sands that characterise much of the area preclude soil sampling as a regional method. Rock chip sampling was also considered unsuitable for use in the area since, given the styles of known W, Cu, Bi, Mo, Au and U mineralisation (i.e. localised vein systems with weak alteration haloes), very high sampling densities would be required. It is believed that stream sediment sampling is the most effective regional geochemical method for use in this area although its effectiveness can be affected locally by the restricted size of many drainage systems, the dominance of quartzose lithologies and the heterogeneity of the geological terrain, which can render interpretation difficult.

Stream sediment samples, both sieved fractions and heavy mineral fractions, were collected in areas both remote from and adjacent to known mineral deposits. The main mineralisation styles can be detected by stream sediment (vein type U mineralisation was the exception) using sample spacings of 3 to 4 km for W and Sn, down to 0.5 km for associated elements, particularly Cu. Heavy mineral fractions may be more useful than sieved fractions in areas dominated by arenite lithologies.

1. **INTRODUCTION.**

1.1 **Objectives of Investigation.**

In 1981 the Bureau of Mineral Resources (BMR), in association with the Northern Territory Geological Survey (NTGS), commenced a regional geological survey of the Davenport Province to define the stratigraphy, structure, sedimentological history and tectonic setting of the Davenport Geosyncline. In the same year the BMR conducted an airborne magnetic-radiometric survey and, during 1981 and 1982, gravity traversing was carried out over most of the Province. A geochemical orientation survey, described in this record, was undertaken in 1982 to compliment the geological and geophysical studies in providing a better understanding of the geological framework and economic potential of the Davenport region.

The geochemical survey concentrated on stream sediment sampling from mineralised and potentially mineralised environments to assess:-

(a) the appropriate sampling medium to delineate the different styles of mineralisation (eg. W, Cu, Bi, Mo, Sn, Au and U),

(b) the mechanisms operating during secondary dispersion: in particular the role played by physical, chemical and organic processes in mineral-element dispersion, and

(c) the characteristics of secondary dispersion, including the selection of pathfinder elements and the density of sampling required to detect the mineralisation.

1.2 **Area of Investigation.**

The Davenport Province, located 180 km southeast of Tennant Creek, is confined to four 1:250 000 Geological Sheets - Bonney Well, Frew River, Barrow Creek, and Elkedra - which collectively are bounded by longitudes 133°30'E and 136°30'E, and latitudes 20°00'S and 22°00'S. During the BMR-

NTGS survey the area was remapped at 1:100 000 scale, with the boundaries of four special map sheets - Devils Marbles, Kurundi, Hatches Creek and Elkedra Regions - shown in Figure 1. Areas relevant to the geochemical orientation survey are shown by the smaller numbered boxes, with details of these sub-areas outlined in Table 1.

1.3 Climate, Vegetation and Soils.

The Davenport region has a semi-arid, tropical climate. The average annual rainfall of approximately 300 mm is largely restricted to the December-March period due to the increased activity of upper-level, moist, tropical air masses. The area is characterised by marked diurnal and seasonal fluctuations in temperature with the average maximum-minimum ranges for December and July being 38-24^{o}C, and 24-11^{o}C respectively (Slatyer, 1962).

The open grasslands of the study area are dominated by low laying varieties of spinifex and grasses with the latter more prevalent on the sandy valley flats. In areas of higher relief small eucalypts (snappy gum - E. brevifolia) occur in protected pockets, with isolated stands of acacia (ironwood - A. estrophiolata) and eucalypts (red gum - E. camaldulensis) characterising channels and braided streams (Perry and others, 1962). Soil developement throughout the region is poor with skeletal, stony lithosols showing little profile differentiation on areas of high relief, and thick red aeolian sands filling valleys. Wind and, during summer, water erosion are both prominent in the Davenport region with the drainage systems often acting as catchments for aeolian material which is then redeposited by the water.

1.4 Physiography and Drainage.

The physiography of the Davenport Geosyncline is largely controlled by the differential rates of erosion of the various rock types and the relationships of these rocks with the folded structures. The region is composed of two parallel northwest-southeast trending, positive relief systems; the Murchison and Davenport Ranges, with the Younghusband Range forming a westerly extension of the latter. Large anticlines and synclines, with steeply inclined axial surfaces and variable plunges, become more open in amplitude to the southeast with a consequent broadening of the higher relief terrain in this direction. Highest points of elevation are Mt Cairns (597 m - Kurundi Region Sheet) and Mt. Figg (521 m - Devils Marbles Region Sheet) with much of the Davenport region close to 500 m elevation (see Figure 1). Strike ridges and bevelled spurs of sandstone, quartzite, pebbly quartzite and conglomerate form the most prominent relief features with intermediate-mafic lava, pyroclastic flows and intrusions characteristically forming flat to gently undulating recessive terrains. Steeply dipping, tightly-folded, interbedded sequences of volcanics and quartzites locally form more rugged terrains. Carbonate and argillite sediments are invariably recessive and often masked by lava flows or laterite cover. Most granite complexes have extensive, shallowly dissected pavements with spectacular tor development, notably on the Stuart Highway at the Devils Marbles National Park. Granites within the geosyncline form small stock like bodies, while those marginal to the main area of outcrop are more extensive areally. Cuestas and mesas of early palaeozoic basinal sediments show greatest development at the southeastern end of the ranges with semi-desert, low sand dune expanses masking the greater portion of the Georgina and Wiso Basins.

Drainage in the Davenport region is dominated by two systems; the east-flowing Elkedra River in the south, and the north-flowing Frew River on the northeastern flank of the Murchison Range. The remainder of the outcropping area is characterised by simple rectangular drainage systems which become dendritic near washout flats. The northwest-southeast rectangular drainage pattern is largely controlled by long sinuous strike-line ridges of sandstone and quartzite which locally inhibit the effectiveness of stream sediment surveys due to preferential dissection of the terrain. Davenport stream sediment sampling is also hindered by confined catchment areas, the short dispersive trains of most tributaries, and the paucity of fine detritus within the drainage (due largely to the dominance of quartz rich rocks thoughout the region as opposed to argillaceous lithologies which usually weather to clay detritus). Most creek systems terminate in sandy flats within some hundreds of metres of their sources and thus stream selection was often determined in the field. The longer drainage systems, which offered greatest scope for the study of secondary dispersion from mineralised environments, included a tributary of Mia Mia Creek draining the Copper Show Mine, and Wauchope Creek draining the Wauchope Wolfram Field. Active dissection of the catchment areas is confined to the summer wet season of about 30 days duration, hence the "monsoonal" character of the area may have the effect of flushing some light detritus out of the drainage systems. All streams are ephemeral with permanent waterholes confined to the largest creeks and rivers.

2. SAMPLING AND LABORATORY METHODS.

Stream sediment sampling, incorporating both sieved fractions and heavy mineral concentrates, is considered the most useful technique for the regional study of mineral-element dispersions within the Davenport region. Immature soil profiles, with a possible high aeolian component, preclude soil sampling as a regional geochemical method. Also, active chemical dispersion in arid soil environments, as occur in the Davenport Province, is often limited due to high soil pH causing the immobilisation of some elements (eg. Sn, W, Pb, etc) in resistant minerals. The styles of known W, Cu, Bi, Au and U mineralisation (i.e. localised small-scale, vein systems with weak hydrothermal alteration haloes) suggest that rock chip sampling would need to be of high density to detect and study these types of mineralisation. Tungsten and, in particular gold, mineralisation are generally heterogeneous throughout the veins, thus adequate geochemical evaluation would require channel chip sampling.

2.1 Field Procedures.

Collection of samples from preplanned sites (utilising 1980 1:25 000 and 1:50 000 colour, and 1963, 1:80 000 RC9 black and white, aerial photographs) was carried out using 2 teams (1 geochemist and 1 fieldhand per team) in 4-wheel drive vehicles. Each 3-5 kg sample was a composite from several spots in the stream bed, normally within a 50 m radius. This was due both to the paucity of fine grained active sediment, and the need to obtain the most accurate geochemical representation of the drainage system. Natural sediment traps, such as depressions in rock pavements and "sediment tails" on the downstream side of spinifex bushes (care was taken to avoid organic matter), were found to be the best sources of fine material. Most drainage on lower relief areas is of the braided type, so that the position of active sediment was often variable within the channel. Descriptions of each sample and sample site were recorded on BMR field data sheets. Coarse material (i.e. >1 mm) was separated off and discarded in the field using a pair of mechanical sieve shakers, with the remainder of the sample, generally 1 to 2 kg in weight, double bagged, boxed and submitted to the BMR laboratories for analysis.

A total of 417 stream sediment samples were collected during the six week program. Sample density was generally 1 to 2 samples/km^2 but in the major mineral fields, blanket coverage of up to 6 samples /km^2 was attained. Contamination from past mining activity is greatest at the two largest fields - Hatches Creek and Wauchope - and it is difficult to assess the impact that this has had on secondary dispersion. The minerals of major economic interest - wolframite, cassiterite, gold, and, to a lesser degree, scheelite - are chemically stable in most surficial environments; thus the increased exposure of these minerals to the weathering environment by man's activity will have little effect on the hydromorphic (chemical) dispersion of most economically significant elements. At the Copper Show Mine in the Hatches Creek Field, the breakdown of sulphides in mine dumps may be inducing an acidic environment, which, in turn, increases the solubility of the tungsten and copper minerals.

2.2 **Sample Preparation Methods.**

All sample preparation and analysis were carried out in laboratories of the Bureau of Mineral Resources, Canberra. A major aim of the orientation survey was to determine which size fraction or fractions (having at least 50 g sample weight) would show the greatest geochemical contrast, that is the difference (or ratio) between anomalous and background populations. A stack of 7 aluminium-bodied sieves fitted with 710 um, 500 um, 355 um, 250 um, 180 um, 118 um and 75 um mesh nylon bolting cloth was used for samples from the major mineral fields; Hatches Creek, Wauchope, and the Munadgee Uranium Prospect. The geochemical contrast for most elements was greatest in the -75 um and +250-500 um size fractions (the significance of this is discussed in section 4.3) and all subsequent sieving of Davenport samples was confined to these two size intervals. Sieving time for most 3-5 kg samples using a mechanical sieve shaker was 3 to 4 minutes; however this increased considerably for samples with a greater mid-size fraction content (i.e 180-355 um). A representative sample of each sieve fraction was submitted for X-ray fluorescence and atomic absorption analysis. The balance of the sieved fractions was combined and passed over a Wilfley table jig, and the light fraction discarded. The "rough concentrate" was passed through a separating funnel containing tetrabromoethane (SG - 2.96) which removed most of the quartz, feldspar and solid aggregates of mica. The concentrate was thoroughly washed with acetone, dried and stored in a glass vial (plastic vials should not be used as acetone coated grains become impregnated on the vial walls). Magnetic and non-magnetic heavy minerals were separated using a Carpco Magnetic Separator. A relatively low amperage of 0.3 A across the magnetic poles was employed due to the moderate magnetic susceptability of wolframite and a wheel speed of 80 to 120 rpm was used depending on the quantity of sample. Repeated passes through the separator removed nearly all magnetite, most martite, and some ilmenite, tourmaline, mica and amphibole.

The magnetic and non-magnetic heavy mineral fractions (averaging 2-5 g weight) were retained for visual examination, with the non-magnetic fraction also scanned with shortwave ultraviolet light for the presence of scheelite, and carbonate and phosphate minerals. Small pieces of white plastic from the vial lids reflected a similar white-blue coloured light to that of fluorescing scheelite, but these could be readily removed by blowing gently over the concentrate. Non-magnetic fractions were also scanned with a portable gamma-ray scintillometer. Heavy mineral grains that could not be identified under a stereoscopic microscope were hand picked, immersed in refractive index oil (n_D = 1.5), crushed with an agate pestle, and examined under a petrological microscope. Any unknown grains were identified using X-ray diffraction methods, provided enough sample was available (20 to 30 grains generally provided a meaningful diffraction pattern). Cassiterite was readily identified by immersing the suspected grains in a droplet of dilute HCl on a zinc plate and noting any coating of pale grey metallic tin on the grains. Sample preparation and laboratory methods used in the Davenport survey are summarised in the flow chart shown in Figure 2.

2.3 **Analytical Methods.**

Sieved stream sediment samples were analysed for Ag, Be, Co, Cr, Cu, Fe, Li, Mn, Ni and Zn by atomic absorption spectrophotometry (AAS) and for As, Bi, Mo, Nb, Pb, Rb, Sn, Sr, Th, W, U, Y and Zr by X-ray fluorescence spectrometry (XRFS). The non-magnetic fractions of heavy mineral concentrates from the Great Davenport and Power of Wealth areas were semi-quantitatively scanned for Ag, Au, Bi, Co, Cu, Ni, Pb, Sb, Sn and V by optical emission spectrography (OES).

AAS Sample (1 g) was heated on a water bath with perchloric (5 ml - 1:1) and hydrofluoric (10 ml - 40%) acids in a platimum basin. When almost dry the sample was transferred to an electric hotplate and fumed to dryness. The residue was dissolved in hydrochloric acid (5 ml - 1:1) and made up to 25 ml in a volumetric flask.

Each sample was analysed for the 10 elements listed above using a Varian AA-6D spectrophotometer interfaced with a Hewlett-Packard 1000 computer. Operating conditions are shown in Table 2. Non-atomic absorption corrections for Co, Ni and Zn were made at the analytical wavelengths using a deuterium continuum lamp.

XRFS. Sample (12 g) was mixed with a binding agent (MOWIOL 2345, 8-88 by Hoeschist Australia P/L: 35 drops of 7% solution in alcohol [1 part] and water [5 parts]) and pressed in a 40 mm diameter die to 2-3 tons pressure. The pellet was air dried before analysis.

Each sample was analysed for the 13 elements listed above using a Phillips PW 1450 X-ray spectrometer with 60 position sample changer and interfaced with a Hewlett-Packard 9820A calculator. The method of Norrish and Chappell (1977) was used to convert total accumulated counts to element concentrations. Empirical interfering element corrections were applied as necessary and mass absorption corrections were measured directly using the Compton scatter method. Operating conditions for the two analytical programs, namely:-

Program 1:- Th, Rb, Pb, Y, U, As, W, Bi
Program 2:- Sr, Sn, Nb, Zr, Mo

are shown in Table 3.

OES. Sample was ground, mixed with graphite (1:1) and loaded into a preformed graphite electrode. The electrode was arced on a Hilger Large Quartz plate spectrograph for at 6 amps electrode current for 1 minute, and then at 12 A until completion. Each sample was arced twice covering 2 wavelength ranges (550-350 nm and 400-250 nm) and the spectra were compared with standard plates using a Jarrell-Ash plate comparator.

3. GEOLOGY AND MINERALISATION.

The geological and economic features of the Davenport region have been discussed by a number of investigators, notably: Sullivan (1952), Ryan (1961), Smith and others (1961), Smith (1964, 1970) Smith and Milligan (1964, 1966), Roarty (1977) and more recently by Blake and Wyche (1983), Blake and others (1983, 1983a), Blake and Horsfall (1984), Stewart and Blake (1984), and Wyche and Blake (1984).

3.1 Geology.

The Davenport Geosyncline, which covers an area of at least 40 000 km^2, forms a northwesterly trending Proterozoic terrain linking the Proterozoic Arunta Block to the south and Tennant Creek Block to the north. The easterly and westerly margins are masked by Lower Palaeozoic platform covers of the Georgina and Wiso Basins respectively. Stewart (1983) believes the ensialic setting and the predominance of early mafic volcanism indicate that the geosyncline represents a mantle-activated, ensialic, cratonic rift, with subsidence related to replacement of light crustal rocks by invasion of denser dyke rocks within a fractured, extended lithosphere.

In the geosynclinal succession, the Hatches Creek Group unconformably overlies the Warramunga Group, the oldest rocks recognised in the Davenport area. This basal group, which extends north to Tennant Creek and probably represents the facies equivalents of Arunta Block successions, consists of tightly folded greywacke-siltstone sequences with interbedded jaspilitic-chert horizons within the Davenport region. Felsic volcanics belonging to the Bernborough Formation of the Warramunga Group north of Tennant Creek, have been U-Pb zircon dated at 1870 Ma (Black, in press).

The Hatches Creek Group consists of a shallow water accumulation of intercalated sediments and volcanics younger than 1870 Ma (lower limit determined by underlying Warramunga Group) and older than 1640 Ma (Rb-Sr whole rock, approximate age of Elkedra Granite which intrudes the Hatches Creek Group; Black, BMR, personal communication, 1983). The sediments are dominantly quartz arenites, feldspathic quartz arenites, conglomerates with minor argillites, and carbonates, while the volcanics form a bimodal mafic, felsic suite of both lava flow and pyroclastic origin. Blake and others (1983a) have subdivided the Hatches Creek Group into the Ooradidgee Subgroup (Lowest Subgroup), the Wauchope Subgroup (Middle Subgroup) and the Hanlon Subgroup (Upper Subgroup) which collectively contain twenty formations and two members totalling at least 10 000 m thickness. A breakdown of these subgroups is shown in Table 4.

The Ooradidgee Subgroup, which is retricted to the central regions of the geosyncline, is composed of recessive felsic and basaltic volcanics, ridge forming quartz arenites, feldspathic arenites, and minor conglomerate. The Ooradidgee Subgroup differs from the two younger subgroups in its greater proportion of volcanic rocks, the largely fluvial character of the sediments (Wauchope Subgroup-mixed marine and fluvial; Hanlon Subgroup-marine; Blake and others 1983a) and the interfingering relationships of volcanics and sediments (both younger subgroups are more regularly layered and display little facies change). The Wauchope Subgroup, consisting of lithic arenites, feldspathic arenites, pebbly arenites, slates, dolomites and minor felsic and mafic volcanics, is more extensive in distribution and locally overlaps the Warramunga and Arunta basements where the Ooradidgee Subgroup is absent. Arenites, conglomerates, carbonate beds and mafic lavas compose the Hanlon Subgroup which is prominent in the eastern part of the geosyncline.

Multiple dyke and sill like intrusions of granophyre, feldspar porphyry, dolerite and gabbro occuring within the Ooradidgee and the lower formations of the lower Wauchope Subgroup, predate the folding of the Hatches Creek Group. Muscovite and muscovite-biotite granites form extensive intrusions marginal to the geosyncline, and smaller stock like bodies within the geosyncline. Most notable complexes are the Devils Marbles (Devils Marbles Region Sheet, GR 265258), Hill of Leaders (Kurundi Region Sheet, GR 630540) and Elkedra (Elkedra Region Sheet, GR 501254) Granites, with the latter two in particular displaying local greisenisation and quartz-aplite veining. Contact aureoles surrounding the intrusions range in thickness from less than 1 m to over 100 m. Regional metamorphic grade throughout the Davenport Geosyncline is of lower greenshcist facies, but upper greenschist or lower amphibolite facies may have been locally attained (Blake and Wyche, 1983). Diagnostic contact or regional metamorphic assemblages are rare throughout the Davenport region due to the dominance of arenite lithologies, the intensity of deuteric-retrograde metamorphic alteration processes, and the low grade of regional metamorphism.

3.2 Mineralisation.

Mineralisation within the Davenport Geosyncline indicates the region is a tungsten province with associated Au, Cu, Bi, Mo, Pb and U mineralisation. Metal price has strictly governed the occurrence of W mining at the two larger fields, Hatches Creek and Wauchope. Intermittent production, since their discoveries in 1913 and 1917 respectively, has collectively amounted to approximately 4,500 tonnes of wolframite and scheelite concentrate (62 to 65% WO_3), with 69.9 tonnes of Cu and 5.7 tonnes of Bi concentrates also produced at the Hatches Creek Field (Sullivan, 1952; Ryan, 1961).

3.2.1 Tungsten

Tungsten mineralisation displays various styles and settings, ranging from concordant vein swarms within sedimentary-volcanic and/or hypabyssal hosts, to the more proximal setting of simple vein systems within the upper levels of granititc bodies. No skarn or stratiform (exhalative) styles of W mineralisation have been recognised at any of the mining centres, which include (1) Hatches Creek (Hatches Creek Region Sheet, GR 200860) (ii) Wauchope (Devils Marbles Region Sheet, GR 305215) and (iii) Hill of Leaders-Mosquito Creek (Kurundi Region Sheet, GR 630535).

The Hatches Creek Wolfram Field, which includes the Wolfram Hill group of mines 4.5 km further to the north, is the largest centre both in terms of metal production and intensity of mining activity. The individual mines form two discrete clusters - the Hit or Miss Gully, Dooleys Ridge and Treasure Gully area of Hatches Creek, and on the flanks of Wolfram Hill and Poseidon Hill to the north. The tight spatial distribution of the mineralisation is believed to be significant in relation to the origin of the W (this is discussed in section 3.3). The W mineralisation, with associated Cu, Bi, Mo, and trace Sn, Au and As, generally occurs within steeply dipping quartz lodes less than 0.5 m wide, but having strike lengths of up to several hundreds of metres. The larger deposits (200+ tonnes WO_3) are generally found in mixed host lithologies of Treasure Volcanics, Kurinelli Sandstone and Taragan Sandstone, or in dolerite and gabbro intrusives, while the smaller deposits are often confined to the sediments. As indicated by Table 5, the lodes have little stratigraphic control but are structurally controlled occurring along shears, in fracture zones, or at intersections of favourable host lithologies. Minor, conformable lodes also occur within the Warnes Sandstone Member of the Kurinelli Sandstone Formation.

Although the dominant W mineral is wolframite, scheelite becomes prominent where gabbro intrusives are the host. Ryan (1961) has recognised the following minerals of economic significance at Hatches Creek: wolframite, scheelite, tungstite, cupro-tungstite, native bismuth, bismuthinite, bismutite, (?) bismite, chalcopyrite, chalcocite, covellite, bornite, tetrahedrite, atacamite, malachite, azurite, chrysocolla, cuprite, native copper, molybdenite, wulfenite, galena, gold and cassiterite. Gangue minerals include quartz, muscovite, biotite, feldspar, sericite, epidote, tourmaline, zircon, garnet and fluorite. Mining activity throughout the field has been at relatively shallow depths with the primary sulphide zone (chalcopyrite-pyrite-bismuthinite) reached only at the Pioneer Mine (63 m level) and the Green Diamond Mine (41 m level).

The mineralisation at Wauchope (wolframite, trace scheelite, pyrite, chalcopyrite, molybdenite and bismuthinite, with gangue quartz, muscovite, sericite, topaz, fluorite and limonite; Sullivan, (1952)) contrasts with that of the Hatches Creek Field in that the quartz lodes are generally conformable with the Hatches Creek Group sediments, and no volcanic or dolerite-gabbro hosts are present. Host rocks include gently dipping silty mudstones, laminated siltstones with sandy lenses, arenites and various hornfelsed variants of these, which collectively belong to the Taragan Sandstone Formation of the Ooradidgee Subgroup. The mineralised lodes average 0.3 to 0.5 m in width and show persistence along strike, with vein systems extending up to 800 m in length and individual veins attaining 250 m strike length. Kaolinisation wallrock alteration is locally intense, with the hydrothermal system also introducing tourmaline, topaz and haematite. Muscovite-biotite granites of the Devils Marbles Complex, located 4.5 km to the northwest of the field, are the closest granitoids known in the area.

Tungsten mineralisation at the Hill of Leaders-Mosquito Creek Field is confined to quartz lodes occupying shear zones within porphyritic muscovite-biotite granites of the Hill of Leaders Complex. The lodes are narrow, less than 0.20 m wide, spatially distant, and with patchy scheelite and wolframite distribution. No production records exist for the area but total tonnage would be considerably lower than either Hatches Creek or Wauchope.

Small, isolated W mines also occur in the Davenport region and include the Juggler Mine (Elkedra Region Sheet GR 480250), where narrow quartz-tourmaline lodes occur within a "greisenised" leucocratic variant of the Elkedra Granite, and the Woodenjerrie Mine (Hatches Creek Region Sheet GR 279369), where minor production has come from wolframite bearing quartz veins in Warramunga Group greywackes and siltstones.

3.2.2 **Gold**

Gold mineralisation is widely distributed throughout the southeast of the Davenport Geosyncline, but, with the exception of the Kurinelli Goldfield (Hatches Creek Region GR 041207) which has a total recorded production of 13.6 kg (Roarty, 1977), all deposits are isolated and of extremely low tenor. Despite their crosscutting nature, the auriferous quartz lodes show a narrow stratigraphic constraint, occuring only in the two lowest sedimentary formations of the Hatches Creek Group (i.e the Kurinelli Sandstone and Rooneys Formations) and in doleritic and gabbroic sills (see Table 5). It is possible that the gold mineralisation represents a lower Hatches Creek Group age, and that remobilisation has been initiated by mafic intrusion, or by a later folding event. Previous investigators have considered that due to the close spatial association of gold with gabbroic and doleritic intrusives (although this was not observed at the Power of Wealth Mine, and the Great Davenport and Cairns Prospects), the gold has been derived from a mafic igneous source of a younger age than the Hatches Creek Group.

The stream sediment survey concentrated on the two largest mines outside the Kurinelli Field (stream sediment sampling is not suitable in this region due to the low relief and the extensive aeolian flood plains), the Great Davenport Prospect and Power of Wealth Mine (Kurrundi Region Sheet GR 972055 and GR 544380 respectively). Both these deposits have similar geological settings with simple quartz lode systems occurring in arenaceous sediments of the Kurinelli Sandstone Formation. At Great Davenport the quartz lode occurs at the intersection of a north-northeast trending fault and an arcuate anticlinal axis plunging to the west-northwest. Flake and coarse gold, the latter associated with pyrite and pyritic boxworks, is of patchy distribution throughout the reef. The total recorded production of 4.7 kg (Smith, 1970; Roarty, 1977) seems excessive given the amount of workings and style of mineralisation at the prospect, and may be questionable. Six kilometres southeast of the Great Davenport Prospect, the Cairns Gold Prospect (Hatches Creek Region Sheet GR 021018) consists of thin quartz and quartz-haematite-magnetite veins within altered porpyritic granophyre, and arenites and siltstones of the Kurinelli Sandstone Formation.

The Power of Wealth mineralisation, situated on the eastern limb of a north-south trending anticline, is located at the centre of an area of intense quartz veining. The orientation of these vein swarms (i.e. northeast-southwest with a second set trending just west of north) appears to be controlled by fault fracture systems of the region. The Power of Wealth lode, trending just west of north, is parallel with the axial plane of the regional anticline, and thus there appears to be some structural control on the emplacement of the mineralisation. Mineralisation at the surface is poor, with most development confined to the 30 m level where even the most intense mineralisation is patchy and discontinuous.

3.2.3 Minor Deposits and Prospects

Although secondary Cu mineralisation is commonly associated with W in the quartz vein systems at Hatches Creek (Copper Show Mine in particular) and Wolfram Hill, it is only a minor to trace component at the other W fields. Chrysocolla, covellite and chalcocite have been reported in amygdaloidal mafic volcanics of the Edmirringee Formation (20 km southeast of Kurundi Homestead), the Treasure Formation (Hatches Creek Region Sheet GR 095976) and the Kundinga Basalt (Hatches Creek Region Sheet GR 376875). This style of Cu mineralisation, which appears to have little economic significance, is probably related to dewatering, leaching and precipitating proceses during the early phases of greenschist metamorphism.

Autunite, torbernite, and carnotite mineralisation occurs within a sheared porphyry intruding the Warramunga Group at Munadgee (Kurundi Region Sheet GR 562492), and minor Pb production has been derived from galena-quartz veinings within the Edmirringee Basalt at the Silver Valley mine/prospect near Murray Downs homestead (Elkedra Region Sheet GR 403773).

3.3 Origin of Tungsten Mineralisation.

The W mineralisation at both Hatches Creek and Wauchope displays many features consistent with epigenetic W-Sn-F (+-Be, Mo, Bi, Zn, Cu and Pb) quartz vein stockworks related to a granitic source (Type 1b. subdivision of Australian Tungsten Deposits; Kwak and others, 1982). However, no proximal granitic source has been recognised at either field. Ryan (1961) suggested that the mineralising fluids of the Hatches Creek mineralisation were derived from an extension of a granite that outcrops 6 km to the south of the Hatches Creek Field (Hatches Creek Region Sheet GR 185805). This is supported by Blake and Wyche (1983) who believe that tourmaline in the felsic Treasure Volcanics at Hatches Creek is porphyroblastic in origin, resulting from a nearby granite. At Wauchope the Devils Marbles Granite Complex, located 4.5 km to the northwest, is the closest granitic complex to the mineralisation. A small quartz-wolframite lode occurs within this granite near Dixon Creek. Kwak and others (1982) note that vein deposits, similar to Hatches Creek and Wauchope, generally occur within 500 m of the intrusive contact and are related to cupola protuberances of Ca-poor, mafic-poor, ilmenite bearing, leucocratic A or S type adamellites and granites. A surprising feature of both the Hatches Creek and Wauchope Fields is the absence of greisenisation and paucity of hydrothermal alteration associated with the vein systems. Kaolinisation and sericitisation appears to be more intense and widespread within the Wauchope Field, but more localised at Hatches Creek. The absence of intense vein alteration may be attributed to the distance of the vein systems from the granitoid source, which results in a lowering of the P/T conditions of the hydrothermal system, and to the low permeability-porosity of the arenaceous country rocks which may retard fluid-volatile movement. Tourmaline and topaz (as shown by the heavy mineral survey) are ubiquitous throughout both fields and are diagnostic of vein systems of hydrothermal origin.

The style of mineralisation at both Hatches Creek and Wauchope, the mineralogy of the vein systems, the strong structural control, the weak stratigraphic constraints, and the spatial clustering of the lodes (due to upward projection of vein systems from granite cupolas at depth) collectively suggest that the tungsten is derived from a proximal granitoid source. Perhaps significantly, the Hatches Creek Field occurs near the axial plane of a large open anticline which coincides with the intersection of two major fault systems, trending northeast-southwest and west northwest-east southeast (see Hatches Creek Region Sheet). This locus of increased deformation and shearing may have provided the "plumbing" necessary for the ingress of mineralising fluids.

There is geophysical and some geological evidence to suggest that a large subsurface granitoid body may exist east of Hatches Creek, stretching north to Teatree Creek (Hatches Creek Region Sheet GR 480300), and south to the Elkedra Granite (Elkedra Region Sheet GR 501254). Regional gravity coverage of the Davenport - Barrow Creek region (Bonney Well, Frew River, Barrow Creek and Elkedra 1:500 000 BMR Bouguer Anomaly Sheets, Reprinted 1970) shows that the Archaean at Barrow Creek and the Proterozoic terrains elsewhere have well defined gravity highs, while nearly all granite complexes coincide with negative gravity anomalies. However, on the Frew River Bouguer Anomaly Sheet, where the Proterozoic swings to the north-northeast (i.e. from immediately east of Hatches Creek to the northeastern corner of the Hatches Creek Region Sheet), a broad gravity low zone is present where a high would be expected. The inference is that the Hatches Creek Group rocks are relatively thin, and may be underlain by a granitoid body. The use of gravity lows to trace subsurface mineralised granites has been widely used in Scotland (Caledonide Granites) and Cornwall (Hercynian Granites) (Plimer, 1980). Coinciding with the gravity low described above is an aeromagnetic low of similar configuration (Elkedra and Frew River 1:250 000 BMR Total Magnetic Intensity Sheets, 1966 and 1967). Vein type W and Sn deposits related to A or S type granites contain primary ilmenite or secondary rutile and no magnetite,and are therefore characteristically non-magnetic. Perhaps significantly, the western margin of the coincident gravity-magnetic low zone occurs along a northeast-southwest line between the Wolfram Hill and Hatches Creek mines (see Figure 3) and thus the postulated subsurface granite contact is proximal to both mineral fields.

Available geological information shows some support for the above model with granite outcrops occurring near the margins of the gravity-magnetic low zone near Teatree Creek, and south of Hatches Creek (Hatches Creek Region Sheet GR 485270 and GR 185805 respectively), at the Elkedra Granite (Elkedra Region Sheet GR 501254) and as greisen within Mia Mia

Volcanics (Hatches Creek Region Sheet GR 185805). It is possible that the change in strike direction of the Hatches Creek Group rocks, immediately east of Hatches Creek, may be related to the doming of a large granite body where the upper contact surfaces tilt off to the southeast.

An alternative is that the W is derived and remobilised from an Arunta aged basement (the Arunta is an extensive tungsten province in central Australia). This however, seems unlikely in view of the style and mineralogy of the vein deposits and the known tungsten-granite associations of the Devils Marbles, Mosquito Creek-Hill of Leaders and Elkedra Complexes.

3.4 **Potential for Tungsten Mineralisation.**

The Davenport-Murchison Ranges area has received limited company exposure in relation to its W potential. Most prospects in the region were discovered and worked by prospectors with company involvement limited to the subsequent evaluation of the mineralised areas. The style of W mineralisation that has been exploited most is the coarse grained wolframite-quartz lode which forms positive relief features which are readily identified by the prospector. Little scope exists for finding new vein W deposits that would be of interest to large syndicates or companies. In Australia mineral deposits of this style are of low tonnage-grade status. An exception is Mt. Carbine, Northern Queensland (a Palaeozoic aged analogue of Davenport) where, by virtue of photometric ore sorting and bulk mining methods, the deposit has been economic.

Skarn W deposits, which are generally confined to well defined metallogenic provinces and are associated with base-metal, intrusive related ores, represent some of the largest W deposits in the world. These deposits are generally related to fractionated granodioritic to monzonitic plutons of I type affinity, often intruded into intercalated carbonate-pelite sediments. The magnetite bearing granitoids are not especially enriched in W but are often spatially associated with minor vein W, Cu, Pb, Zn, Ag and Bi mineralisation. Granites within the Davenport region are muscovite and/or biotite types (hornblende-magnetite bearing I type variants are absent), have narrow contact aureoles, and consequently appear unfavourable for skarn tungsten mineralisation. Compounding this is the paucity of carbonate lithologies in the Hatches Creek and Warramunga stratigraphies.

Stratiform or exhalative scheelite mineralisation is believed to offer greater potential for a large tonnage tungsten deposit within the Davenport region. This style of mineralisation has received little attention in Australia and because fine grained scheelite is difficult to recognise, large surficial deposits could have been undetected by the prospector. Stratiform scheelite mineralisation occurs within calcsilicates or siliceous chemical sediments, often in close spatial association with mafic-ultramafic volcanics. The scheelite may display temporal and lateral facies relationships with exhalative base-metal mineralisation. Despite the shallow water nature and low metamorphic grade of the Hatches Creek stratigraphy, (exhalative scheelite mineralisation is often related to deep water sediment-volcanic accumulations of amphibolite metamorphic facies), cherts and non-detrital quartzites intercalated with mafic volcanics, or carbonate facies of the Frew River and Lennee Creek Formations, may be prospective for fine grained versions of stratiform W mineralisation, particularly since this style of mineralisation is known in the nearby Jervois-Bonya district of the Arunta Block.

3.5 Behaviour of Tungsten Minerals in the Weathering Zone.

Although more than 20 species of W bearing minerals are known, only the three minerals of the wolframite group (hubnerite-$MnWO_4$, wolframite-$(Fe,Mn)WO_4$ and ferberite-$FeWO_4$), and scheelite ($CaWO_4$) are of economic significance. The secondary W minerals - tungstite (H_2WO_4), stolzite ($PbWO_4$) and cuprotungstite ($Cu_2WO_4(OH)_2$) - may form minor constituents of the oxidized zones. Despite the prominence of W in geochemical surveys, many aspects of its secondary dispersion are poorly understood.

It is generally recognised that although wolframite and scheelite are fairly insoluble at the pH range of surface waters, they are slowly attacked by acidic surface waters, in particular near weathering sulphide deposits. Scheelite is believed to be more soluble under acid conditions than wolframite, although oxidation of the latter is facilitated by the presence of iron & manganese. Tungsten released by acid attack is probably partly dissolved as HWO_4^-, and partly converted to some form of tungstic oxide (tungstite, hydrotungstite, or ferritungstite-$Fe_2(WO_4)(OH)_4.4H_2O$). If Pb or Cu sulphides are present, the W may form stolzite, cuprotungstite or be a minor constituent of wulfenite ($PbMoO_4$) or vanadinite ($Pb_5(Cl(VO_4)_3)$)

(Krauskopf, 1970). Studies by Dekate (1967) in India show that W released by acid attack under semi-arid conditions forms anthoinite ($Al(WO_4)(OH).H_2O$), cuprotungstite, and ferritungstite. In a warm humid climate tungstite or hydrotungstite will form if sulphides are present, or else tungsten will be adsorbed on iron and manganese oxide in the absence of sulphides. Varlamoff (1971) believes that under hot, humid tropical and equatorial conditions the dispersion of tungsten does not start with the primary minerals but with their alteration products, namely anthoinite, ferritungstite, hydortungstite and tungstite. These alteration products, upon complete pulverisation or dissolution, are assimilated into the finest fraction of the eluvium and dispersed for tens of kilometres in the alluvial systems. The mechanical resistance of wolframite and scheelite is greatly reduced by the presence of alteration products and subsequently dispersion of these minerals is confined to a few hundred metres of their source.

Most alkaline solutions have little effect on W minerals although wolframite may be partialy soluble under strongly alkaline conditions. The general chemical stability under most conditions and high specific gravity of wolframite (SG increases from 7.12 to 7.51 with increasing Fe content) and scheelite (SG 6.10, which decreases with increasing substitution of Mo) suggest they should form placer accumulations, although the strong cleavage and brittle nature of these minerals renders them liable to rapid mechanical breakdown during transportation. Despite its physical vulnerability, detrital scheelite has been reported occurring more than 3 km downstream from calcsilicate hosted mineralisation in northeastern Portugal (Santos Oliveira, 1982), and scheelite and hubnerite grains persist for more than 50 km from tungsten deposits within the Front Range, Colorado, USA (Theobald & Thompson, 1959). However the claim by Zeschke (1961) that scheelite is transported over 1500 km by the Indus River in Pakistan seems unlikely.

Geochemical surveys involving studies of W dispersion have been widely used throughout Europe and parts of central Africa. However, despite a better understanding of W behaviour in recent years, documented studies of its secondary dispersion are not abundant. Santos Oliveira (1982), using statistical and factor analysis of stream sediment data, demonstrated that Cu, Pb, Zn, Ni, Co, V and Cr were suitable pathfinder elements for calcsilicate hosted scheelite mineralisation in Portugal. Theobald & Thompson (1959) and Stendal (1978) successfully used heavy mineral stream sediment surveys to delineate new W deposits in Colorado, USA and southwest

Norway respectively, and Dekate (1967) and Varlamoff (1971) investigated the hydromorphic dispersion of W minerals in India and central Africa respectively. Cachau-Herreillat and Prouhet (1971) utilised a combined soil and stream sediment survey to define skarn scheelite deposits within the French Pyrenees, and Helman and Webb (1957) undertook one of the earliest soil surveys involving a vein ferberite deposit in Uganda. Quin and others (1974), in a biogeochemical survey, demonstrated that the W content of ash from shallow rooted tree ferns in New Zealand correlated well with the W content of soils superimposed on vein scheelite-wolframite mineralisation.

4. DISCUSSION OF RESULTS.

4.1 Comparison of Channel and Bank Sampling.

Two suites of corresponding bank and channel samples were collected along Wauchope Creek (major drainage system of the Wauchope Wolfram Field) and a tributary of Mia Mia Creek (draining the Copper Show Mine at the Hatches Creek Wolfram Field) to determine relationships between element dispersions and the sample medium, and to assess the application of bank sampling as a regional geochemical method. The elements of major economic interest (i.e. W, Sn and Cu in the -75 um size fraction) are compared for bank and channel samples in Table 6.

4.1.1 Tungsten

Tungsten shows considerable variation between the bank and channel samples for Wauchope Creek, with the latter consistently higher except at low W levels (i.e. sample 5054). For channel samples the W content decreases with distance from the source of mineralisation (e.g. sample 5047 is closest to the source with following sample numbers progressively further away), whereas bank samples downstream from the Wauchope Field show an erratic, increasing trend. This is interpreted as being due to coarse grained, heavy wolframite (scheelite is rare at the Wauchope Field) being confined to the main channels proximal to the source, and upon rapid physical breakdown the finer fractions become more widely dispersed across the drainage profile. The redistribution of finer, detrital wolframite throughout the bank region of the drainage system may be also accentuated by seasonal flooding cycles. With the exception of sample 1005, W shows low concentrations for both the bank and channel samples from the stream draining the Copper Show Mine at Hatches Creek (for convenience called Copper Show Creek).

4.1.2 Tin

Bank and channel Sn values for both Wauchope and Copper Show Creeks show similar concentrations, with the channel samples often approximating the average of the two bank sample values. For Wauchope Creek, Sn in both the channel and southern bank samples decreases uniformly downstream indicating little redistribution of detrital cassiterite across the drainage profile. This further implies that cassiterite is experiencing less size reduction in the drainage system than the more brittle wolframite. Tin levels draining the Copper Show Mine are generally too low (less than 8 ppm) to establish reliable trends, but values for channel samples are marginally higher than those for bank samples.

4.1.3 Copper

Copper in Wauchope Creek channel samples is consistently higher than in the corresponding bank samples, particularly for those samples near the source of mineralisation (by a factor of 2 for samples 5047 and 5049). Little change occurs downstream in the Cu content of the bank samples although channel samples uniformly decrease suggesting little redistribution of Cu occurs across the drainage profile. Channel Cu values from near Copper Show Mine are also generally greater than the bank samples, although large variations are present within the corresponding pairs of bank samples indicating that bank material in areas of high copper concentration (greater than 30 ppm) may not be a reliable sampling medium.

In summary, alluvial bank sampling appears to be useful in detecting Sn and low concentration Cu anomalies derived from vein type W-Cu-Sn mineralisation; however bank sampling is not a suitable sampling medium for W since the dispersion of this element appears to be influenced largely by the rapid mechanical breakdown of wolframite, which subsequently is heterogeneously redistributed across the drainage profile (channel and bank region).

4.2 The Nature of Secondary Element Dispersion Patterns.

This section describes the dispersion characteristics of elements believed to be of economic significance in the Davenport Province. For the two larger mining centres, the Hatches Creek and Wauchope Wolfram Fields, the distribution of these elements in stream sediment material is shown as profiles of element concentration versus particle size. For smaller centres -Munadgee (U), Great Davenport (Au) and Power of Wealth (Au) - element distribution maps only are included with a brief discussion of the characteristics of element dispersions (i.e. elements are discussed collectively). Geochemical results for the remaining surveyed areas are summarised in Table 8.

4.2.1 Hatches Creek Wolfram Field.

Figure 4 shows the distribution of mines and sample locations in the Hit or Miss Gully, Dooley's Ridge, Treasure Gully and Copper Show areas of the Hatches Creek Wolfram Field. Element concentration versus particle size profiles are included for a suite of samples which provide an "east-west section" through the Hit or Miss Gully-Dooley's Ridge area. Geochemical trends for these profiles, and similar profiles at Wauchope, are summarised in Table 7.

Tungsten. The heavy mineral survey indicated that wolframite is the dominant W mineral in the Hatches Creek region with scheelite only a minor and rare component (see Table 11) from both the Hit or Miss Gully mines and the Copper Show Mine. No scheelite was observed in streams draining the Treasure Gully mines. Therefore, it is likely that the dispersion of W in this area is largely related to the behaviour of wolframite (the stability of W minerals during weathering is discussed in detail in section 3.5). The W contents of the more common rock forming minerals at Hatches Creek is not known, although concentrations of up to 500 ppm are reported from muscovites near granite-related W deposits, and in excess of 10 ppm from iron oxides and titanium minerals (Krauskopf, 1970).

Figure 5 shows that W is widely distributed throughout the Hatches Creek region, with highest W values for the -75 um sieve fractions occurring at Hit or Miss Gully and Dooley's Ridge. Mining activity was intensive along this valley-ridge system and man's activities will have had a considerable influence on the dispersion of W in this area; in particular the complex W trends downstream from the mines, and the local high values (e.g. 1335 ppm W for sample 1019). Tungsten levels in streams draining the Copper Show Mine are low (less than 45 ppm) with short dispersive trains indicating that closely spaced sampling (e.g. 100 to 200 m) is required for the detection of W in Cu dominant lodes. Tungsten levels in Treasure Gully are clearly influenced by wolframite shedding from the mines upstream from sample 5006.

The distribution of W concentration with particle size for samples draining the Hit or Miss Gully-Dooley's Ridge mines (Figure 6) shows a prominent depression, the "Davenport Dip" (discussed in detail in section 4.3), centred on the +75-118 um size fraction. This trend is interpreted as resulting from the presence of two sample populations resulting from different weathering episodes. The fine (-75 um) fraction W high is attributed to detrital W minerals that have experienced complete size reduction over a relatively long time period, with the +118-500 um high due to more recent coarse grained material from a proximal source. A similar trend is seen close to the Wauchope Wolfram Field, but there samples distant to the source show no coarse fraction W high suggesting that the presence of a +118 um W high may be a good proximity indicator for vein type W mineralisation.

Copper. Copper has a strong affinity for S, and often occurs as the primary sulphide minerals chalcopyrite and bornite, or as complex Cu-As-Sb-S minerals, in the late differentiation products of granitic magmas. However, in the weathering environment these minerals are unstable and readily alter to secondary carbonates, sulphates and silicates. The mobility of Cu may be limited by (i) pH conditions (e.g. high mobility where pH is less than 5.5, low mobility at neutral to alkaline pH's), (ii) copreciptation with limonite, and to a lesser degree (iii) by adsorption onto organic matter and clay minerals (Hawkes & Webb, 1962).

Copper shows a similar distribution to W at Hatches Creek (Figure 7) with highest concentrations occurring in the Hit or Miss Gully-Dooley's Ridge area, but with rather surprisingly low values draining the Copper Show Mine. The association of Cu with W appears to be consistent with the mutual occurrence of malachite, azurite and chrysocolla with detrital W minerals in heavy mineral samples from the area. No primary Cu sulphides were observed in the heavy mineral concentrates implying that Cu passes into solution, and precipitates as carbonate or silicate phases, or is adsorbed onto Fe and Mn oxides or hydrated oxides. The paucity of clay particles in the finest size fractions (determined from solution suspension studies) suggests that adsorption of Cu by clays has little significance, particularly in areas draining arenite lithologies.

The distribution of Cu with particle size (Figure 8) displays the "Davenport Dip" with a slightly higher coarse fraction (+118 um) to fine fraction (-75 um) ratio than for W. As for W, the -75 um and the +118-500 um size fractions are the optimum size intervals for the detection of Cu mineralisation of the type at Hatches Creek.

Bismuth. Bismuth, because of its strong chalcophile tendency, most commonly occurs as bismuthinite (Bi_2S_3) or in associated sulphide minerals; notably galena (Bi content varies from less than 10 ppm to almost 4%), and pyrite (10-100 ppm Bi), with lower concentrations in sphalerite (less than 10 ppm Bi) and chalcopyrite (a few ppm Bi). Although Bi exhibits some lithophile character (e.g. apatite is a known host), less than 1 ppm Bi can normally be expected in the common silicate minerals. Bismuthinite, which generally occurs with other late stage acid magmatic minerals, is unstable in the weathering environment due to its brittle nature, strong cleavage and vulnerability to acid attack, and undergoes alteration to the secondary carbonate bismutite $(BiO)_2\ CO_3.H_2O$ and oxide bismite (Bi_2O_3) (Ahrens, 1969).

Bismuth is widely distributed throughout the Hatches Creek Field with concentrations in the -75 um fractions generally in the 5-15 ppm range (Figure 9). Highest levels occur downstream from the Treasure Gully mines (45 ppm) and Masters Gully Mine (36 ppm), with no Bi detected near the Copper Show Mine. Bismuth displays a strong spatial correlation with W, both in distribution and concentration trends, suggesting a common source, although Bi locally has an antipathetic association with Cu in the Masters Gully-Fortune Mine area. It is likely that the secondary dispersion of Bi at Hatches Creek is largely related to the distribution of bismuthinite which is a rare component in the heavy mineral concentrates while the coincidence of high Pb and Zn values with Bi (see Figures 9, 22 and 23) may indicate that Bi is tied up with galena-sphalerite-pyrite mineralogy or its alteration products. The preference for Bi to occur in the coarsest fractions (see below) indicates that these is little contribution from the secondary Bi minerals, bismite and bismutite, since these friable minerals would be concentrated in the finest fractions.

The distribution of Bi with particle size (Figure 10) has the characteristic inflection at the +75-118 um size interval, although the trend in the coarser fractions differs from those of W and Cu in that the concentration continues to increase with increasing grain size. This indicates that the optimal sampling size fraction for Bi is greater than 500 um.

Molybdenum. Apart form minor molybdenite (MoS_2) present in the Hit or Miss Gully heavy mineral concentrates, it is not known in which form Mo occurs in the secondary environment at Hatches Creek since its mobility is controlled by the rate of solution of primary MoS_2 and variations in pH conditions during dispersion (Hansuld, 1966). In acidic environments (pH 2.5 to 7) the mobility of Mo is limited by adsorption on limonite to form ferrimolybdite ($Fe_2(MoO_4)_3.8H_2O$), or by precipitation as insoluble compounds of the acid molybdate ion ($HMoO_4^-$). Under alkaline conditions, Mo becomes more mobile with the formation of soluble molybdate (MoO_4^{2-}) compounds. At Hatches Creek Mo remains in the coarser fractions and has short dispersion trains (Figures 11 and 12) suggesting that there is little hydromorphic dispersion, and that the Mo is fixed as molybdenites or ferrimolybdite. The extremely low Mo concentrations in the fine fractions also suggests that there is little Mo enrichment in the minerals that persist in these fractions, for example the W minerals (most common Mo hosts), or minerals containing Ti^{4+} and Fe^{3+} (i.e. ilmenite, titanomagnetite, sphene and biotite; Manheim & Landergren 1978).

Tin. Tin displays similar distribution trends to W and Bi throughout the Hatches Creek Field with highest -75 um fraction concentrations occuring near the Masters Gully and Treasure Gully mines. Tin levels decline at the eastern and western extremities of the Hatches Creek Field (Figure 13). The dispersion of Sn at Hatches Creek is dominated by mechanical processes due to the chemical stability of cassiterite (SnO_2). This is highlighted by subhedral to euhedral prismatic grains of detrital cassiterite in samples from Treasure Gully and the persistence of Sn in the coarse fractions (Figure 14).

Tin, which is rare in early magmatic sulphides, shows a strong affinity for volatiles in the late pneumatolytic-hydrothermal phases of acid magmatic activity. This affinity for late stage volatile elements is emphasised at Hatches Creek by the association of Sn with W, Bi, Mo, Li, Be and Rb in stream sediments and, in the heavy mineral concentrates, by the mutual occurrence of topaz, tourmaline, micas, apatite, and cassiterite. At low temperatures Sn's affinity for sulphur increases, whereas at intermediate to high temperatures it occurs almost exclusively in oxygen bearing compounds notably cassiterite (Hamaguchi & Kuroda, 1969). The occurrence of cassiterite in preference to stannite (Cu_2SnFeS_4) at Hatches Creek implies that a mineralising granitoid source may be relatively close to the Hatches Creek Wolfram Field.

At Hatches Creek Sn, Mo, Bi and, to a lesser degree, Cu show strong spatial correlations with W and therefore are considered important pathfinder elements which, in themselves, are of economic significance. However, optimal sampling size fractions for those elements vary with (i) Sn and Mo concentrared in the +180-500 um fraction (ii) Bi in the +500 um fraction and (iii) Cu in both the -75 um and +180-500 um size fractions. The difference in optimal size intervals complicates the planning of multielement geochemical surveys where sampling is proximal to the mineralised source but, as is shown by element dispersion trends in the longer Wauchope Creek, (Section 4.2.2), sampling of the -75 um fraction suffices for the above elements with the exception of Sn.

Manganese. Although Mn appears to have little direct economic significance at Hatches Creek, its role as a potential scavenger of other elements in the secondary environment may be of importance.

In the weathering environment Mn is primarily released from the ferromagnesian minerals in the divalent state (Mn^{2+}) as bicarbonate, chloride, and sulphate species (Boyle, 1972). Nichol and others (1967) have shown that the solubility and precipitation of Mn^{2+} is particularly sensitive to changes in the Eh and pH conditions of the geochemical system. In poorly drained terrains of high rainfall, where soil Eh and pH are both low (i.e. an oxygen deficient, acidic environment), Mn^{2+} is stable in groundwater solution. However, if these solutions experience an abrupt rise in Eh or pH (i.e. rapid change in water table levels, or in solutions entering a drainage channel), Mn^{4+} precipitates as the hydrated oxide ($MnO_2.xH_2O$). During precipitation, adsorption of metal cations (e.g. Co, Cu, Ni, Pb, and Zn) leached from adjacent rocks can occur. Enhancement by "manganese scavenging" is prominent in a number of geological environments, notably over laterite profiles, and along channel ways for meteoric waters such as faults, fractures, lithological contacts and bedding planes.

In the Davenport region, which has a short, well defined wet season (on average 30 days) combined with high relief and streams ending in sandy flats, it is unikely that the soil profile remains waterlogged for any length of time. Consequently, Mn precipitation and potential metal scavenging in stream sediments would be limited by the similarity of Eh and pH conditions in the soils and drainage channels. It is therefore unlikely that Mn adsorption of metals plays a major role in the Davenport Province.

Manganese in the Hatches Creek region (Figures 15 and 16) displays similar concentrations in all size fractions, except for the characteristic depression in the +75-118 um fraction. The uniformity of concentration with grain size reinforces the belief that hydromorphic dispersion of Mn is not significant. Manganese shows only weak correlations with W, Mo and Bi and therefore it is unlikely that Mn is enriched in the Hatches Creek mineralised vein systems.

Beryllium and Lithium. Lithium generally shows a strong association with Mg in the ferromagnesian minerals (i.e. amphiboles, pyroxenes and micas), whereas Be has a greater affinity with Al and Si, occurring predominantly in the feldspars, micas and epidotes, or as the Be minerals beryl ($Be_3Al_2Si_6O_{18}$) and chrysoberyl ($BeAl_2O_4$). The mobility of these lithophile elements in the secondary environment is controlled by the stability of the host minerals, with the ferromagnesian minerals, micas and feldspars being unstable to moderately stable, whereas beryl and Li-bearing tourmalines are relatively stable during weathering. Both Li and Be are often associated with the late stage elements, such as B, Nb, La, Th and U, and may be enriched in the residual phases of crystallising acid magmas, in particular in pegmatite veins (Hawkes & Webb, 1962).

At Hatches Creek Be shows a moderate to locally strong correlation with W, (cf Figures 5 and 17), whereas Li shows more widespread anomalies (except for near background values at the Copper Show Mine; Figure 18). This spread of anomalous Li values (3 to 4 times background) is possibly due to the development of sericitic mica and/or tourmaline during granitoid related contact metamorphism or hydrothermal alteration. It is unlikely that there is any significant Li contribution from ferromagnesian minerals in the Treasure Volcanics since these rocks are of intermediate to acid compositions with little primary mafic mineralogy surviving in the weathering zone. Both elements display similar concentration versus size fraction trends (Figures 19 and 20).

Rubidium. Rubidium parallels the distribution of Li at Hatches Creek in having a weak correlation with W, but shows widespread anomalies throughout the field (Figure 21). Rubidium forms no minerals of its own but is always incorporated in potassium bearing minerals, notably the micas and feldspars (Heier & Billings, 1970). Lesser amounts may occur in the ferromagnesian minerals and tourmaline. The major host mineral group common to both Li and Rb are the micas, and it is likely that both these elements are enriched in the Hatches Creek region due to the growth of sericitic micas during contact metamorphism or hydrothermal processes (i.e. greisenisation or potassic alteration) related to intruding granitoids. Lithium and Rb appear to be useful in delineating alteration zones related to granitoid intrusion but may not be as effective as Be in focussing in on vein type W-Cu-Bi-Mo mineralisation.

Other Elements. Lead (Figure 22) and Zn (Figure 23) show, respectively, moderately strong and weak spatial correlations with W. It is not known in what form Pb occurs, although wulfenite ($PbMoO_4$) has been reported by Ryan (1961) in the main lode at the Hit or Miss Mine, immediately upstream from the second highest Pb value obtained in the -75 um fractions (sample 1015 - 18 ppm). The coincidence of high Mo (22 ppm) in sample 1015, and the preference for Pb to occur in the finer fractions (Figure 24) suggests wulfenite, a brittle mineral typical of oxidised zones, is the dominant Pb species. Lead is one of the few elements at Hatches Creek to show decreasing concentration with increasing grainsize (Figure 24).

Zinc levels throughout the Hatches Creek Field are two to three times background, but there is poor spatial correlation with W. Zinc displays closer spatial correlations with Mn and Fe (Figure 26), both in distribution and concentration versus particle size trends (cf Figures 25 with 16 and 27). To investigate the possibility that Zn is closely associated with Mn and Fe, variation diagrams for these elements with Zn and with Cu, Pb, Ni, Cr and Co, which are susceptible to "manganese-iron scavenging", are shown in Figures 28 to 30. The variation trends indicate that only Zn, and to a lesser degree Co, show positive correlation with Fe and, in particular, Mn, thus some adsorption of Zn, and Co, cations may be occurring at Hatches Creek. Zinc and Co display little or no correlation with W and Cu (Figure 31), and therefore the Mn-Zn-Co association is independent of the Hatches Creek vein mineralisation.

Other elements, which are often enriched in late magmatic phases (e.g. Th, Nb, Y, As and U), show near background levels at Hatches Creek. Arsenic and U are surprisingly low (both less than 5 ppm), and appear to show depletion relative to the regional values throughout the Davenport Province. Zirconium distribution is clearly dominated by ubiquitous detrital zircon, which has no relevance to the Hatches Creek mineralisation. Silver was detected in only one sample (e.g. 1020 - 1 ppm).

4.2.2 Wauchope Wolfram Field

The Wauchope Wolfram Field shows certain geological similarities in the Hatches Creek Field, with the most significant differences relating to the mineralogy and attitude of the W lodes and to the absence of volcanic country rocks (see Section 3.2 for descriptions of the Hatches Creek and Wauchope Fields). Stream sediment sampling in the Wauchope area concentrated on the southern margin of the Devils Marble Granite Complex and along Wauchope Creek. Wauchope Creek provides the longest drainage system (approximately 13 km) in the Davenport Province, and so the following discussion will concentrate on the mechanisms of secondary dispersion operating downstream from the Wauchope Wolfram Field (Figure 32).

Tungsten. Tungsten in the -75 um sieve fraction, displays a consistent decrease away from the mineralisation, with approximately 200 ppm near the source dropping to 25 ppm near the Stuart Highway (Figure 33). The high value of 2188 ppm in sample 5044 is attributed to contamination from former battery operations immediately upstream, while the relative low 108 ppm value for sample 5042, closest to the Wauchope Field, is due to the W largely occurring in the coarser size fractions (i.e. +250 um). The source of W (121 ppm) and Sn (113 ppm in the 250-500 um fraction) in sample 5053 is not known and requires further investigation. Tungsten levels near the southern intrusive contact of the Devils Marbles Granite are near background, indicating that there is little likelihood of proximal vein or skarn type W mineralisation in this region.

The dispersion of W in Wauchope Creek stream sediments, as shown by the heavy mineral survey and concentration versus particle size plots (Figure 34), is controlled by the instability of wolframite. These trends are clearly illustrated by the longitudinal diagram in Figure 35. Tungsten close to the source (sample 5042) occurs mainly in the +355 um fraction with a minor increase in the -75 um fraction. There is a broad concentration depression in the intervening size interval (+75-355 um), with the overall profile resembling the "Davenport Dip" observed at the Hatches Creek Field.

With samples farther downstream, the coarse fraction W high quickly diminishes with a subtle increase in the relative W concentration of the intermediate size fraction and a marked relative increase in the -75 um fraction. Samples more than 3 km downstream (5052-5060) show no coarse or intermediate size fraction highs, with W largely confined to the -75 um fraction. This trend indicates that wolframite grains from the Wauchope Field rapidly break down mechanically (due to its brittle character and strong cleavage) through the coarse and intermediate size fractions and are ultimately concentrated in the -75 um fraction. The persistence and uniformity of the -75 um W levels down Wauchope Creek (a distance of at least 13 km) indicates little if any hydromorphic (chemical) dispersion of W has occurred. The long disperion train for W is encouraging for stream sediment surveys, with the optimal sampling size interval being -75 um, but the presence of high W levels in size fractions greater than 355 um is a valuable proximity indicator for vein type mineralisation.

Tin. Tin shows a similar regional distribution (Figure 36) to W although the mechanisms of dispersion appear to be different. The dispersion of Sn at Wauchope is controlled by the mechanical and chemical stability of cassiterite, which is a ubiquitous phase of the heavy mineral concentrates. Apart from Wauchope Creek, detrital cassiterite was also observed in a number of its tributaries and thus Sn mineralisation (?) appears to be quite extensive throughout this region and warrants further investigation. These (with Sn values in the +250-500 um fraction; see Figure 37) include samples 5041 (40 ppm), 5043 (67 ppm), 5045 (151 ppm), 5046 (82 ppm), 5050 (185 ppm), 5051 (40 ppm), 5053 (113 ppm), 5062 (18 pm) and 5064 (22 ppm). Figure 32 showns the location of these samples.

Tin concentration, as a function of particle size, in samples downstream from the Wauchope Mines (Figure 38) is distinctly different to that of W, and can be related to the stability of cassiterite during alluvial transport. Tin within several kilometers of the Wauchope Field (i.e. samples 5042 to 5049) is concentrated in the coarse size fractions (+355 um) with a steep dip to the -75 um fractions. Further downstream (e.g. samples 5052, 5054 and 5056), the coarse fraction Sn values decrease with Sn now concentrated in the intermediate size fractions (+180-500 um). Further downstream (e.g. samples 5057 to 5060), the Sn concentration maximum progressively moves towards the finer size fractions. The increase in Sn content for samples 5058 and 5059 is unlikely to be due to a contamination since their position on the size fraction scale is consistent with the overall trend, but rather a more representative sample collected in the channel. Unlike W, which very quickly concentrates in the finer fractions, Sn moves progressively through the intermediate and finer fractions. Moreover, at no time in the alluvial cycle does Sn concentrate in the -75 um fraction rendering this medium of little use in detection of Sn mineralisation in the Davenport Province. The choice of the sampling size interval is difficult due to the variability of the Sn concentration maximum, but sampling of the +180-500 um size interval will define a Sn anomaly some distance from the source (up to 6 km), while the +355 um fraction is preferred for short dispersion trains of 2-3 km.

Copper. Copper shows a relatively uniform distribution throughout the Wauchope region (Figures 39 and 40) with highest values immediately downstream from the Wauchope Wolfram Field (i.e. sample 5042 - 38 ppm Cu; sample 5044 - 47 ppm Cu maybe contaminated due to battery operations). Arenite sediments are widespread throughout the area and since no mafic-ultramafic rocks are known, there is little likelyhood of Cu contribution from the country rocks. Copper in Wauchope Creek appears to be derived from the Wauchope Field. As with streams draining the Copper Show Mine at Hatches Creek, the dispersion train of Cu in Wauchope Creek is short, with concentrations dropping to 23 ppm (sample 5047) less than 1 km from the source, and maintaining this low level for a further 8 km downstream.

Trace chalcopyrite with pyrite has been reported in the primary zones of the Wauchope mineralisation (Sullivan, 1952) and thus it is likely these low levels of Cu result from precipitation of malachite and azurite, (as indicated by heavy mineral concentrates) or by coprecipitation of Cu and limonite, as suggested by a positive correlation between Cu and Fe (Figure 41) and the similarity of Cu and Fe distributions in the -75 um fraction (cf Figures 39 and 42), particularly close to the mineralisation. The absence of high Cu levels in the coarse fractions at Wauchope (Figure 40 - unlike the Hatches Creek Field) suggests that hydromorphic dispersion of Cu involving coprecipitation with Fe may be more significant than mechanical processes. This "fixation" of the Cu with limonite, and as secondary carbonate minerals, may account for the short dispersion train evident in Wauchope Creek. The absence of correlation between Cu and Mn (Figure 41) indicates that there is little Cu coprecipitating with Mn oxides and hydroxides during secondary dispersion.

Bismuth and Molybdenum. Bismuth (Figure 43) shows low concentration levels at Wauchope while Mo was detected in only one sample (5044 -12 ppm). Bismuth (excluding sample 5044) has a maximum concentration of 7 ppm in the -75 um fractions of sediments from streams draining the Wauchope Field, with anomalous levels persisting for 3.5 km downstream. Hence, despite the low concentration levels, Bi is remaining in the weathering environment for some time. The preference for Bi to occur in the finer fractions (concentration versus particle size profiles are not included for elements of low concentration, namely Bi, Mo, Be and As) indicates that Bi may occur as finely abraded bismuthinite and/or as the secondary friable minerals, bismutite or bismite.

Metallic zonation surrounding mineralising granitic intrusions has been well documented in the literature (Taylor & Stevenson, 1972; Blake & Smith, 1970), with metals occuring away from the contact in the order Sn-W-Cu-Bi-Zn-Pb-Sb. The dominance of Sn and W over the base metals, Bi and Mo, at Wauchope, which contrasts with the Hatches Creek Field, suggests that a mineralising, intrusive source is relatively close to the Wauchope Field, probably closer than that present at Hatches Creek. The ubiquitous occurrence of topaz and tourmaline in the heavy mineral concentrates from Wauchope is also consistent with a proximal mineralising source. It is suggested that a subsurface, late intrusive phase of the Devils Marbles Granite Complex (which hosts W mineralisation at Dixon Creek) may extend underneath the Wauchope Wolfram Field and be the source of the W-Sn mineralisation.

Other Elements. Elements which show similar enrichment trends at both the Wauchope and Hatches Creek Wolfram Fields include Rb, Li, Be, Co, and Zn, (Figures 44 and 45 for Rb, 46 and 47 for Li, 48 for Be and 49 and 50 for Zn) and can be considered important path finder elements for W-Sn mineralisation. All these elements show decreasing concentration with increasing particle size although the coarse fraction concentrations increase slightly near the source of mineralisation. The optimal sampling size is -75 um. Approximate dispersion train lengths for these elements are Rb (+13 km), Li (+13 km), Be(3 km), Co(1 km) and Zn(4 km). Unlike the Hatches Creek Field, Sr (Figure 51) and Y (coarse fractions only) display moderate enrichment at the Wauchope Wolfram Field. Manganese, which shows a decreasing but erratic trend down Wauchope Creek (Figure 52), has positive correlation with Zn (Figure 41), such that coprecipitation of these elements may be occurring during secondary dispersion. Elements which do not define the Wauchope mineralisation include Th, Nb, As, U, Zr, Cr, Ni, Pb and Ag.

4.2.3 Munadgee Uranium Prospect

Figure 53(a) shows sample locations and the drainage pattern in the vicinity of the mineralised (autinite, torbernite, ? carnotite) ridge at the Munadgee Uranium prospect. Rock types in the area include felsic intrusive porphyry (host to the mineralisation), and greywacke-chert metasediments of the Warramunga Group and arenite sediments and felsic volcanics of the Hatches Creek Group. Drainage in the area is poorly developed with short, discontinuous gullies only present along the western flank of the mineralised ridge.

Uranium (Figure 53(b)) in all size fractions in the Munadgee area was low (generally less than 3 ppm) with slighlty anomalous levels (4 to 6 ppm) draining the main mineralised ridge. The low U levels in the stream sediment sieve fractions, and the absence of any radioactive response from scintillometer scans of the heavy mineral concentrates, is believed to be due to the limited surface expression of the mineralisation and to the extreme solubility and mobility of the UO_2^{2+} ion under the alkaline and, in particular, oxidising conditions that are typical of desert environments (Hawkes and Webb, 1962). The low U and Th (less than 26 ppm) in the fine sieve fractions also suggest that there is negligible coprecipitation of these elements with organic matter, hydrated Fe and Mn oxides or clays as observed for U in the Georgetown area, northern Queensland (Rossiter, 1975). Path finder elements characteristic of vein type U deposits, notably Cu, Bi, As, Co, Mo and Ni (Levinson 1974), give little or no indication of the Munadgee U mineralisation (Figure 54 for Cu and Bi), however Zn (Figure 55(a)), Sr (Figure 55(b)), Y (Figure 56(a)) and Rb (Figure 56(b)) show moderate concentration increases near the mineralisation. The higher Rb and Sr values may be partly due to the greater feldspar content of the host porphyry and/or felsic volcanics in the region, so that Zn and Y appear to be the only pathfinder elements of any significance. The source of the possible mineralisation in sample 5137 is not known, but the relative proportions of the elements and their occurence in the coarsest fraction (+500-710 um; 86 ppm W, 28 ppm Sn, 11 ppm Bi, 40 ppm Mo and 92 ppm Cu) indicates that the mineralised source is close, and possibly of Hatches Creek style (Figure 57 for W and Sn).

4.2.4 Great Davenport Gold Prospect.

Stream sediment sampling near the Great Davenport and Cairns Gold Prospects (Figure 58) was aimed at investigating element dispersion patterns immediately downstream and along geological strike from the prospects. Low tenor gold mineralisation at Great Davenport occurs in discordant, limonitic quartz veins intruding arenites of the Kurinelli Sandstone Formation, and within quartz haematite-magnetite veins that are hosted by altered granophyre, arenites, and siltstones at the Cairns Prospect. Rock types in the southwestern corner of the survey area (near samples 1155-1164) include rhyolites of the Treasure Volcanics and arenites of the Taragan-Unimbra Sandstone Formations.

Estimates of gold levels determined by optical emission spectrographic analysis of heavy mineral concentrates are shown in Figure 59. Gold dispersion trains at both the Great Davenport and Cairns Prospects appear to be short, with gold not detected at or further than 500 m downstream from the Great Davenport Prospect. The short dispersion trains may suggest conditions in the secondary environment are favourable for the solubilisation of native gold as a complex ion, (i.e. chloride $[AuCl_4]^-$, thio $[Au(S_2O_3)_2]^{3-}$, or cyanide $[Au(CN)_2]^-$ - Lakin and others, 1971). The presence of flake gold in the Great Davenport lode (see section 3.2.2) suggests the gold is not confined to the immediate vicinity of the mineralised source because of its coarse grain size and little subsequent transportation. The most interesting feature of the gold distribution in the survey area is in the southwestern corner where samples 1155 to 1158, and 1160, showed low levels (approximately ? 10 ppm) of gold. In these samples the common source rocks are rhyolites of the Treasure Volcanics with minor arenites of the Taragan and Unimbra Sandstone Formations. Extensive fault related brecciation-silicification features occur immediately west of these samples with a series of northeast-southwest trending faults occurring upstream, so that gold may be shedding from quartz veins within Treasure Volcanic rhyolites.

Element associations with the gold mineralisation at both Prospects are weak, with only As (Figure 60) having any obvious spatial correlation with Au. Arsenic shows weak anomalies (up to 9 ppm) close to the mineralisation but, in the case of the Great Davenport Prospect, drops to background levels within several hundred of metres of the source. The low mobility of As may be attributed to coprecipitation of the $[AsO_3]^{3-}$ ion with limonite, or as scorodite ($FeAsO_4$). The application of As as a pathfinder element for auriferous quartz lodes appears to be limited by the low As content of the lodes and the relatively short dispersion trains. Low As levels also characterise a Au anomaly in the southwestern corner of the survey area, perhaps indicating the Au source is some distance upstream. Sample 1173, west of the Cairns Prospect, has anomalous As (10 ppm) with associated trace Au, and warrants further investigation. Of the other elements, Zn shows high levels (64 ppm) near the Cairns Prospect (Figure 61). The source of the Zn is ambiguous since, while it is likely the haematite-magnetite (replacement of primary sulphides?) lodes contain some Zn, the high Mn contents of samples in the area (Figure 62) may indicate Mn scavenging.

4.2.5 Power of Wealth Gold Mine.

Rock types in the Power of Wealth Gold Mine area include feldspathic and quartzose arenites of the Kirinelli Sandstone Formation (samples 1179 to 1201, Figure 63) and felsic lavas and arenites of the Epenarra Volcanics (samples 1202 to 1209). Basic volcanics of the Kudinga Basalt and Edmirringee Volcanics form a minor component of the catchement areas of samples 1179 to 1201. A feature of the area bounded by Opal Creek and sample sites 1188 to 1208, is the intensity of quartz veining which is described in Section 3.2.2. Stream sediment samples were collected downstream from the Power of Wealth Mine and in those tributaries of Opal Creek which traversed the region of quartz veining.

Low levels of gold (Figure 64) detected by optical emission spectrographic analysis of heavy mineral concentrates were confined to the headwaters of Opal Creek (1197), downstream from the Power of Wealth Mine (1230 and 1208), and an isolated sample (1209) in the southewestern corner of the survey area. Rock types in the catchment areas of these four samples consisted of arenites of the Kurinelli Sandstone Formation, and Epenarra Volcanics. It is surprising, in view of the Au dispersion trains at the Great Davenport Prospect, that Au was still detected 1 km, and possibly in excess of 5 km, downstream from the source. This implies that Au may be remaining as native metal during secondary dispersion. The source of the Au in samples 1197 and 1209 is not known, but catchments of both samples coincide with the region of quartz veining described above.

Arsenic (Figure 65) throughout the surveyed area remains at background levels with no enrichment near the Power of Wealth Mine. This is not surprising since, unlike the Great Davenport lode, the sulphide content of the Power of Wealth lode, at surface, is low. Copper (Figure 66) displays two sample populations throughout the region and these can be related to source rocks. Copper in excess of 10 ppm is typical of the Edmirringee and Kudinga Basalts while samples from streams draining the arenites and felsic volcanics of the Kurinelli Sandstone Formation and Epenarra Volcanics rarely exceed 10 ppm Cu (i.e. samples west of the Power of Wealth Mine). The high Cu in sample 1188 (42 ppm) is associated with anomalous Co (26 ppm), Cr (55 ppm), Zn (90 ppm), Ni (40 ppm), Mn (602 ppm) and Fe (5.8%), and may be related to an ultramafic rock source, or iron-manganese scavenging. Zinc, which shows several weak anomalies near the Power of Wealth Mine, is not a suitable pathfinder element for Au since its distribution parallels that of Mn throughout the region (Figures 67 and 68).

4.3 **The Significance of the "Davenport Dip".**

It was important in the initial stages of the survey to determine which grainsize interval or intervals should be selected as a basis for the stream sediment program. The distribution of elements with various size fractions is dependent on a number of variables unique to each area, in particular; the style and mineralogy of the source, the history of weathering and erosion in the area, the relative roles played by physical and chemical processes, proximity of sampling to the source, etc. Previous orientation surveys undertaken by the BMR have generally established that for most elements the concentration increases with decreasing grainsize, for example in the Georgetown-Forsayth district of Northern Queensland (Bain, 1973; Rossiter, 1975; Rossiter and Scott, 1978) and at Westmoreland in Northern Territory - western Queensland (Rossiter 1976). However, there are numerous examples where this trend does not apply. For example, uranium oxide is more abundant in both the -75 um and +1700 um fractions than in the intermediate size fractions in sediments draining the Koongarra Uranium Deposit - Northern Territory (Foy and Gingrich, 1977). In the heavier rainfall area of coastal southwestern Australia, Pb, Zn and Nb concentrate in the -75 um fraction, Cr in the coarser fractions, and Cu and Sn display a complex distribution between the grainsizes (Fairburn, 1973). In stream sediments draining the Ishasha Claims, Uganda, high Be values in the coarse fraction are due to beryl, while Be adsorbed onto clay minerals is believed to account for the fine fraction highs (Hawkes and Webb, 1962).

The concentration-size fraction plots for Bi, Cu, Fe, Li, Mn, Rb, W, Zn and, to a lesser degree, Cr, Sr, Sn and Y, in samples from Hatches Creek all show pronounced dips, or minimums, at the +75 -118 um fraction. This is most pronounced for W, Cu and Bi, the elements of greatest economic significance. The magnitude of this feature, the "Davenport Dip", appears to decrease uniformly with distance away from the source. The dip occurs only in samples from the Hatches Creek area and in samples close to the Wauchope mineralisation. Several factors may contribute to this, namely:-

(a) Mineral species
(b) External influences
(c) Mechanical versus hydromorphic dispersion, and
(d) Source mineralogy and proximity of sampling to source.

(a) **Mineral species:** Tungsten mineralisation at Hatches Creek is dominantly wolframite with minor scheelite and rare secondary W minerals. The wolframite forms coarse, bladed aggregates up to several centimetres in length, with finer grained scheelite often closely associated with the wolframite. It is unlikely that the "Davenport Dip" is caused by any particular mineral species preferentially occurring within the different size fractions, for example scheelite in the -75 um fraction and wolframite in the +118 um or vice versa, since the trend is not unique to W but is apparent for a number of elements. Shortwave ultraviolet light scans of several W bearing size fractions did not indicate any preferential accumulation of scheelite in either the fine or coarse fraction.

(b)**External influences:** That the -75 um fraction is in part due to an external input, for example an aeolian source, is not considered likely since relative concentrations between size fractions is maintained even as the overall concentration increases, that is as one approaches the source. If a aeolian source is credible then this should give a more random contribution to the system. An aeolian input would dilute the finer fractions, but this is unlikely since the total sample weight for each size fraction decreases very sharply with decreasing grain size for the Davenport samples, suggesting that any diluting influence has occured in the coarser grained fractions and not in the +75 -118 um fraction. In the Flinders Rangers, South Australia, a desert environment similar to the Davenport

Ranges, the -75 um fraction was dominated and diluted by aeolian limonitic sand and silt grains, with the base metals concentrated in the coarse size fractions, particularly near the source (Muller & Donovan, 1971).

(c) **Mechanical versus hydromorphic dispersion:** With the exception of strongly acidic environments, for example in close proximity to eroding sulphide deposits, wolframite and scheelite are chemically stable and moderately stable respectively. The low sulphide content and limited surface exposure of the Hatches Creek mineralisation, the alkaline conditions of this semi arid region and the "fresh" appearance of the wolframite grains in heavy mineral samples collectively suggest that hydromorphic dispersion of W in the Davenport region is of little significance. Suspension studies of selected samples indicate that the clay contents of the fine size fractions are negligible, hence it is unlikely that the metals are incorporated in clay mineral lattices, or adsorbed in exchange positions on particle surfaces. The dominant dispersion mechanism for all sizes fractions of the W minerals appears to be related to mechanical processes, with both wolframite and scheelite having strong cleavage and brittle structures which facilitate rapid size reduction during transportation.

(d) **Source mineralogy and proximity of sampling to source:** The "Davenport Dip" observed at Hatches Creek and Wauchope is believed to be largely a function of three factors namely:-

- the coarse grainsize of the mineralisation,
- the dominance of mechanical processes over chemical dispersion, and
- the proximity of the sampling to the mineralised source.

The characteristic minimum is interpreted as resulting from the presence of two sample populations of different time origins in the weathering history. The -75 um concentration high is believed to represent an older detrital population which has experiencd complete size reduction, while the coarser size fractions (i.e. +118 um) represent more recently dispersed material from proximal sources which has experienced little physical modification. The release of coarse grained material into the drainage systems of these areas no doubt has been accelerated by mining activity, with numerous surface gougings, coasteanings, and several small stamp batteries characterising the Hatches Creek and Wauchope Fields (most sampling in the Hatches Creek area was within 200 m of the mineralised source). Element dispersion near the Wauchope mines displayed the "Davenport Dip", but 1.5 km down Wauchope Creek (main drainage system of the mines), the -75 um W high still persisted although the +118 um high had disappeared indicating rapid size reduction of the W minerals during dispersion.

4.4 Statistical Analysis of Davenport Geochemical Data.

Data accumulated during any geochemical survey can be reduced to more convenient forms by the application of mathmatical statistical procedures. Most of these assume that sampling is random whereas in this survey, as in most geochemical orientation surveys, sampling was deliberately biassed towards areas containing mineralisation, many of which have been subjected to mining activity or intensive exploration. Therefore, although a number of adjacent and remote "barren" areas were also sampled, the total sample population contains an unrealistically large number of samples derived from mineralised source rocks (approx. 15-25% of the total) and two distinct populations, one comprising the "barren" or background samples and the other the "mineralised" or anomalous samples, are evident for the mineralising elements (e.g. W, Sn, Cu, etc). Despite these limitations, a number of useful observations can be drawn from analysis of the data. Summary statistics for the -75 um fractions of all stream sediment samples collected (N = 415) are listed in Table 9.

A number of elements (e.g. Th, Pb, Y, U, As, Sr, Nb, Zr, Fe, Mn and Zn) show only small differences between their arithmetic means, geometric means and median values, and also have small coefficients of variation (i.e. SD/AM <0.5), indicating little, or at most, subtle, variations in the concentrations of these elements over the areas sampled. This strongly suggests the absence of second, or anomalous, populations. For these elements the maximum concentration value found is only two to four times the mean value. Other elements (e.g. Rb, Be, Co, Cr, Li and Ni) show greater differences in these parameters and larger coefficients of variation (i.e. 0.5-1.0). Where sufficient data are available (e.g. for W, Sn and Cu), the mineralised elements show larger differences and coefficients of variation (i.e. >1.0). For three elements (i.e. Bi, Mo and Ag), "not detected" values were recorded for more than 75% of the samples. No statistical parameters have been recorded for these except to note the correlations between these and other elements.

Strong mutual correlations (r >0.60) were evident between:-

(i) Rb, W, Bi, Sn, Mo, Be, Cu and Li (+-Zn),

(ii) Co, Cr, Fe, Mn, Ni and Zn,

and (iii) Th, Y, U and Nb.

Correlations in group (i) between the mineralisation elements W, Bi, Sn, No and Cu, and Rb, Be and Li suggest fluids from a differentiated granite magma as the likely source of the mineralisation. This confirms the observations made above concerning the close spatial correlation between these elements at centres such as Hatches Creek and Wauchope. Groups (ii) and (iii) appear to result the presence or weathering of mafic minerals, possibly from the many mafic volcanic units, and from an epidote-apatite-zircon association from felsic units, respectively.

Cumulative frequency plots for W, Sn and Cu each show two populations with threshold values (i.e. equivalent to the break in slope of the plot) of 8, 5 and 20 ppm respectively. These are the concentrations above which stream sediment values may be of interest for exploration purposes. For the other mineral elements (e.g. Bi and Mo), detectable values may be of interest. The detection limits are 2 and 3 ppm respectively.

Arithmetic means and standard deviations for samples from each of the centres:- (i) Hatches Creek (areas 1, 2, 3 and 8 in Fig. 1), (ii) Wauchope (area 9), (iii) Hill of Leaders (areas 10 and 11), (iv) Great Davenport (area 4), (v) Power of Wealth (area 5), and (vi) Elkedra Granite (area 6) are listed in Table 10.

4.5 **Results of the Heavy Mineral Survey.**

Heavy mineral samples are a valuable tool for defining W-Sn-Cu mineralisation throughout the Davenport-Murchison Ranges area, but have limited application in discriminating geological units or provinces. This is believed to be due to;

(a) the composite nature of the geology with moderately to steeply dipping, interbedded volcanic-pyroclastic-sedimentary sequences characterising much of the region. Monotonous quartz-feldspathic arenites of the Middle Hatches Creek Group (ie. Unimbra Sandstone, Errolola Sandstone) and Lower Hatches Creek Group (ie. Taragan Sandstone, Kurinelli Sandstone) are the most extensive areally, and these formations provide few diagnostic heavy mineral assemblages.

(b) drainage catchments are areally small with dispersion trains often directionally biased by the extensive strike ridges, resulting in limited dissection of the terrain, and

(c) diagnostic metamorphic assemblages are absent (although some contact metamorphic minerals have been identified) due to the low grade of regional metamorphism (ie. greenschist facies) and the dominance of arenite lithologies. Primary minerals from basalt and gabbro-dolerite-granophyre intrusives are rare or absent due to deuteric and/or retrograde metamorphic alteration processes.

Heavy minerals of direct economic importance identified in the survey include wolframite, scheelite, cassiterite, bismuthinite, molybdenite, malachite, azurite, chrysocolla and a molybdic variety of scheelite (see Table 11), while those of indirect significance include topaz, two varieties of tourmaline, and fluorapatite. Gold was not observed in samples from either the Power of Wealth Mine or the Great Davenport Gold Prospect. This may be due to the depth of the mineralisation at the Power of Wealth, and to the occurrence of friable, secondary flakes of limonite after pyrite at Great Davenport (Yeaman, 1965). The following section summarises the distribution and morphology of heavy minerals from the Davenport region. Representative grains of economically important minerals are shown in Plates 1 to 3.

4.5.1 Distribution and Morphology of Heavy Minerals of Direct Economic Significance

Wolframite. Wolframite was the dominant W (modally) mineral observed in stream sediment concentrates. With the exception of the Wolfram Hill Mining Centre (i.e. Ricketty Kate, Bonanza and Green and Black Diamond group of mines), scheelite is subordinate to wolframite where quartz lodes intrude altered volcanics and sediments. However, where the quartz veins are granite hosted scheelite becomes the dominant species. The relationship of the W species to country rocks is interpreted as being largely a function of the chemistry of the mineralising fluids. Hobbs and Elliot (1973) believe that the precipitation of the W species wolframite and scheelite is controlled by the relative amounts and activities of Fe, Mn, Ca, CO_2 and F. The secondary W minerals tungstite (H_2WO_4) and cuprotungstite ($Cu_2WO_4(OH)_2$) (as observed in Ryan, 1961) were not identified in the heavy mineral fractions but scheelite was observed pseudomorphing (replacing?) wolframite from Pioneer Mine ore samples, and as secondary coatings on mineral grains from the Wauchope Wolfram Field.

Wolframite was identified in the Hit or Miss and Treasure Gully drainage systems at Hatches Creek, at Copper Show Mine, at the Wolfram Hill mines and at the Wauchope Wolfram Field, and formed a rare component at the Hill of Leaders Mines. New areas of wolframite mineralisation defined by the heavy mineral survey are summarised in Table 12. The wolframite often formed long prismatic, "splintery" grains (up to 3 mm in length) although grains from Wauchope differed in their short and more prismatic, tabular habit. Smaller grains showed no evidence of rounding, inferring size reduction was rapid due to their brittleness and strong cleavage. Wolframite grains could be readily identified by their submetallic lustre on cleavage faces. Grains were generally brownish-black to black. Brownish-black colour streaks, the weakly magnetic character (the magnetic susceptability of wolframite necessitates the examination of both magnetic and non-magnetic heavy mineral fractions) and X-ray diffraction patterns indicate that ferberite ($FeWO_4$ - the iron rich member of the Fe-Mn wolframite series) is the dominant mineral. Rare wolframite grains were observed attached to clear quartz indicating a possible vein type origin. Tables 11 and 13 show the distribution and frequency of wolframite and other minerals of economic importance from the various mining centres and the different styles of W mineralisation found in the Davenport region.

Scheelite. Scheelite ($CaWO_4$) shows a sympathetic occurrence with wolframite except in granitic terrains where wolframite is rare or absent. Thus it appears to be more extensively distributed but of lower tenor than wolframite mineralisation. Scheelite was observed widely throughout the mining centres, including drainage systems of the Hit or Miss Gully at Hatches Creek (but absent from nearby Treasure Gully), the Wolfram Hill mines, the Hill of Leaders mines (also called Mosquito Creek), the Juggler Mine (Elkedra Granite), and is rare at the Wauchope Wolfram Field.

Detrital scheelite was also recognised in samples from areas where mining activity is unknown and these are summarised in Table 12. The most significant new occurrence relates to the Elkedra Granite where scheelite is shedding from both the southern-central region and the northwestern contact zone (scheelite source maybe within schistose country rocks of the Rooneys Formation since the drainage parallels the intrusive contact in this region) of the granite complex. The scheelite (pale white-blue fluorescene) is associated with fluorapatite (yellow-gold fluorescence), apatite, schorl-dravite tourmaline, zircon, ilmenite, topaz and various micas, indicating that the granite body has widespread alteration, in particular greisenisation and tourmalinisation. No wolframite was observed with the scheelite. The Elkedra Granite appears to be a high-level, altered intrusive containing known W mineralisation (at the Juggler Mine, a small tourmaline-quartz lode at the western end of the granite complex), with the erosional level of the intrusive favourable for the preservation of Sn-W vein stockworks or marginal-sheeted greisen type mineralisation. Scheelite forms small (generally less than 1 mm), irregularly shaped grains displaying an uneven fracture and, where proximal to the source, a vitreous lustre. Colour ranges from honey-brown where country rocks are volcanics or sediments, to translucent to milky-white in granitic terrains such as the Hill of Leaders area. Scheelite can be readily identified in the concentrates by its white to blue-white fluorescene, but grains from Hit or Miss Gully and Wolfram Hill fluoresce with a yellowish-blue colour indicating a molybdic variety of scheelite ($Ca(Mo,W)O_4$). This also appears to be consistent with the occurrence of molybdenite in concentrates from these two areas. Replacement of wolframite by scheelite and vice versa has been well documented in the literature, but it is difficult to ascertain from heavy minerals the extent of secondary W mineralisation within the Davenport Province with the exception that secondary scheelite at the Wauchope Wolfram Field may be of greater significance than primary scheelite mineralisation.

Cassiterite. Cassiterite displays a similar distribution to that of wolframite, but it appears that both minerals are not shedding from the same source but rather from different vein or greisen networks resulting from the same mineralising processes. Cassiterite is ubiquitous throughout the Wauchope Wolfram Field and in many samples was 50 to 60 percent by volume, and occassionally up to 90 percent, of the total concentrate. This is perplexing since cassiterite has not been recognised in the W deposits, and Sn was only at trace levels in concentrates obtained from the Government treatment plant (Sullivan, 1952). The regional occurrence of cassiterite at Wauchope indicates that it is not derived from operations at the battery located at the headwaters of Wauchope Creek (ie. sources external to the Wauchope Field). Cassiterite shows another distribution anomaly at Hatches Creek where it is a rare component in the Hit or Miss Gully samples, but is a significant component of concentrates from nearby Treasure Gully, an area of similar geology. As outlined in Table 12, the source of some cassiterite is unexplained and worthy of follow up investigation. Cassiterite is one of the most distinctive heavy minerals from the Davenport region and can be readily identified by its "solid equant" form and colour. At Hatches Creek and Wauchope cassiterite grains proximal to the source are prismatic in habit (commonly 1 mm in size), often well crystal faced, while downstream grains are subrounded but of similar size indicating strong resistance to both mechanical and chemical weathering processes. Colour was extremely variable ranging from almost colourless, through pinkish-red, reddish-brown, and bronwish-black to black at Wauchope, and with grains sometimes polychromic. Rare grains at Hatches Creek were attached to quartz.

Bismuth Minerals. Bismuthinite (Bi_2S_3) forms a rare component of heavy mineral concentrates from the Hit or Miss Gully and Wolfram Hill. Ryan (1961) noted that bismuthinite is more prominent at the Pioneer Mine (no stream sediments were collected in this area due to poor drainage) where it forms fibrous patches associated with native bismuth, wolframite, scheelite, pyrite and chalcopyrite. Bismutite ($(BiO)_2CO_3$) and bismite (Bi_2O_3) are also believed to be present. Bismuthinite forms an accessory to sulphides at the Wauchope Wolfram Field (Sullivan, 1952).

The paucity of primary bismuth minerals within the drainage systems is not only attributed to their localised distribution in the mineralisation but also to their susceptibility to alteration in the weathering cycle. A perfect cleavage, brittle character and readiness to alter to the secondary carbonates and oxides indicate they are susceptible to both mechanical and chemical breakdown. The geochemical susceptability of the Bi minerals is also influenced by the stability of associated minerals, such as chalcopyrite, galena and pyrite, where these minerals are attacked by acid solutions releasing Bi for redistribution in the secondary geochemical environment to form bismite or bismutite (Ahrens, 1974). These secondary Bi minerals would be extremely difficult to recognise in a heavy mineral concentrate dominated by limonite.

Molybdenite. Molybdenite shows a similar, tight distribution to that of bismuthinite, occurring rarely in the Hit or Miss Gully samples and more commonly at Wolfram Hill. It occurs as small (less than 1 mm) scaly plates which have burred, compressed margins due to mechanical abrasion during transportation. Molybdenite can be confused with bismuthinite, but molybdenite grains will "smudge out" to form diverging platy aggregates and bluish-grey films on paper, when pressed.

The molybdenite from these two areas may be of contact metamorphic origin, but its association with the W-Cu detrital minerals suggest it is derived from the hydrothermal quartz vein systems.

Copper Minerals. Malachite and azurite show similar distributions to W minerals where ever wolframite-quartz lodes intrude altered volcanics or sediments. Malachite and azurite grains were common at the Hit or Miss Gully and Wolfram Hill, rare at the Wauchope Wolfram Field, and absent in Treasure Gully. Secondary Cu minerals were surprisingly scarce downstream from the Copper Show Mine considering that the lodes from this area contain more copper than any other mine in the Davenport region (Ryan, 1961). No new area of copper mineralisation was indicated by the heavy mineral survey, with the possible exception of sample number 1005 (300 m north of Copper Show Mine) which contained minor malachite and trace chrysocolla, and associated cassiterite, wolframite and scheelite. The chrysocolla was attached to denser limonitic country rock (SG of chrysocolla at 2.0-2.4 is less than the 2.96 for tetrabromoethane).

Malachite and azurite occur as veinlets, vugh fillings, coatings on limonitic fragments, botryoidal masses and, rarely, pseudomorphing each other. Grains size is generally less than 1 mm. Since these grains display vivid colours of various blues and greens, a visual examination of the concentrates provides a valuable and quick method for detecting Cu and/or wolframite (not scheelite) mineralisation. Primary Cu sulphides were not observed in the concentrates. This is believed to be due to the depth of primary mineralisation throughout the district and the chemical instability of these minerals at surface. Ryan (1961) notes that the primary zone has only been reached at the Pioneer Mine (at approximately 63 m depth) and the Green Diamond Mine (41 m depth) at Wolfram Hill.

4.5.2 Distribution and Morphology of Heavy Minerals of Indirect Economic Significance

Tourmalines. Tourmaline is one of the more ubiquitous heavy minerals throughout the Davenport region. It occurs widely throughout the mining areas of Hit or Miss and Treasure Gullies, Wolfram Hill, the Wauchope Wolfram Field, the Hill of Leaders and Elkedra Granites, and the Great Davenport Gold Prospect, but is rare at the Power of Wealth Gold Mine and the Munadgee Uranium Prospect.

Two types of tourmaline (a black schorl and a more magnesian dravite member) are often present with wolframite+-scheelite grains in volcanic-sedimentary terrains, so the presence of this two tourmaline association is considered an important indicator of potential W mineralisation. Where only one type exists, W mineralisation is generally absent. The best examples of this two tourmaline-tungsten association are downstream from the Hit or Miss Gully mines and Wolfram Hill. For granite terrains, where scheelite dominates over wolframite, (i.e. Hill of Leaders and Elkedra Granites), dravite is subordinate to schorl.

Both schorl and dravite display varied morphological features throughout Davenport Province, but locally they show similar degrees of rounding and fracturing possibly indicating a similar alluvial history. Schorl, the Fe-rich variety, is invariably dark brown to black and strongly pleochroic from deep reddish-brown through to bluish-green, while the almost clear to tan-brown magnesian dravites have moderately pleochroic, yellow and brown colours. Grains proximal to their source are of elongated prismatic form, rarely terminated and have striated faces with the schorls, in particular, having convex triangular cross sections. Where the schorls attain some size (up to several mm from the Elkedra and Hill of Leaders Granites) grains are strongly fractured and fragmented with quartz occasionally filling internal fractures. Dravites at the Great Davenport Gold Prospect and the Wauchope Wolfram Field are completely rounded and of polished, globular form.

The origins of the two types of tourmaline are not clear but the close spatial relationship of the two minerals with wolframite+-scheelite suggests they may be related to the same mineralising processes, either within the hydrothermal vein system itself, or products of boron metasomatism within the hornfelsed country rocks. Deer and others (1962) and Krynine (1946) note that the Mg:Fe ratio in the dravite-schorl continuous series, which governs the mineral colour, is controlled by the composition of the rock in which the tourmaline is developed. Thus, both tourmalines could be derived form the same mineralising system in areas of composite rock types, such as Hit or Miss Gully and Wolfram Hill.

Topaz. Topaz is the best indicator of W-Sn mineralisation at the Wauchope Wolfram Field, and at the Hit or Miss and Treasure Gullies at Hatches Creek. Topaz has not previously been recognised at the Hatches Creek mines, but at Wauchope it occurs as individual crystals or clots up to 1 mm in size within tourmalinised serititised hornfelses (Sullivan, 1952). Its close association with wolframite, cassiterite, scheelite, tourmaline, zircon, apatite and various micas in these two areas, suggests that the topaz is a wall rock alteration product related to the W veining, or is derived from cassiterite bearing greisen zones spatially close to the W mineralisation. The distribution of topaz at Hatches Creek appears to be zoned, occurring only east of a line trending northwest from the White Diamond Mine (Hit or Miss Gully) to the Treasure Mines (Treasure Gully), where cassiterite also shows greatest development.

Topaz is readily identified in the concentrates by its coarse, blocky quadratic form (averaging 1 mm in size), frosted surface appearance and yellow, orange and red (ferruginised) colours. Transparent types are also present. Irregular grains can be confused with ferruginised crystalline quartz, but the subhedral character and coarser grainsize of topaz are diagnostic. Topaz from Wauchope Creek forms a major component with cassiterite and persists all the way to the Stuart Highway, a distance of more than 13 km. In Wauchope Creek, topaz shows only minor size reduction and occurs in a subangular form with fine cuspate fracture faces.

Fluorapatite. Fluorapatite is rare being confined to the granitic terrains of the Hill of Leaders, Devils Marbles and Elkedra granite complexes. Within each of these three regions fluroapatite was associated with scheelite grains, although it is not certain whether it is related to W mineralisation. Fluorapatite can be identified by its strong pale yellow to gold fluorescence (similar to the molybdic varieties of scheelite both in general appearance and fluorescent colour). The fluorapatite occurs as small irregular grains, usually transparent to milky-white in colour but with lime green types common from the Devils Marbles Granite indicating an Fe rich-Mn poor variety (Deer and others, 1962). The morphology of some grains suggests they may represent a hydrothermal, or alteration products of other phosphate minerals.

4.5.3 Distribution and Morphology of Heavy Minerals of No Economic Significance

Heavy minerals identified but of little or no economic importance include actinolite-hornblende, anatase, rutile, apatite, zircon, epidote, andalusite, various micas, magnetite, ilmenite, leucoxene, psilomelane, limonite pseudomorphs after pyrite, and possible columbite-tantalite and wulfenite-stolzite.

Amphibole was prominent in areas draining a gabbro-granophyre (Pd, Pgy) complex northeast of Hatches Creek (GR 225925), the Kudinga Basalt (Phb) in the Little Edinburgh Creek area, and schists of the Rooneys Formation (Phn) at the northern margin of the Elkedra Granite. The amphibole varied from dark green to almost black in well cleaved lustrous grains, to various stages of soft pale green-brown fibrous alteration products. Less altered grains were strongly pleochroic from dark green to pale yellowish-green and in many cases probably represent actinolite-hornblende replacements of primary pyroxene.

Anatase is rare in both distribution and abundance, occurring as small euhedral milky-white to pale brown, acute dipyramids. Crystal faces displaying fine striations, with most crystals sharply terminated, indicate an immature weathering history. Anatase was most common in streams draining the Frew River Formation (Phf) and Coulters Sandstone (Phc) sequence near the Murray Downs road (Hatches Creek Sheet GR 035800). Anatase is a low temperature form of TiO_2 commonly occurring in hydrothermal veins where the TiO_2 is derived from alteration and leaching of the country rock. However, it may be that the anatase near the Murray Downs road is of authigenic origin, forming within the Frew River sediments.

Rutile, a rare mineral of varied habit, was confined to the area around the Hill of Leaders Granite. It occurs as long slender prismatic crystals with fine striations on the prism faces, or as more stubby crystals displaying perfect geniculate, or knee shaped, twins. The latter grains are often a deep reddish-brown colour while the prismatic grains are a vivid red. Rutile is the commonest form of TiO_2 being the high temperature polymorph associated with high pressure-temperature assemblages and thus its origin is almost certainly related to the Hill of Leaders Granite.

Apatite and zircon are widespread and abundant throughout the Davenport Province occurring in varying proportions in most drainage systems. However, they are rare in Gilbert Creek draining the Warramunga Group, and in streams draining the mafic Treasure Volcanics northwest of the Pioneer Mine (Hatches Creek Sheet GR 090980). Apatites commonly form very small polished transparent "beads" or, more rarely, short prismatic crystals, their hexagonal sections distinguishing them from the tetragonal zircon prisms. Zircons are extremely variable in form ranging from singly and doubly terminated euthedral prisms up to several mm in length, to completely rounded polished grains. Colours are commonly yellows, oranges and reds (colour relates to the oxidation state of iron) with the most euhedral prisms transparent, and the larger, completely rounded grains having a faint pink colour.

Epidote occurs in areas draining Edmirringee Volcanics (Phg), Treasure Volcanics (Phtm) and the gabbro-dolerite intrusives (Pd), that is in mafic-ultramafic volcanic-intrusive terrains. It forms a minor to rare component in acid-intermediate volcanic and sedimentary terrains, and is rare to absent in granitic terrains. Epidote displays great variation in form and colour, the latter ranging from rich deep greens (typical of Edmirringee Volcanics), through apple to yellow greens (typical of Treasure Volcanics), to milky-whites and "dirty-browns". Crystal forms include thin delicate prisms, subradiating sprays, short euhedral prismatic grains and crumbly amorphous masses. Some grains display dark inclusions, possibly of Fe rich material. The epidote is probably derived largely from deuteric alteration and/or retrograde metamorphic processes within the mafic-ultramafic rock types.

Rare andalusite grains locally occur in the Hit or Miss Gully at Hatches Creek as brownish-black tetragonal prisms, pseudomorphed by fine mica aggregates. Significantly, these may be of contact metamorphic origin (petrographic studies of rock samples from Treasure Gully suggests tourmaline may be porphyroblastic; D. Blake, BMR, personal communication, 1983) possibly related to subsurface mineralising granites. Plates of biotite and lesser muscovite and secondary chlorite aggregates are locally prominent, particularly form the Hill of Leaders and Elkedra Granites. Distribution studies of the micas are unreliable because their SG (2.76 to 3.10) overlaps with that of tetrabromethane (2.96).

Distinctive euhedral octahedra of magnetite and martitic magnetite are ubiquitous throughout the survey area. Their perfect symmetry and common attachment to frosted milky quartz suggests they are largely of vein type origin. Magnetic character is variable, and their black to red colours are related to the intensity of oxidation. Ilmenite often shows an antipathetic distribution with magnetite and occurs as weakly magnetic, very small, highly lustered black, bead like grains. Ilmenite dominates over magnetite in all granite terrains suggesting the complexes have a greater S-type character (rather than I-type) which may have implications in relation to their Sn-W potential. Pale yellowish to white leucoxene often pseudomorphs both rounded and euhedral ilmenite grains, indicating a complex alteration history. Manganese minerals of botryoidal and massive form are extremely rare, with limonite pseudomorphs after pyrite locally common, particularly in Kurinelli Sandstone (Phk) terrains. Highly lustered, equant bluish-black grains and small euhedral honey-brown platy grains from the Treasure Volcanic terrain 7 km northwest of the Pioneer Mine, were tentatively identified as columbite-tantalite and wulfenite-stolzite respectively. Their scarcity throughout the concentrates suggest they have little economic significance.

5. CONCLUSIONS.

The stream sediment orientation survey was primarily aimed at developing an understanding of the mechanisms of secondary dispersion in the Davenport Province, and to provide a geochemical framework to help identify anomalous populations. An important parameter in the orientation survey was the choice of sampling mediums. Insitu soil profiles throughout the Davenport region are poorly developed, and the immature skeletal soils and aeolian sands that characterise the outcropping areas preclude soil sampling as a regional geochemical method. The styles of known W, Cu, Bi, Mo, Au and U mineralisation throughout the province (ie. localised thin veins with weak alteration haloes) indicate that relatively high density rock chip sampling (in the order of 0.50 m spacing) would be required to detect and evaluate these mineralised environments. It is believed that stream sediment sampling is the most effective regional geochemical method for use in the Davenport Province, although the effectiveness of this technique is restricted by:-

(i) the short drainage trains which rarely exceed 500 m in length, and the associated small catchment areas,

(ii) long strike length ridges of the arenite lithologies which often result in the preferential dissection of the terrain and the dominance of coarse grained (+250 um) quartz-feldspar detritus in the drainage system, and

(iii) the heterogeneity of the Davenport geological terrain which also reduces the effectiveness of such surveys in discriminating individual litholigies or formations, either by geochemical or heavy mineral methods.

The orientation survey, which concentrated on stream sediment channel sampling, involved both sieved fractions and heavy mineral concentrates from mineralised and potentially mineralised environments. Studies of variations in element concentrations with particle size in samples from these environments indicated that the optimal size fraction for the detection of most elements distant (+2 km) from the source is the -75 um fraction. The dispersion of Sn, which is controlled by the mechanical stability of cassiterite, is a noted exception with +180-500 um being the optimal size fraction. Element associations and optimal sampling intervals for detection of the various styles of mineralisation occurring in the Davenport Province are summarised in Table 14.

Secondary dispersion mechanisms for most elements in this semi-arid environment appear to be controlled by mechanical processes, with hydromorphic dispersion largely restricted to Mn and Fe adsorption of Zn and, to lesser degrees, Co and Cu. The role played by clay adsorption processes appears to be insignificant and certainly has little influence on the interpretation of geochemical data on a regional basis. Due to the dominance of mechanical processes in the weathering environment, element dispersion patterns are largely determined by the mechanical stability of the mineral species in which the elements occur. As indicated by the length of the dispersion trains listed in Table 14, a sample spacing of 3 to 4 km along the stream should detect W and Sn derived from hydrothermal vein systems, although closer spacing, of the order of 0.5 km, is required for the associated elements Bi, Mo, Be, Co, Zn and, in particular, Cu. Stream sediment surveys do not appear to be useful in detecting vein type U mineralisation. This may be due to the extreme solubility and mobility of uranyl complexes under the alkaline and oxidising conditions typical of semi-arid environments. Bank sampling carried out at the Copper Show Mine at Hatches Creek, and at the Wauchope Wolfram Field, showed this sampling medium is useful for detecting Sn and Cu anomalies derived from hydrothermal vein mineralisation, but not W since the initial dispersion of this element is largely controlled by the mechanical instability of wolframite and scheelite. These detrital W minerals experience rapid size reduction during alluvial transport and are erratically redistributed across the drainage profile during flooding cycles, or by aeolian processes. Cassiterite, which shows greater mechanical resistance during alluvial transport, appears to be largely confined to the main channel region.

Heavy mineral concentrates are more useful than sieve fractions in catchments dominated by arenite lithologies. In these terrains, which are extensive throughout the Davenport Province, limonitic-quartz and feldspar grains dominate the alluvium and have the effect of diluting the geochemical contributions from smaller, recessive geological formations. Several heavy minerals, diagnostic of the various styles of W mineralisation, show persistence in the weathering cycle (e.g. cassiterite, topaz and tourmaline) and can be readily identified in the concentrates (e.g. scheelite and fluorapatite by their fluorescence, copper carbonate-silicate minerals by their vivid colours and bismuth and molybdenum minerals by their metallic lustre). The dominance of mechanical weathering over hydromorphic dispersion processes also enhances the application of heavy mineral concentrates in the Davenport Province, thus it is recommended that stream sediment surveys should include both the analysis of specific sieve fractions and the visual examination of heavy mineral concentrates.

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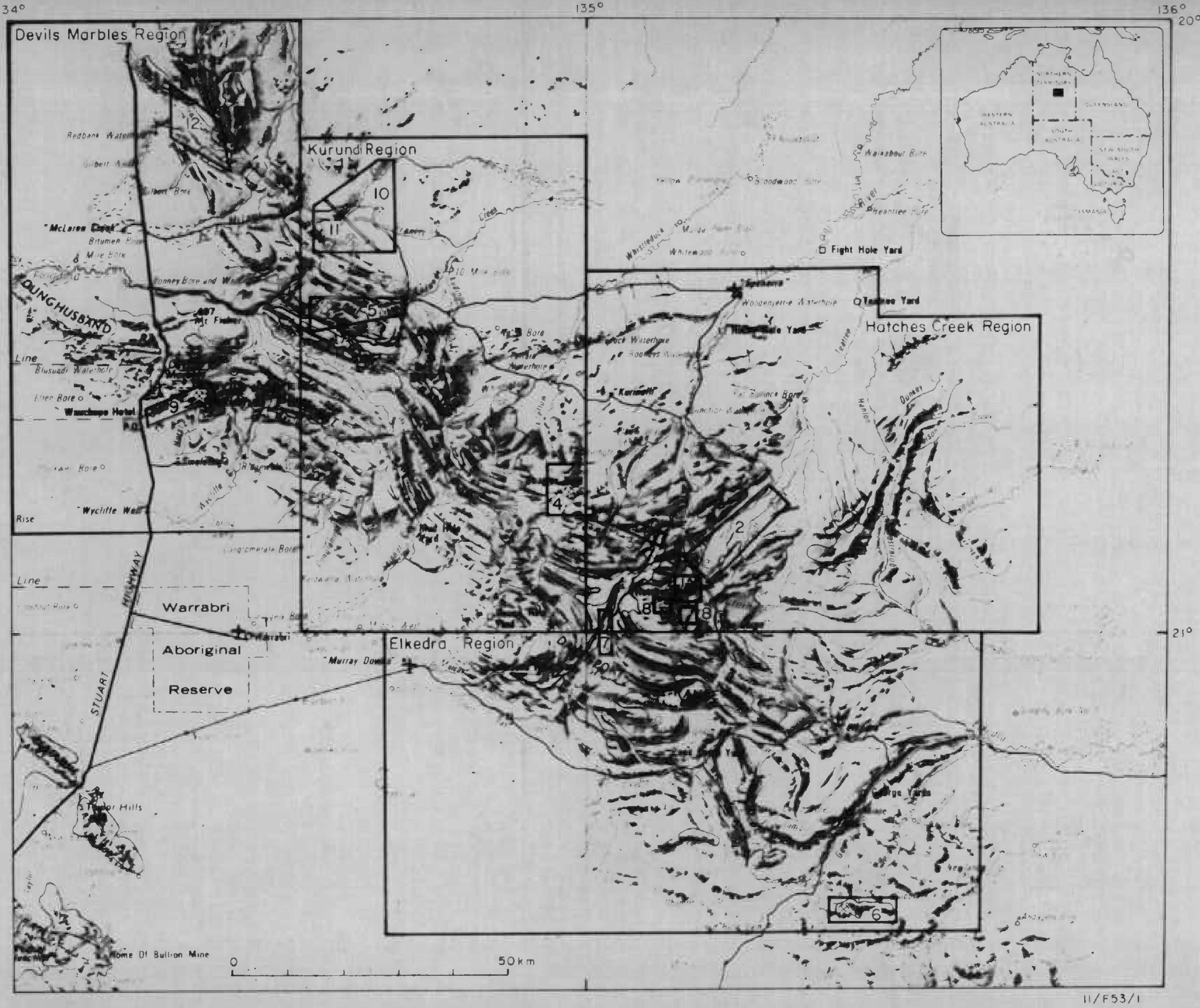

Figure 1 : Physiographic map of the Davenport Province showing geological sheet coverage (1:100 000 scale), mines, prospects and the subareas of the geochemical survey

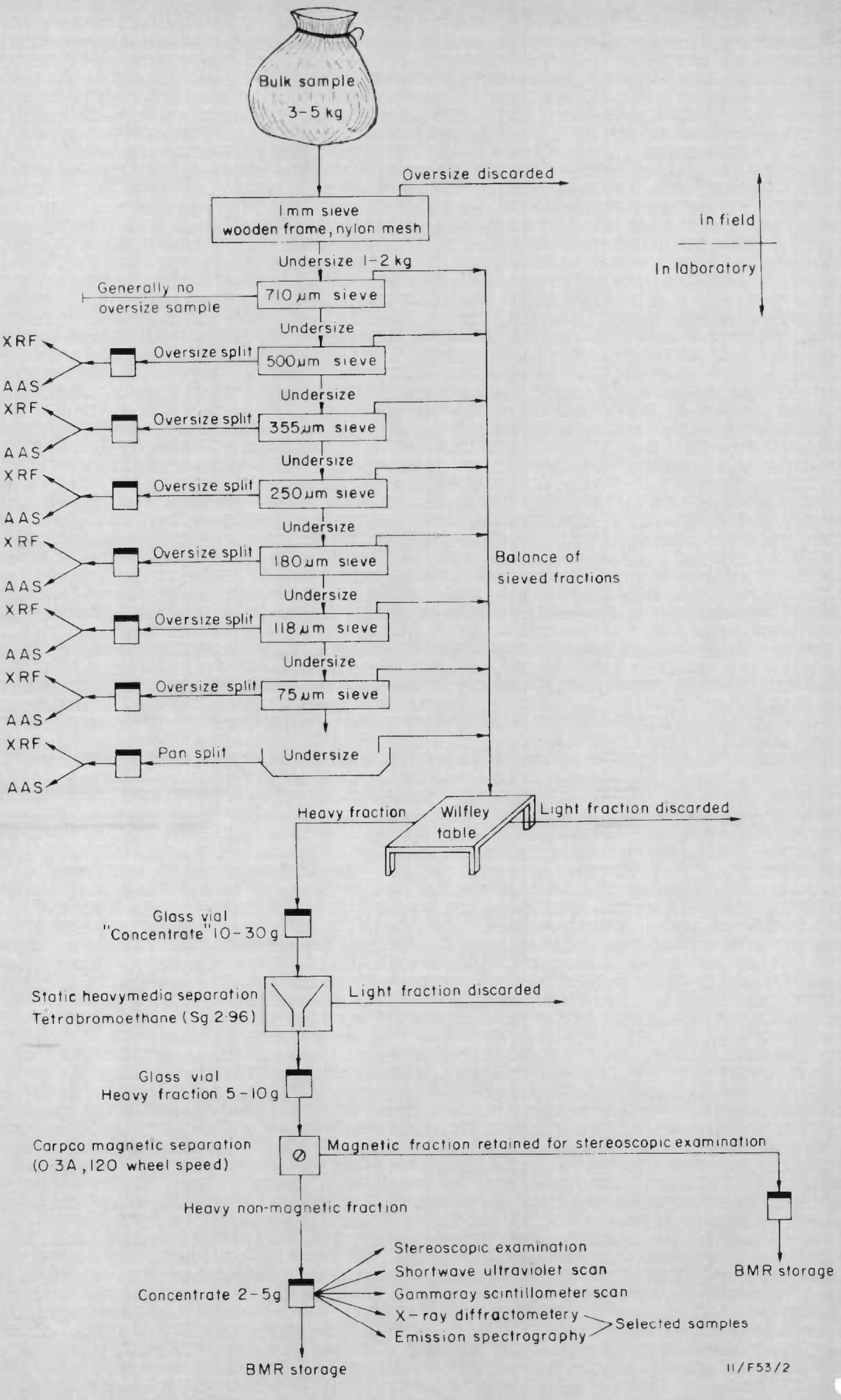

Figure 2: Sample preparation and laboratory methods flowchart

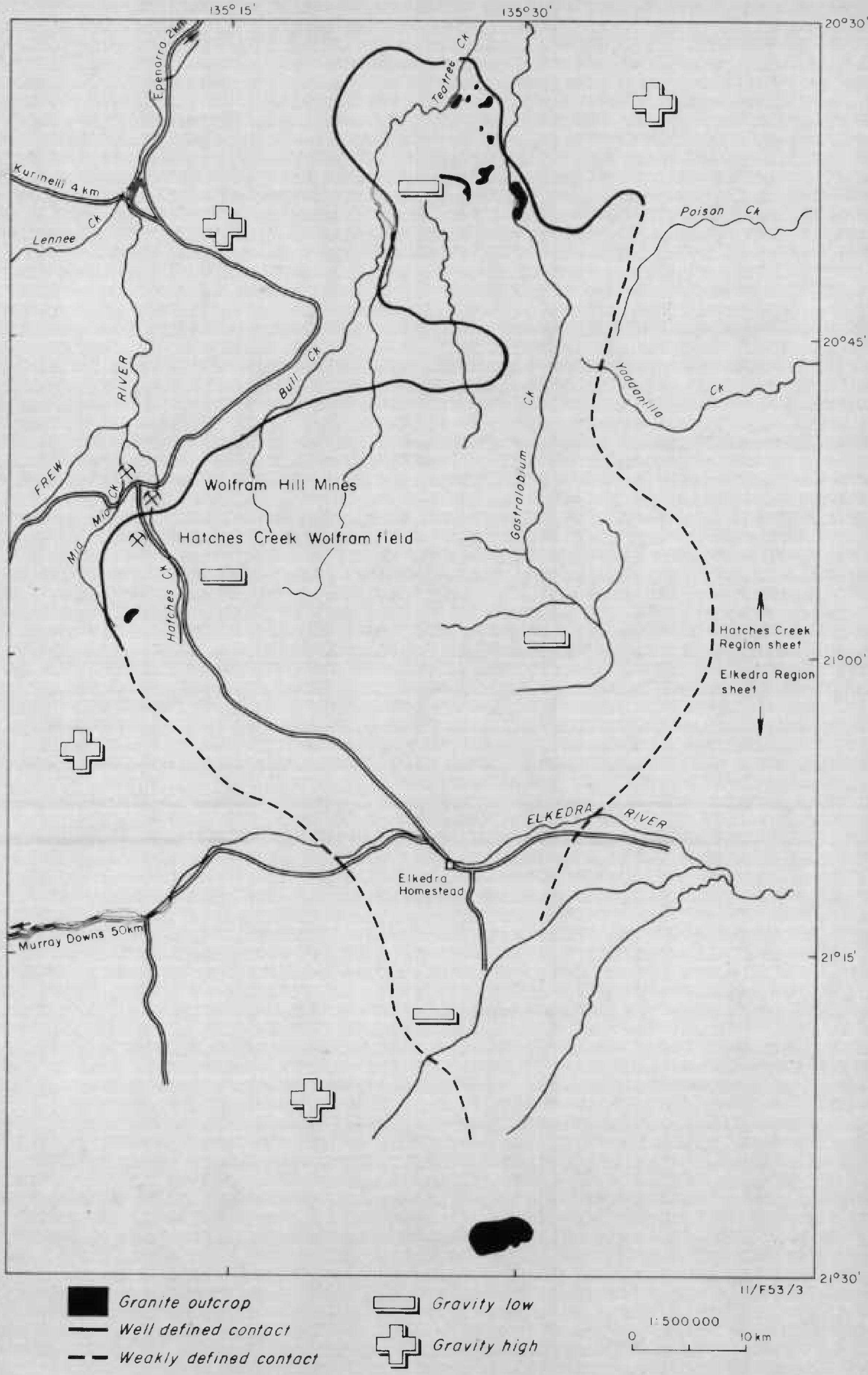

Figure 3: Distribution of interpreted subsurface granite based on gravity and aeromagnetics

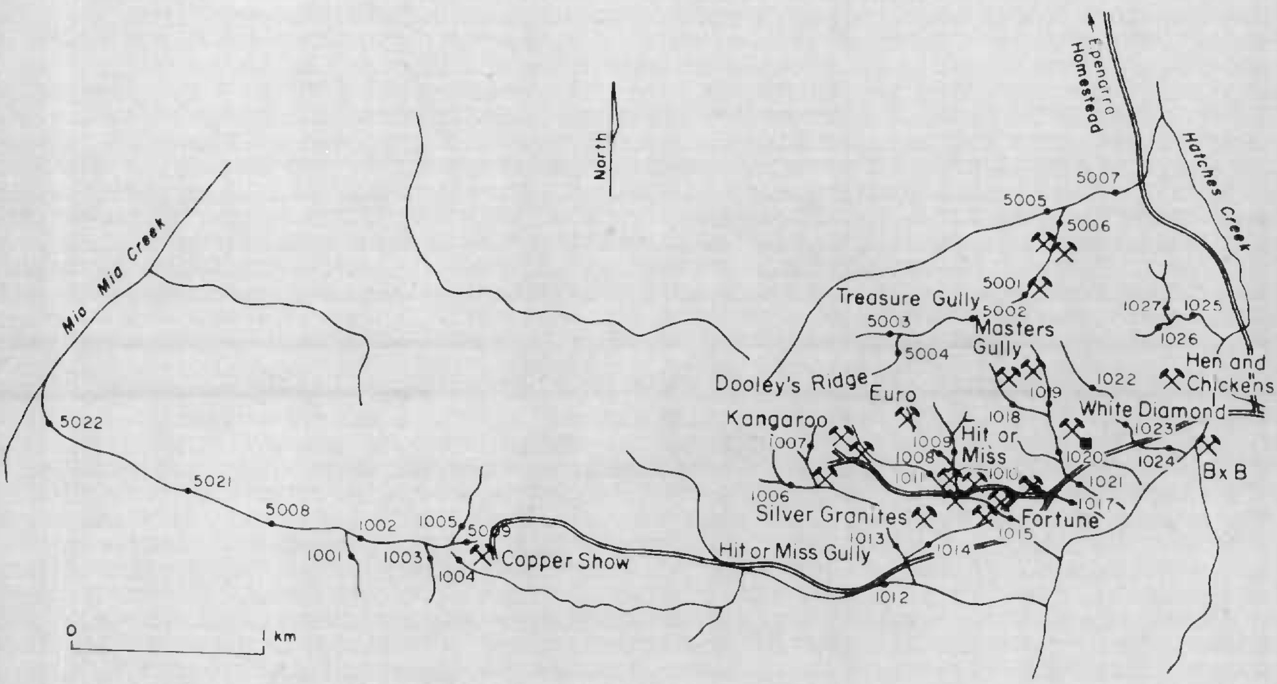

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Figure 4: Distribution of mines and sample locations (prefixed by 8202), Hatches Creek Wolfram Field

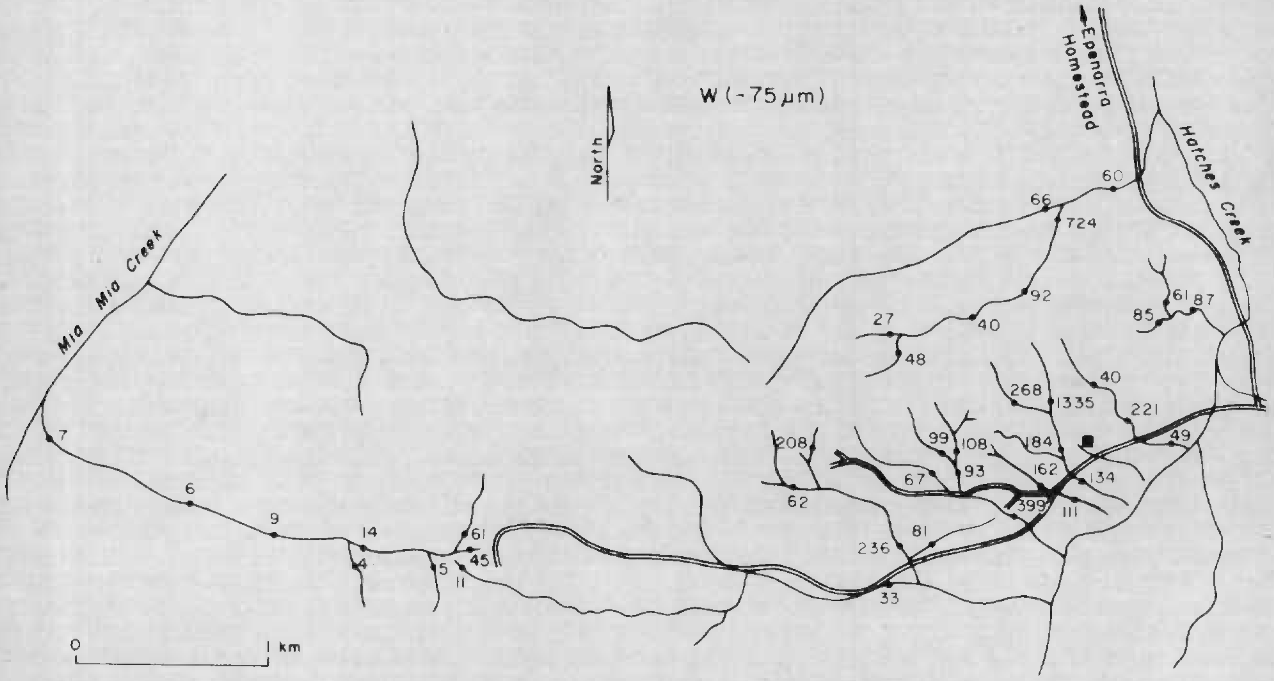

Figure 5 : Distribution of tungsten (ppm) in the -75µm stream sediment fraction, Hatches Creek Wolfram Field

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Figure 6 : Concentration of tungsten with particle size, Hit or Miss Gully

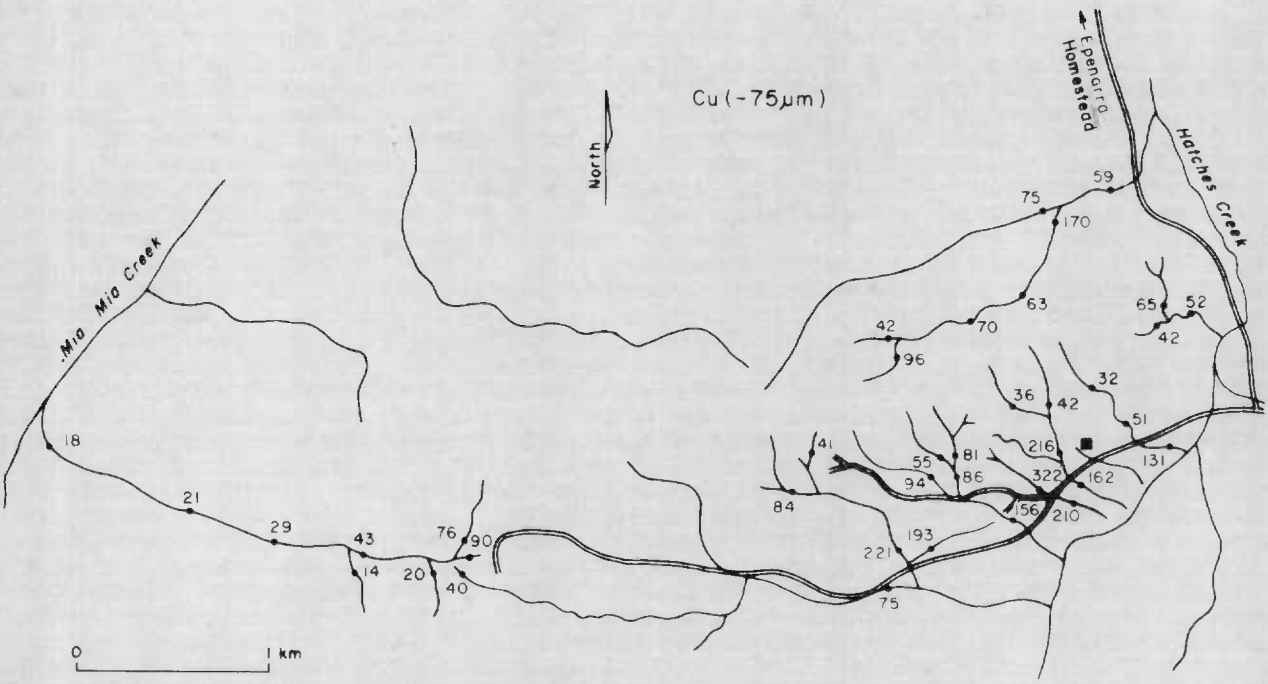

Figure 7 : Distribution of copper (ppm) in the -75 µm stream sediment fraction, Hatches Creek Wolfram Field

Figure 8 : Concentration of copper with particle size, Hit or Miss Gully

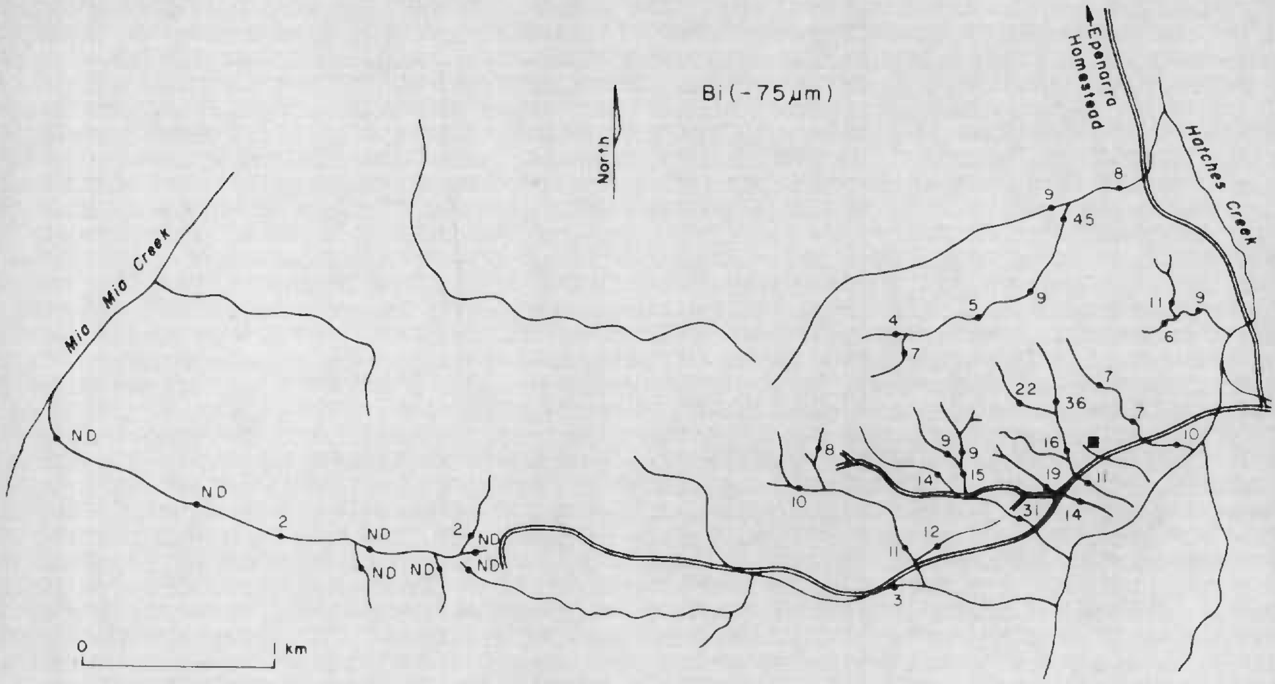

Figure 9 : Distribution of bismuth (ppm) in the −75μm stream sediment fraction, Hatches Creek Wolfram Field

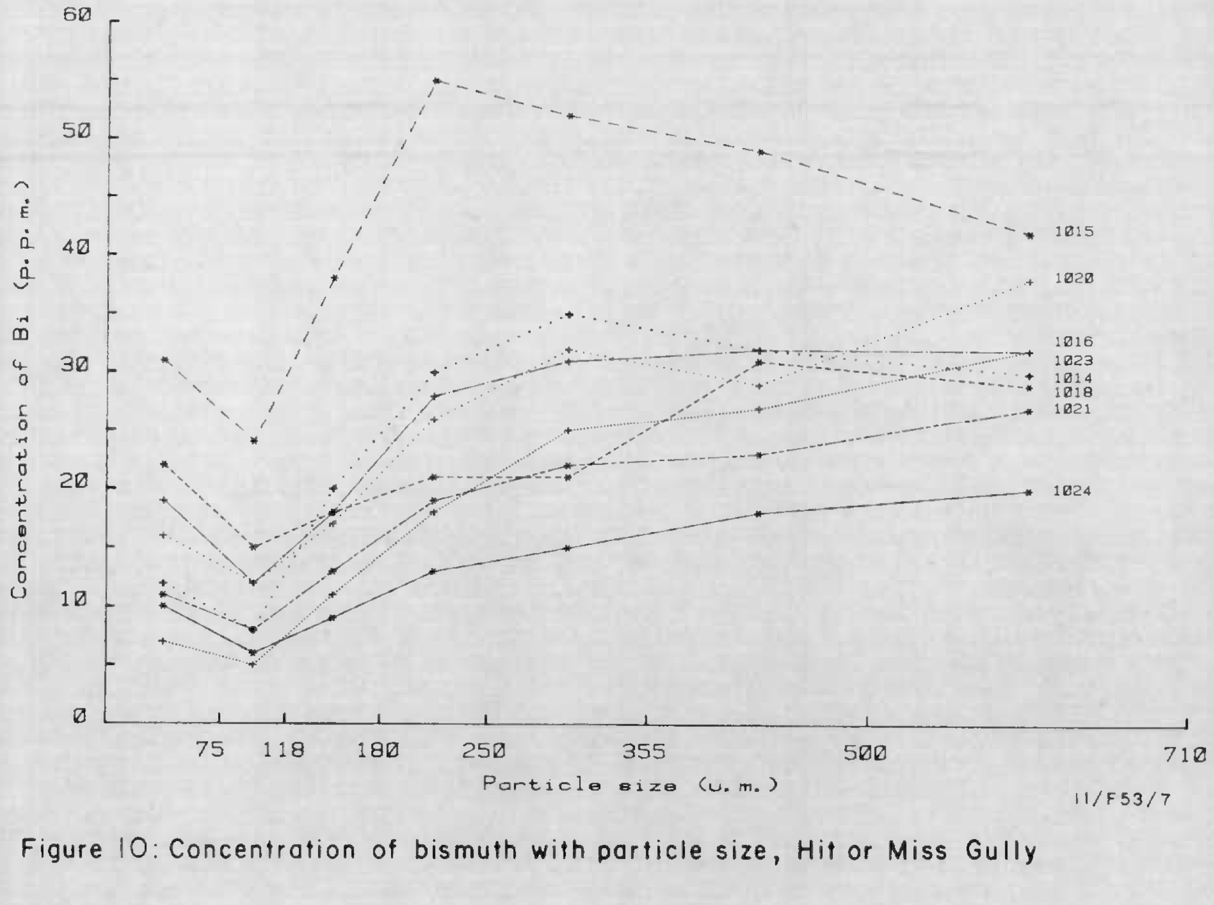

Figure 10: Concentration of bismuth with particle size, Hit or Miss Gully

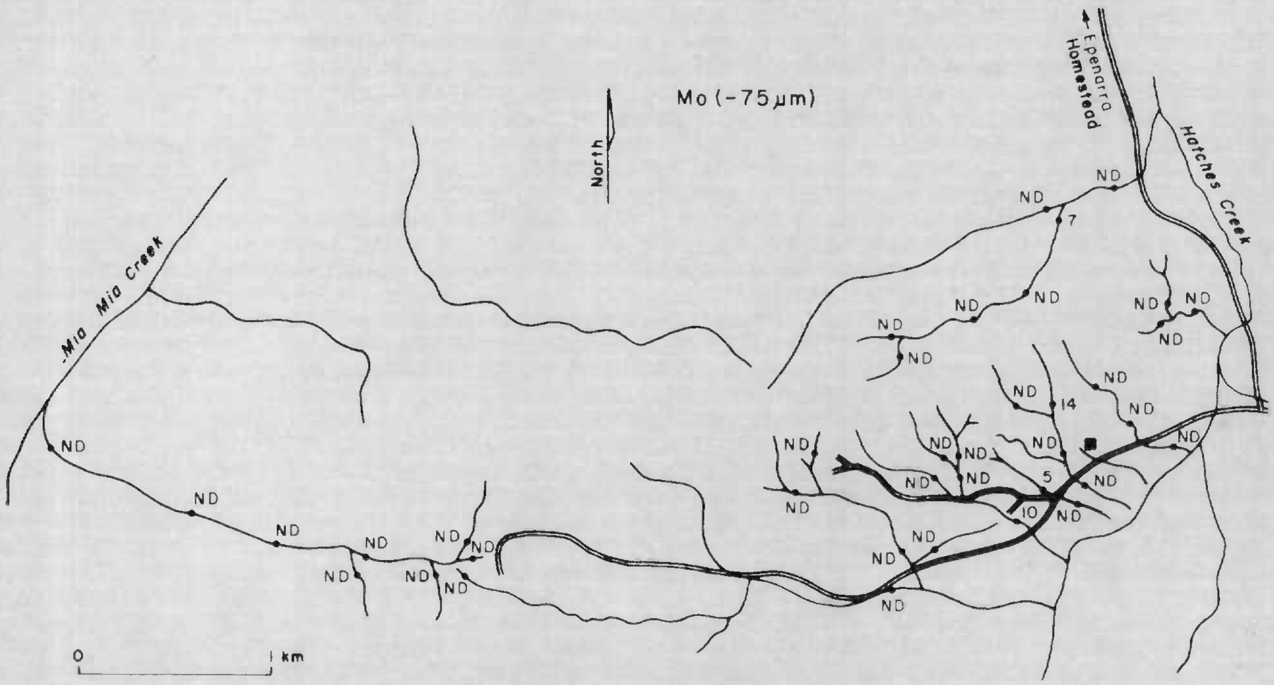

Figure 11 : Distribution of molybdenum (ppm) in the -75 µm stream sediment fraction, Hatches Creek Wolfram Field

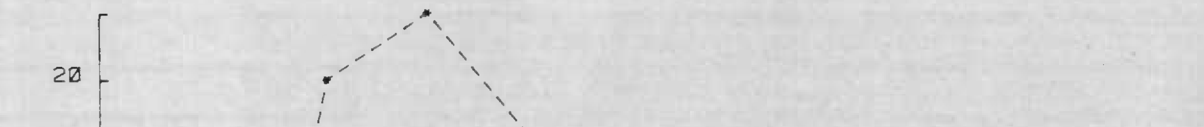

Figure 12 : Concentration of molybdenum with particle size, Hit or Miss Gully

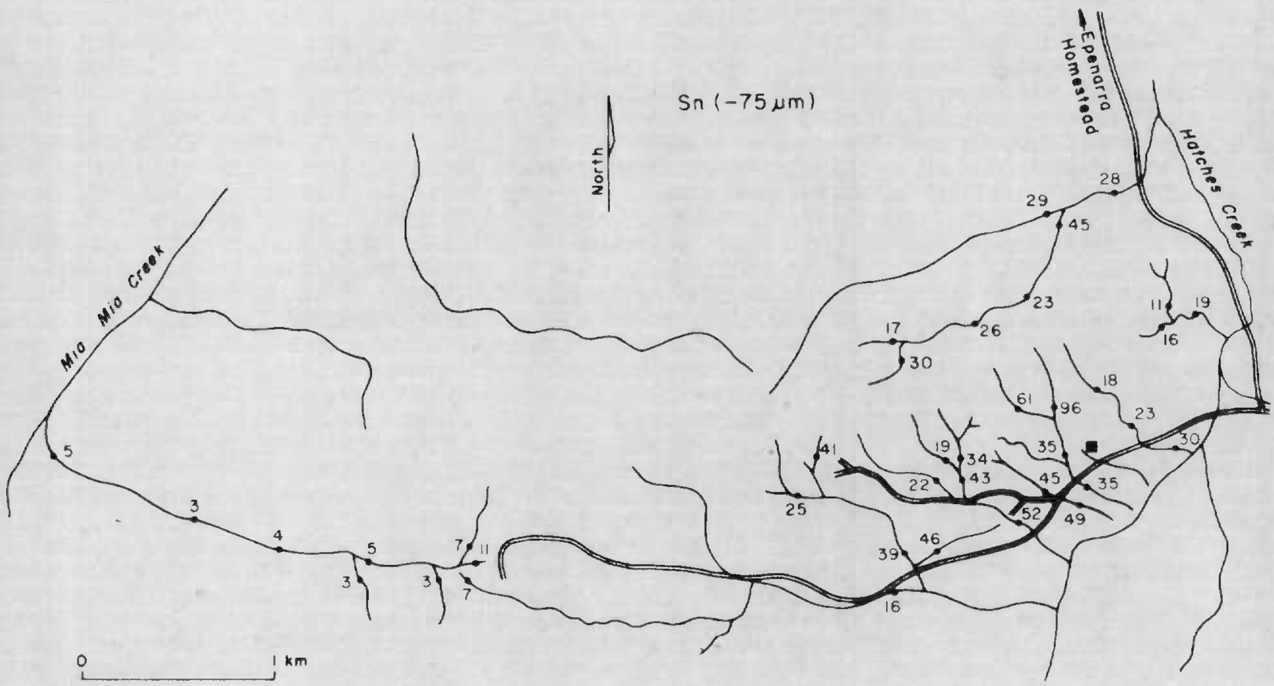

Figure 13: Distribution of tin (ppm) in the -75µm stream sediment fraction, Hatches Creek Wolfram Field

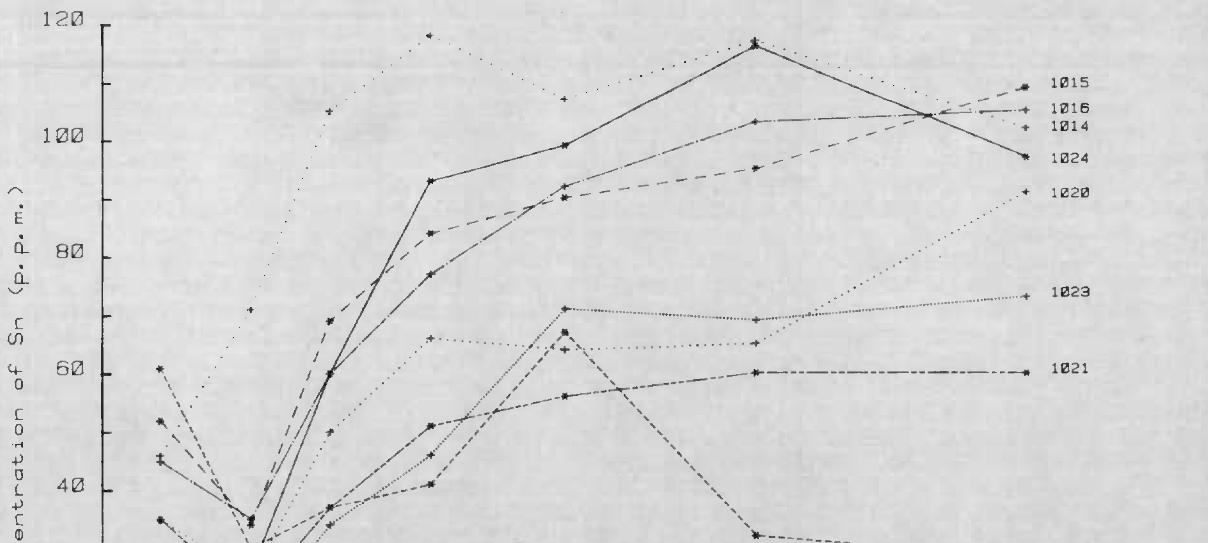

Figure 14: Concentration of tin with particle size, Hit or Miss Gully

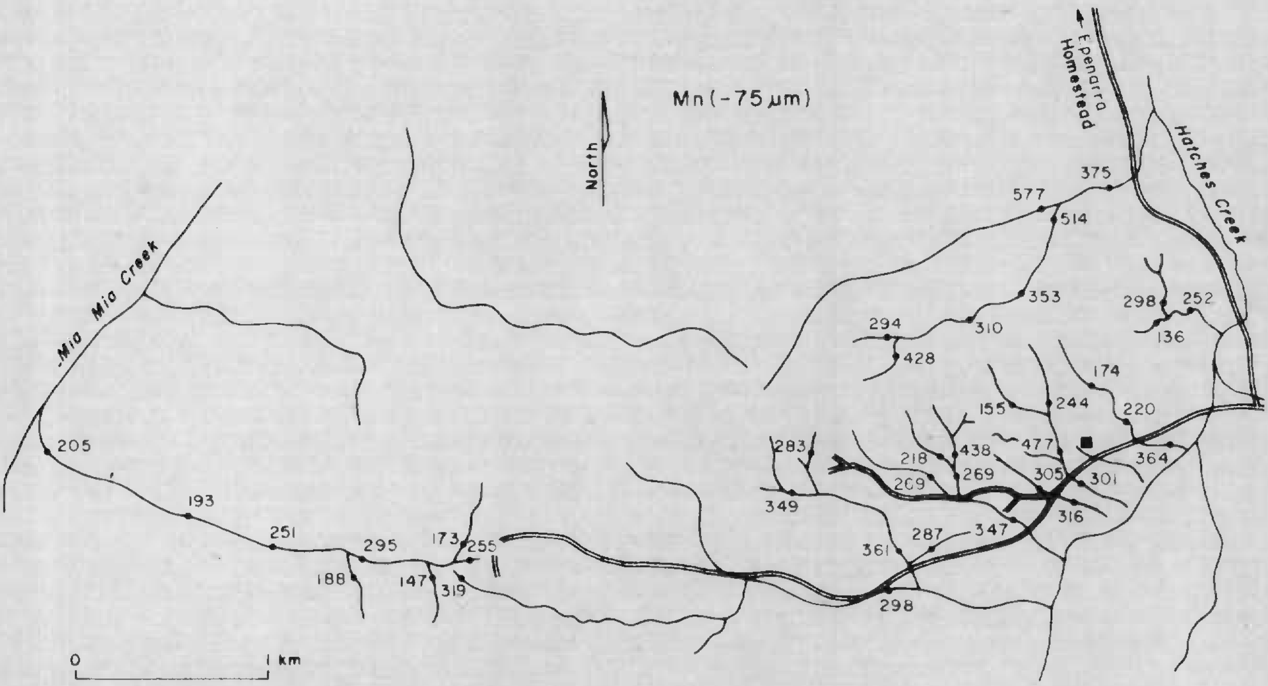

Figure 15: Distribution of manganese (ppm) in the -75 µm stream sediment fraction, Hatches Creek Wolfram Field

Figure 16: Concentration of manganese with particle size, Hit or Miss Gully

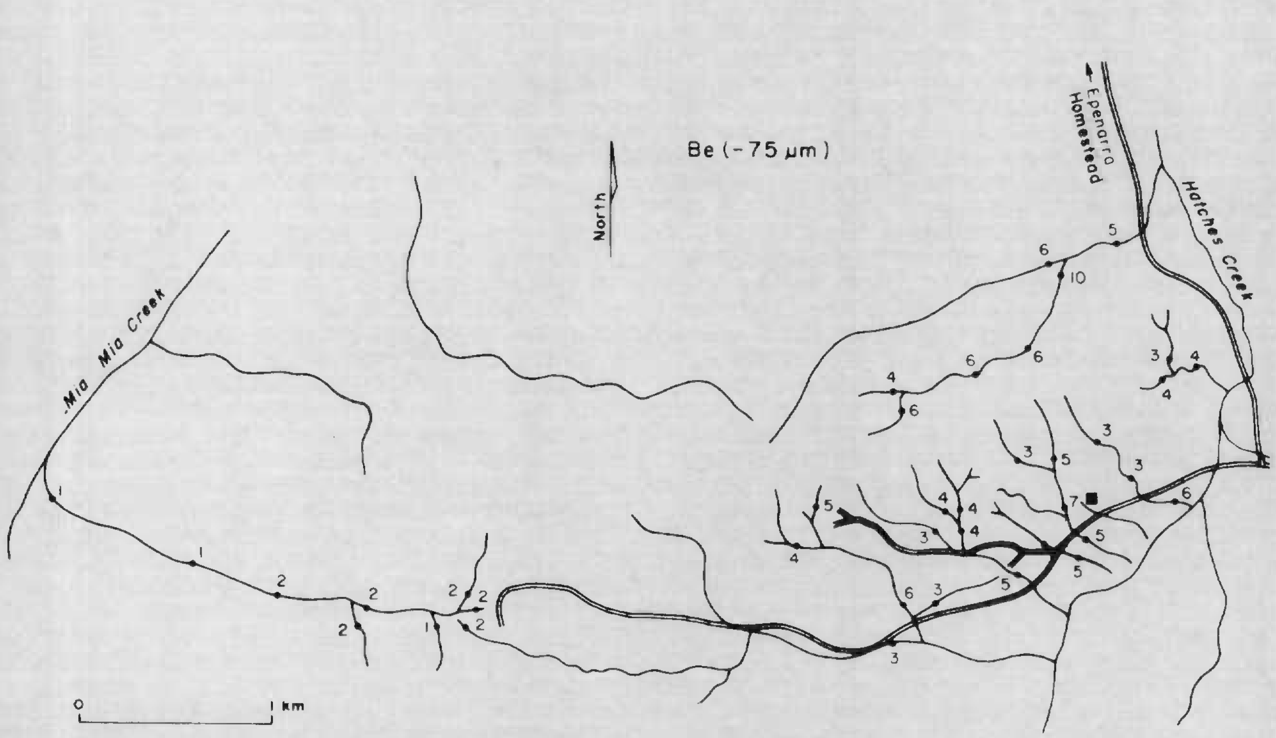

Figure 17: Distribution of beryllium (ppm) in the -75μm stream sediment fraction, Hatches Creek Wolfram Field

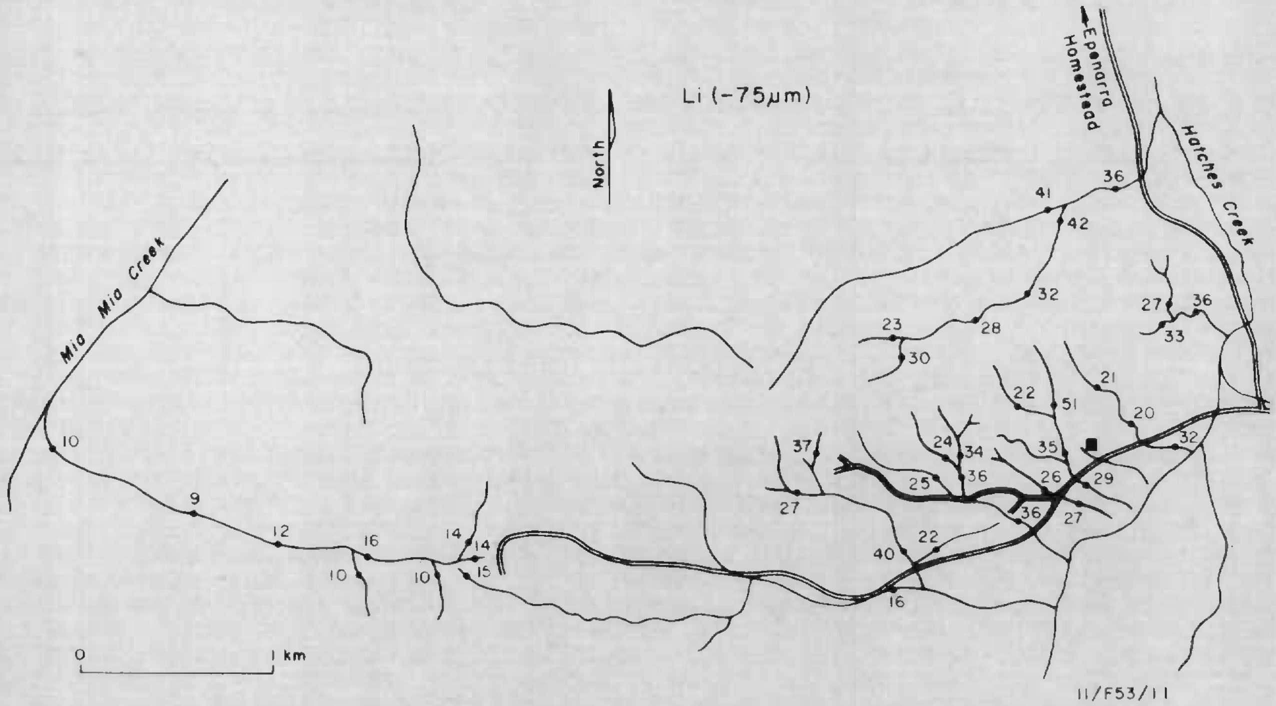

Figure 18: Distribution of lithium (ppm) in the -75μm stream sediment fraction, Hatches Creek Wolfram Field

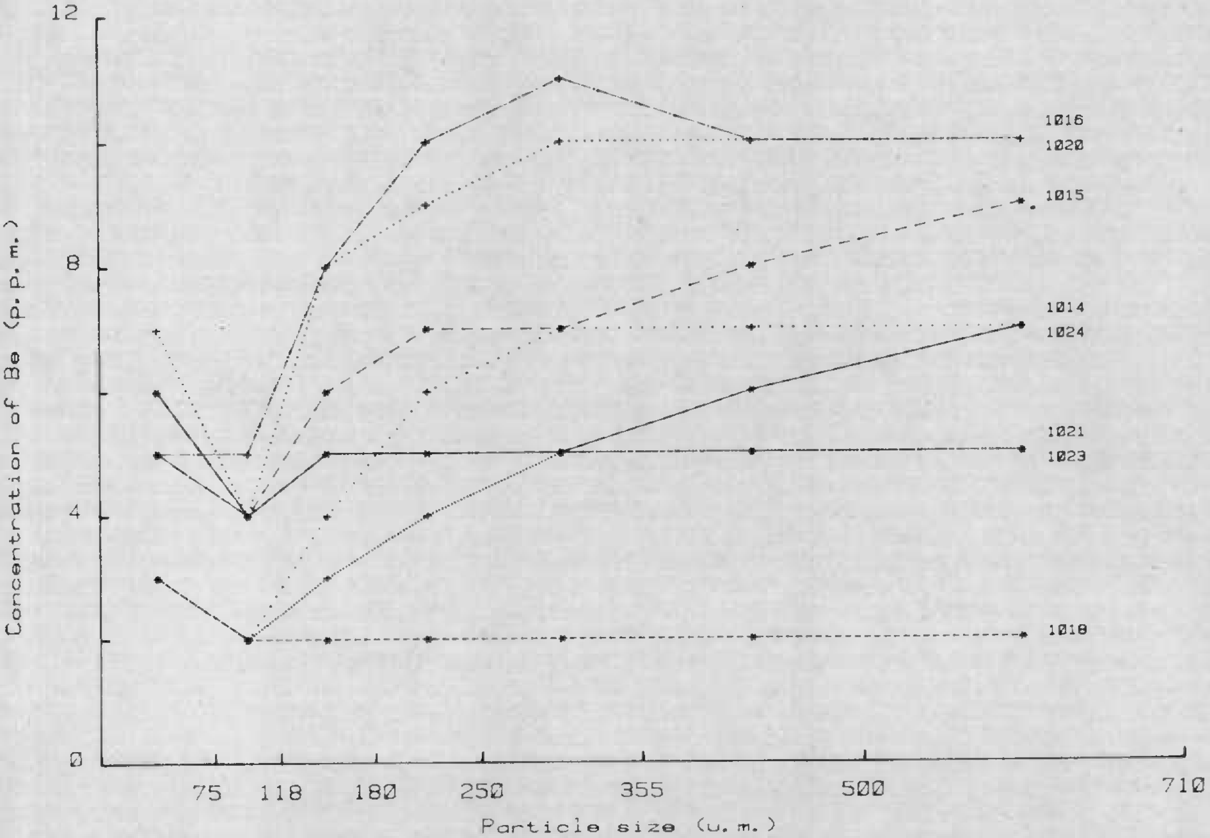

Figure 19 : Concentration of beryllium with particle size, Hit or Miss Gully

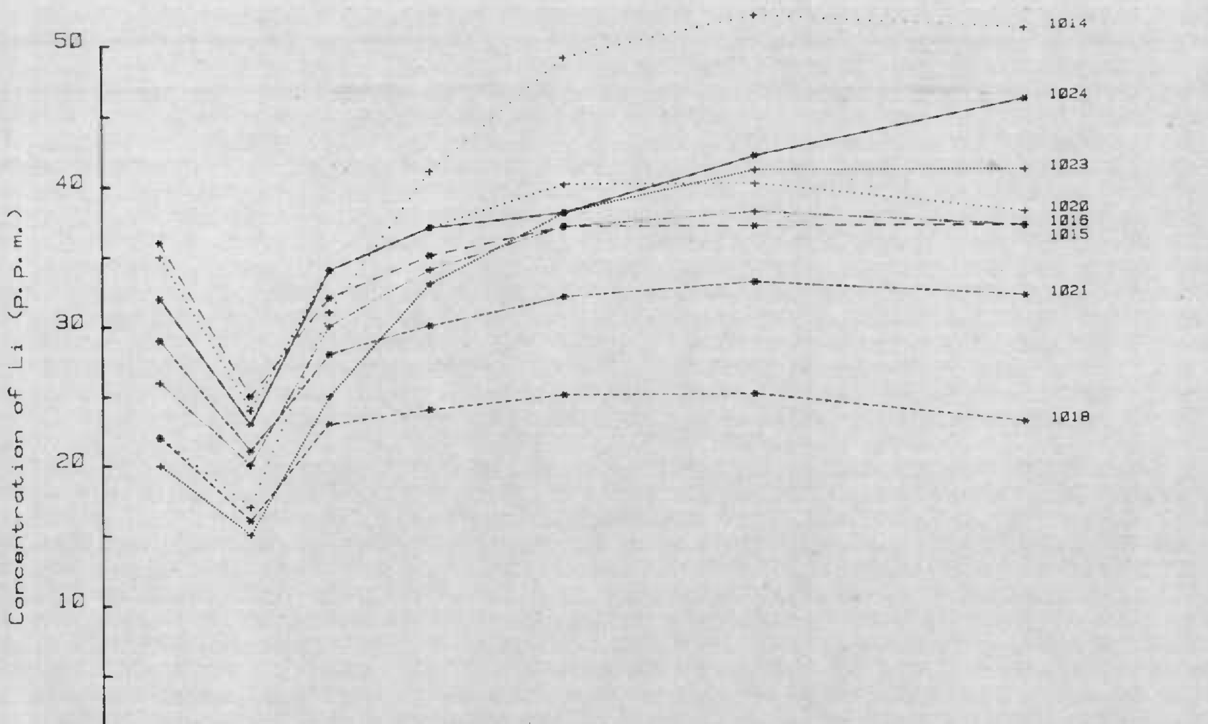

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Figure 20 : Concentration of lithium with particle size, Hit or Miss Gully

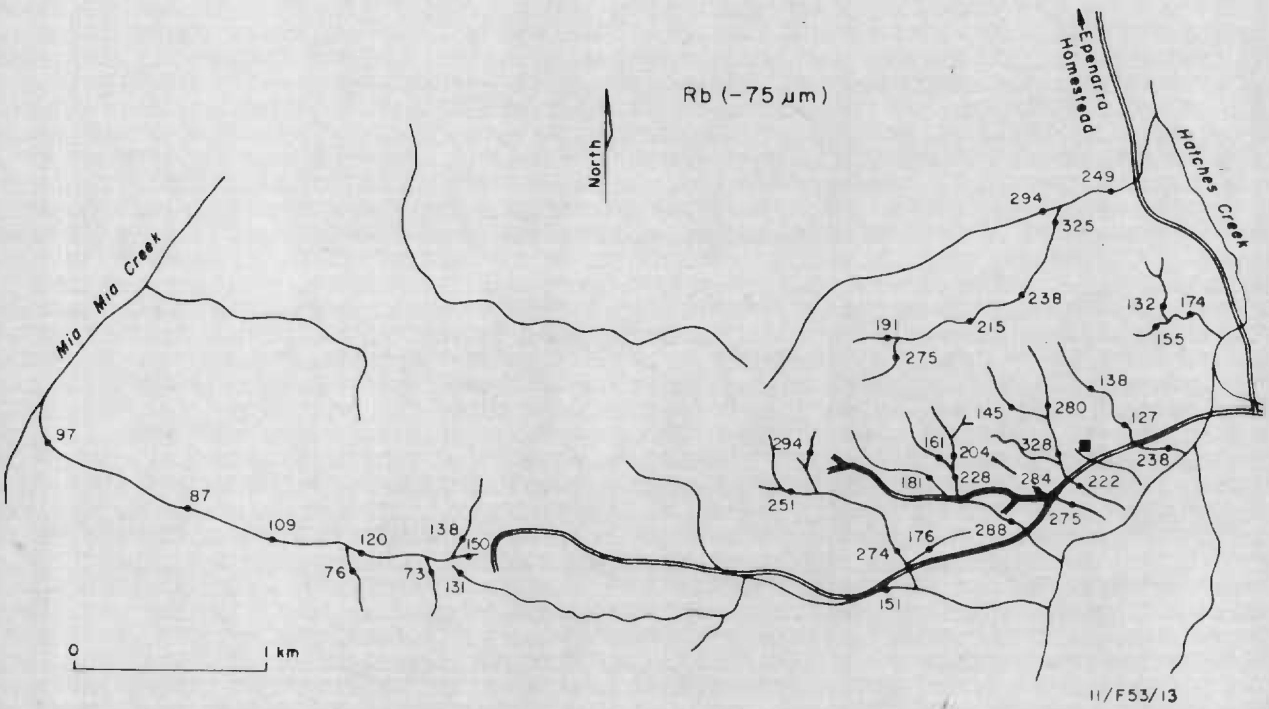

Figure 21 : Distribution of rubidium (ppm) in the -75 µm stream sediment fraction, Hatches Creek Wolfram Field

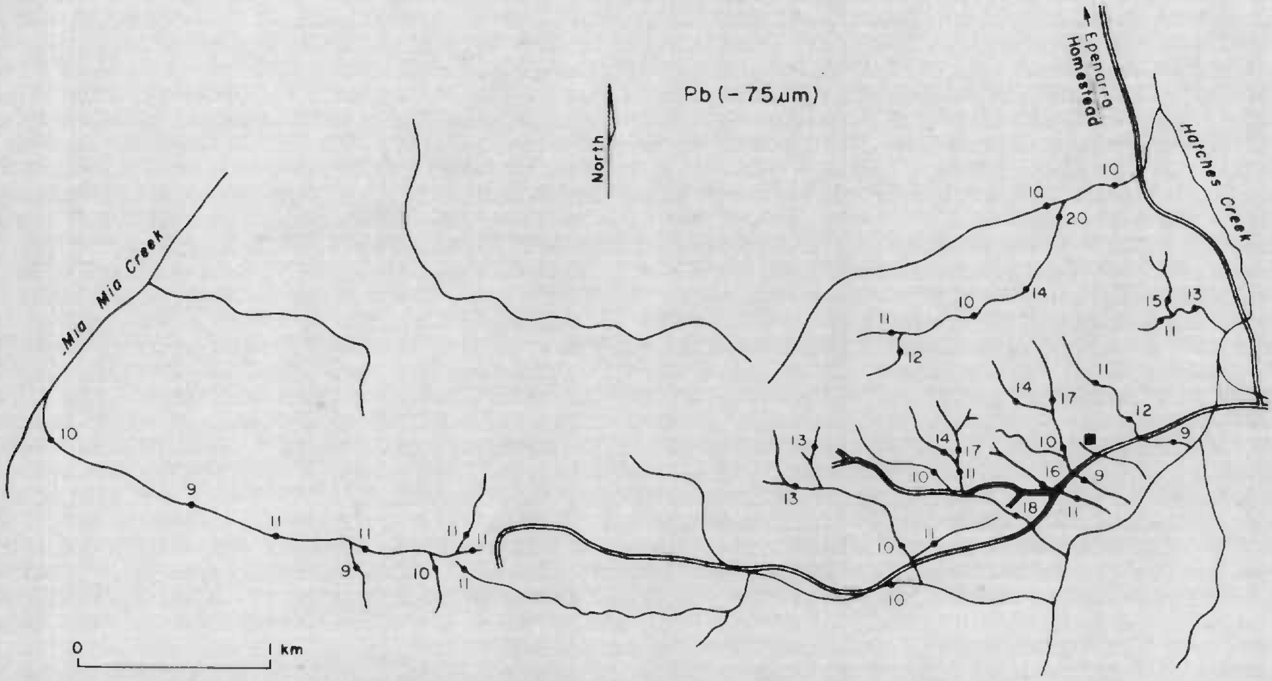

Figure 22: Distribution of lead (ppm) in the -75 µm stream sediment fraction, Hatches Creek Wolfram Field

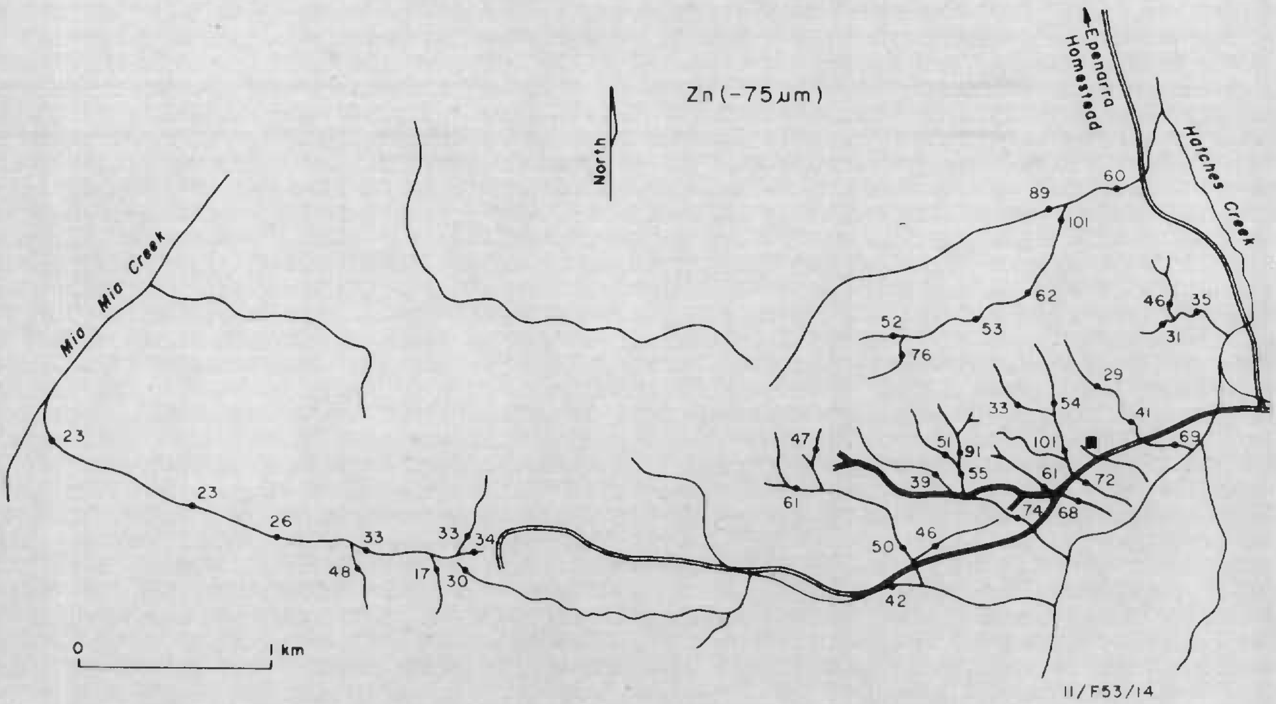

Figure 23: Distribution of zinc (ppm) in the -75 µm stream sediment fraction, Hatches Creek Wolfram Field

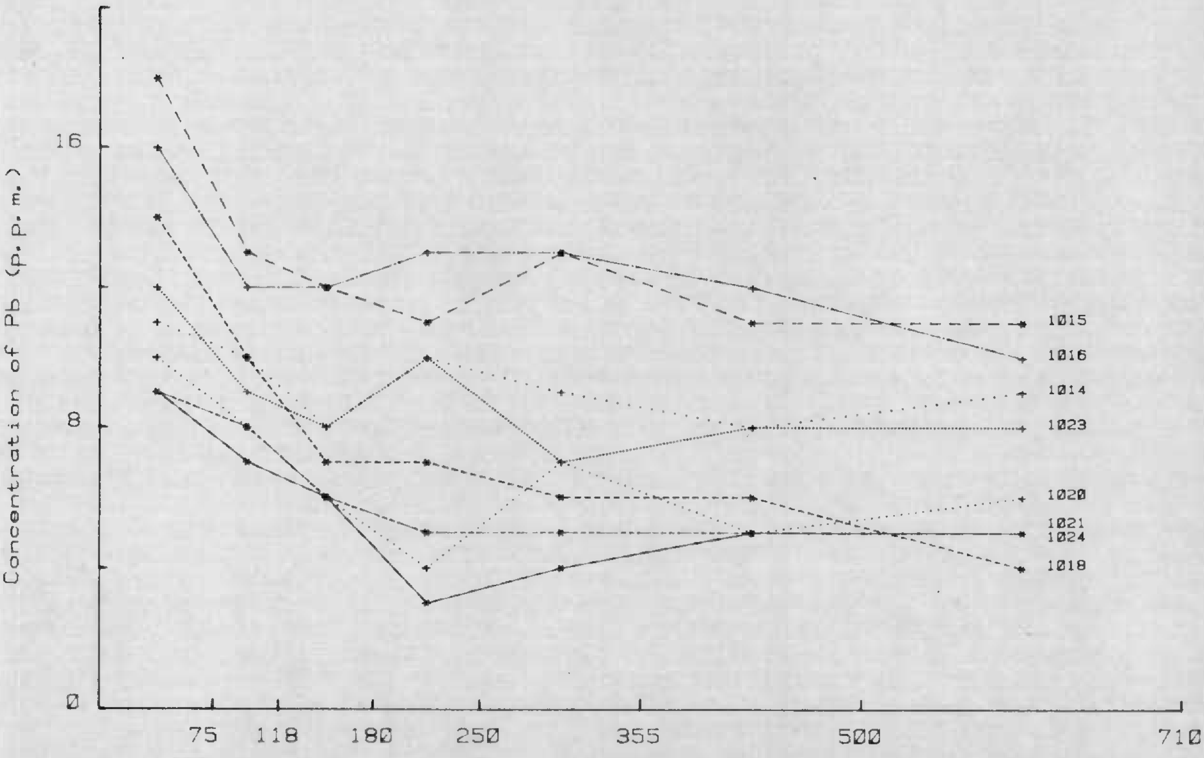

Figure 24: Concentration of lead with particle size, Hit or Miss Gully

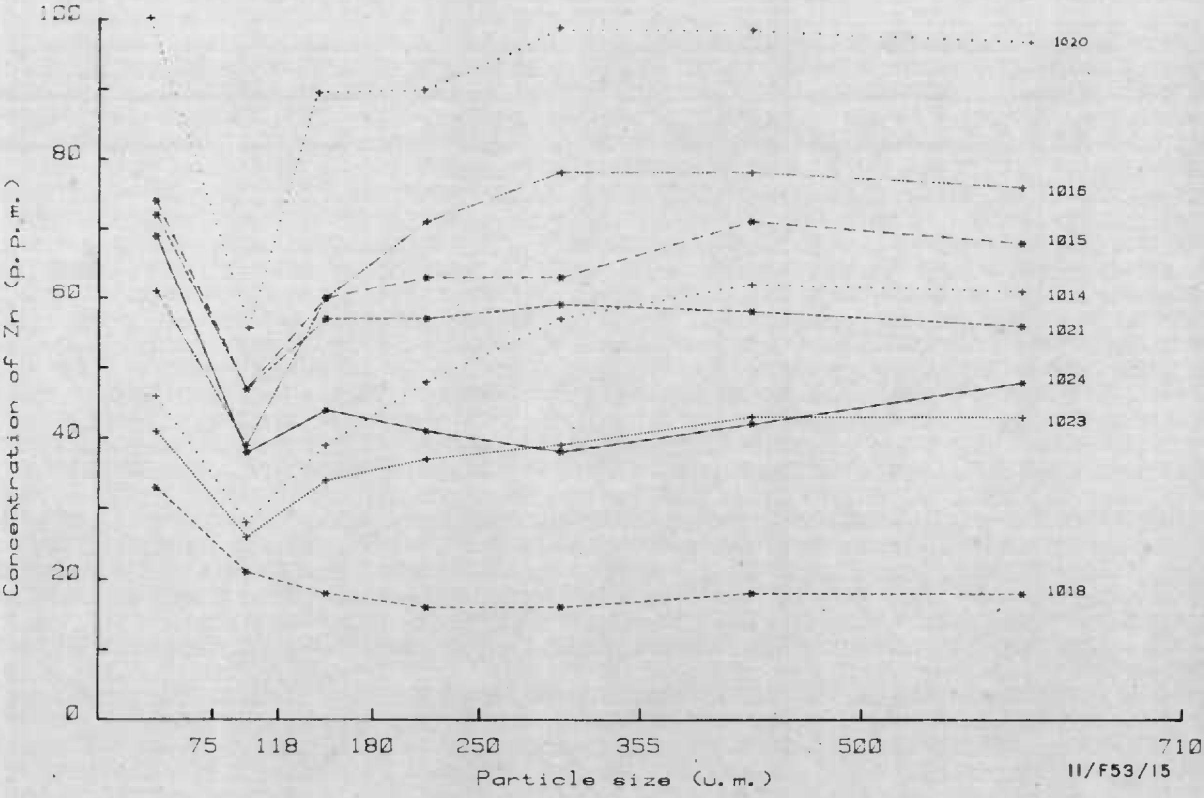

Figure 25: Concentration of zinc with particle size, Hit or Miss Gully

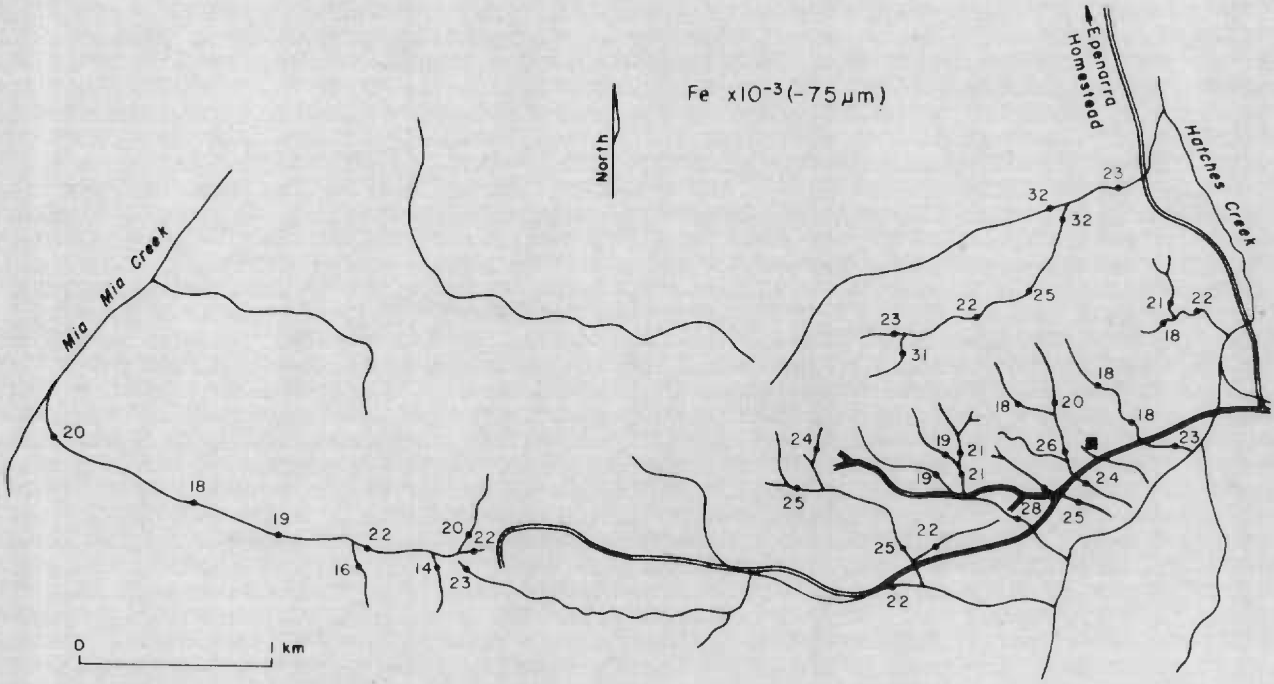

Figure 26 Distribution of iron (ppm x 10^{-3}) in the −75μm stream sediment fraction, Hatches Creek Wolfram Field

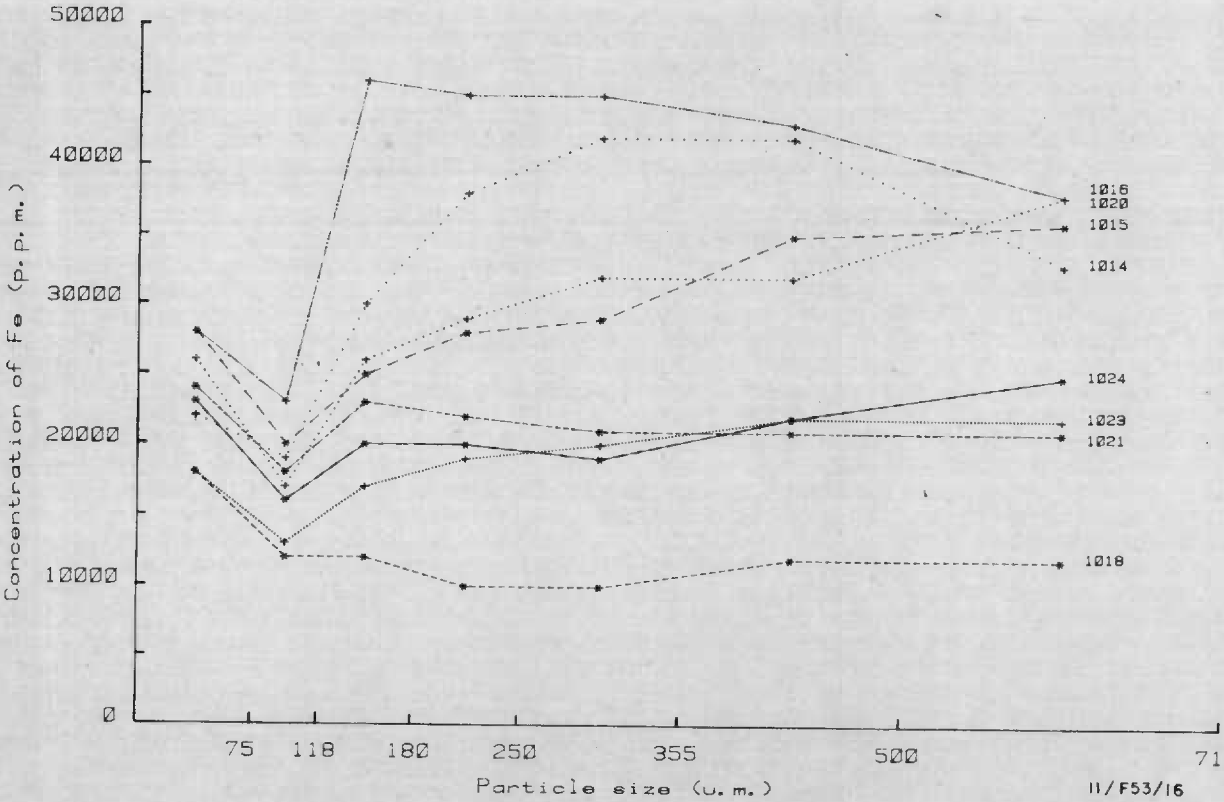

Figure 27: Concentration of iron with particle size, Hit or Miss Gully

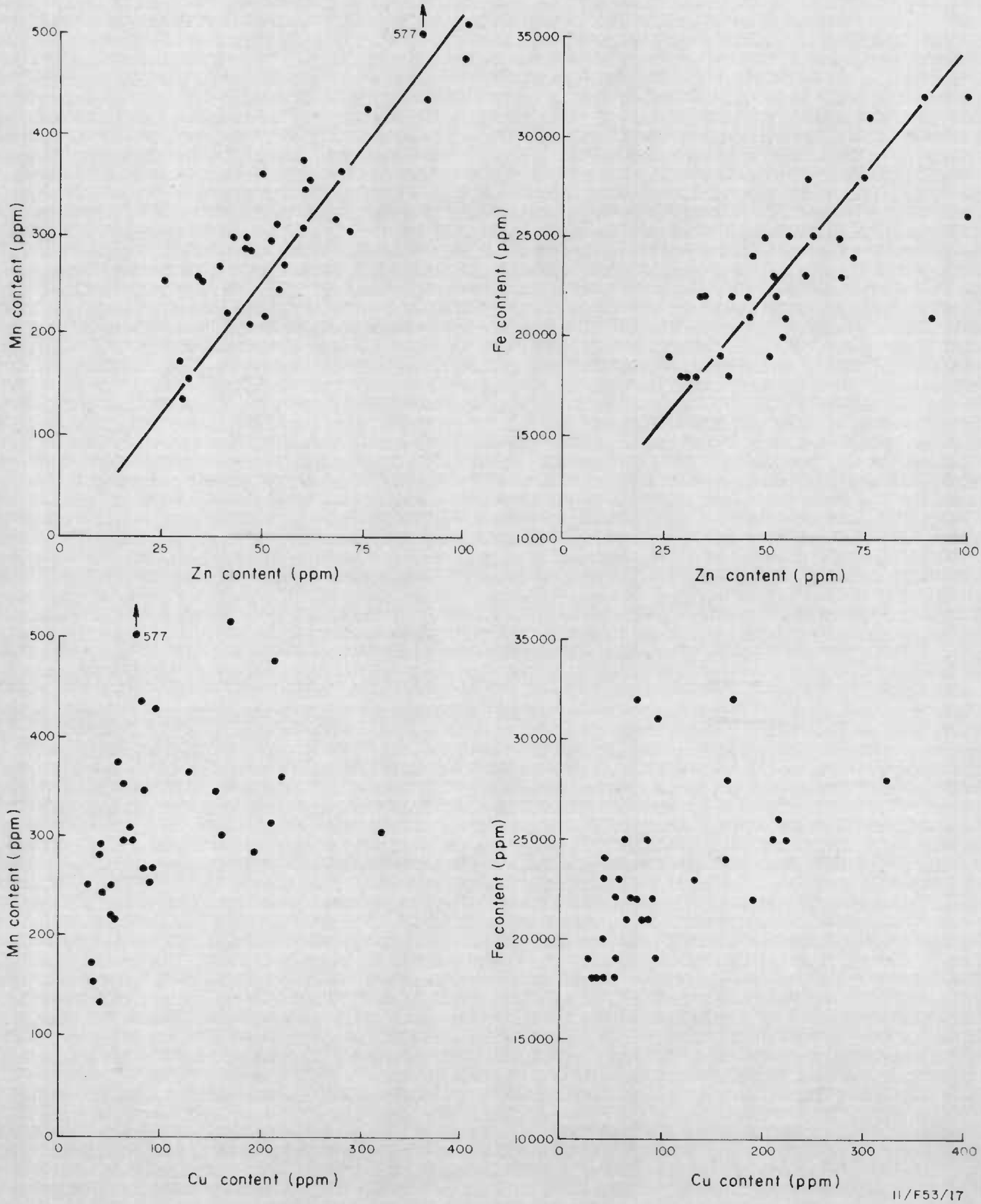

Figure 28: Distribution of zinc and copper with manganese and iron, Hatches Creek Wolfram Field. Data for the -75 µm fraction

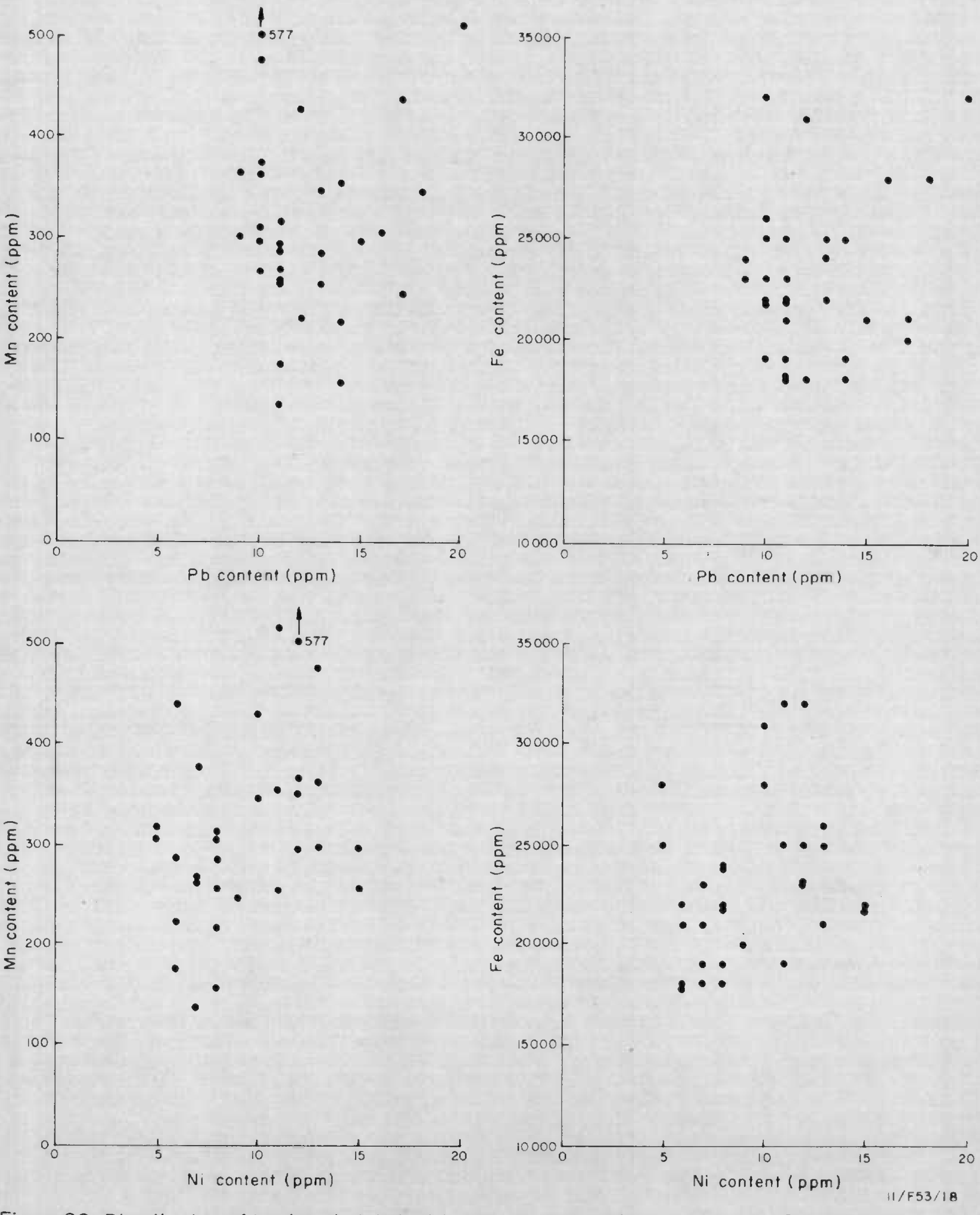

Figure 29: Distribution of lead and nickel with manganese and iron, Hatches Creek Wolfram Field. Data for the −75 µm fraction

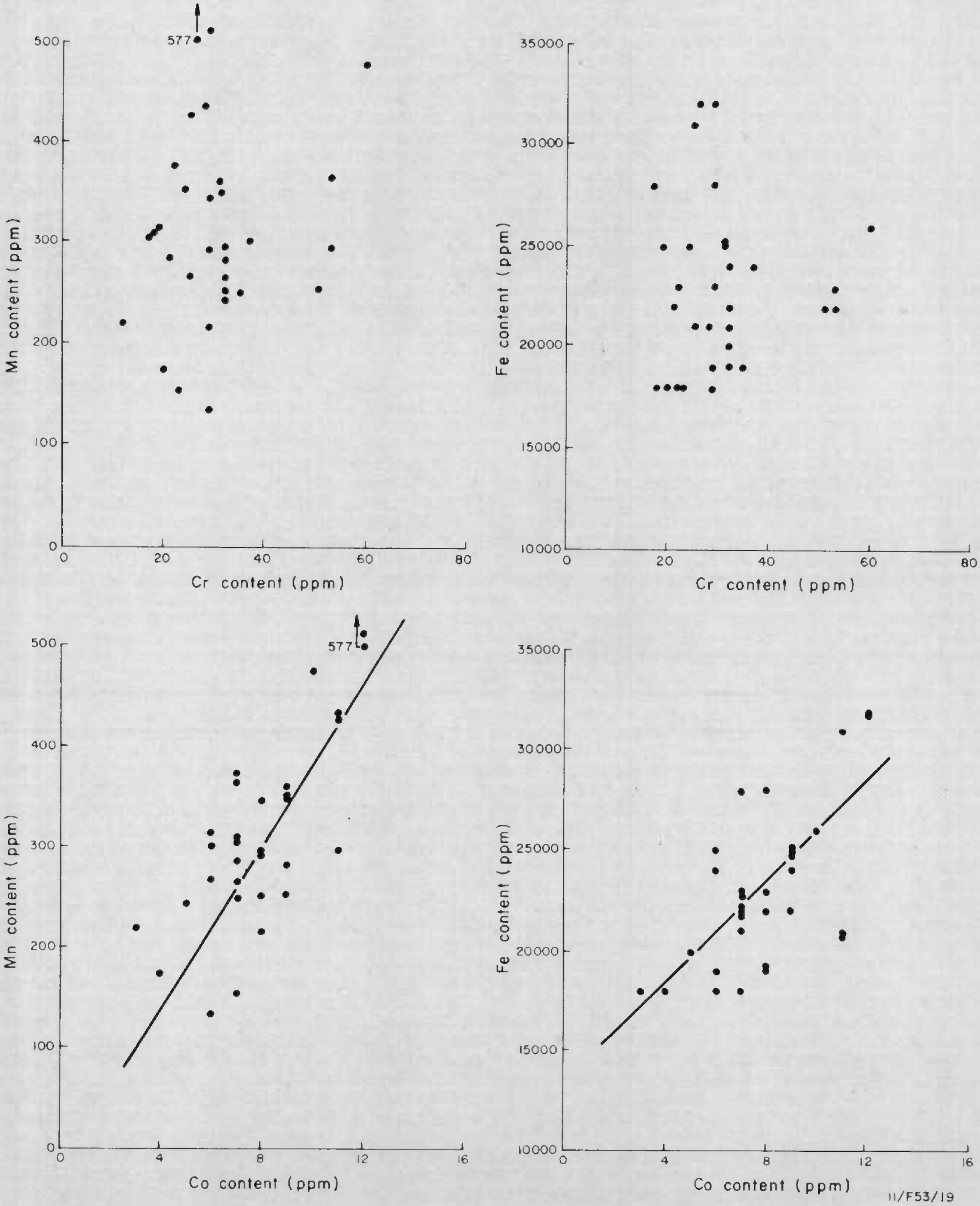

Figure 30 Distribution of chromium and cobalt with manganese and iron, Hatches Creek Wolfram Field. Data for the −75 μm fraction

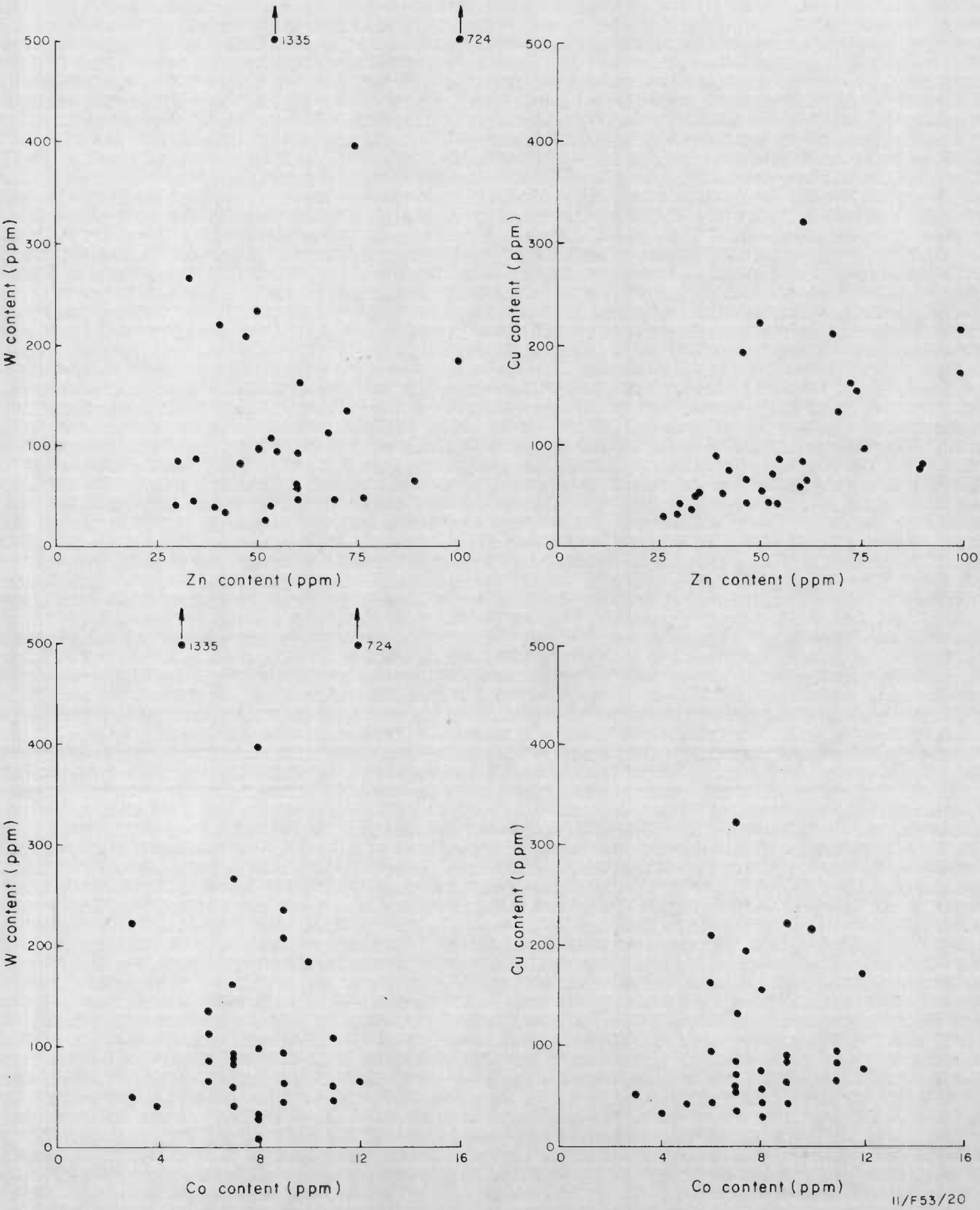

Figure 31 : Distribution of zinc and cobalt with tungsten and copper, Hatches Creek Wolfram Field. Data from the $-75\,\mu m$ fraction

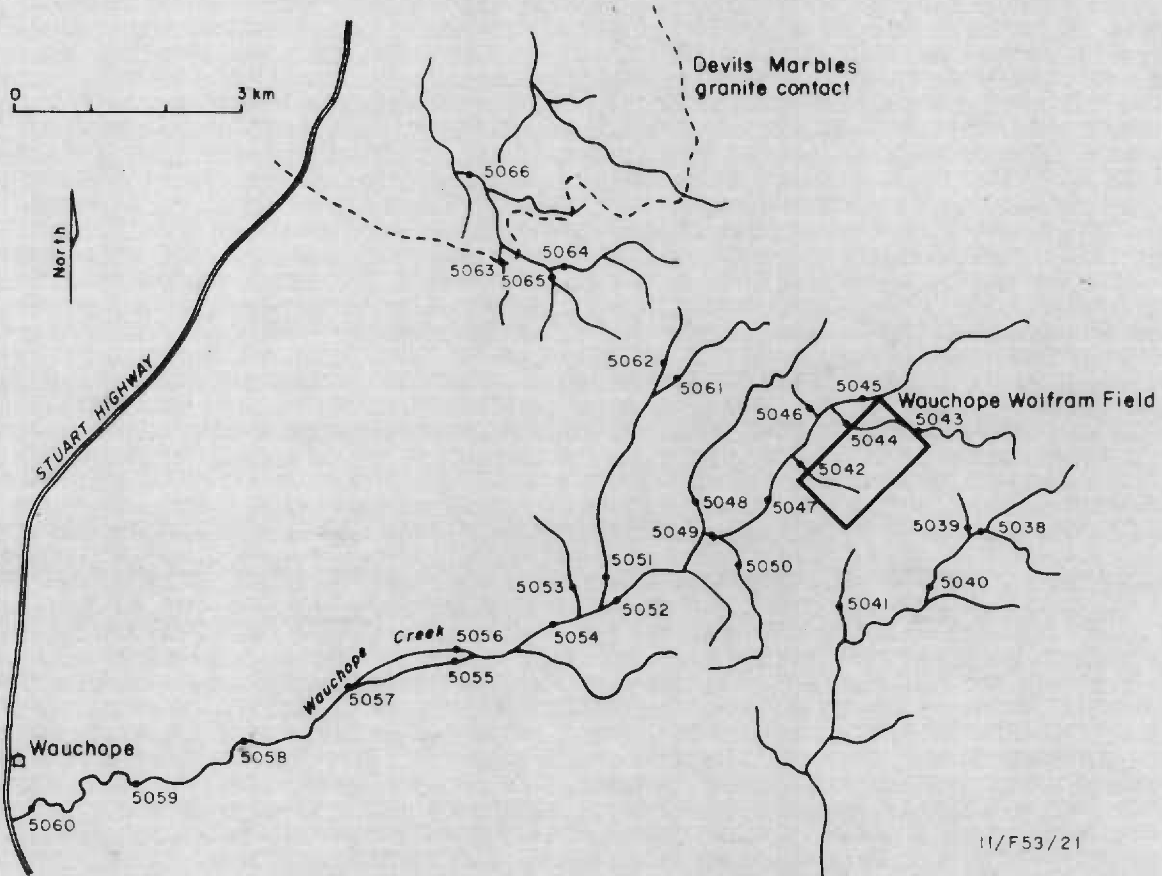

Figure 32 : Sample locations (prefixed by 8202), Wauchope Wolfram Field

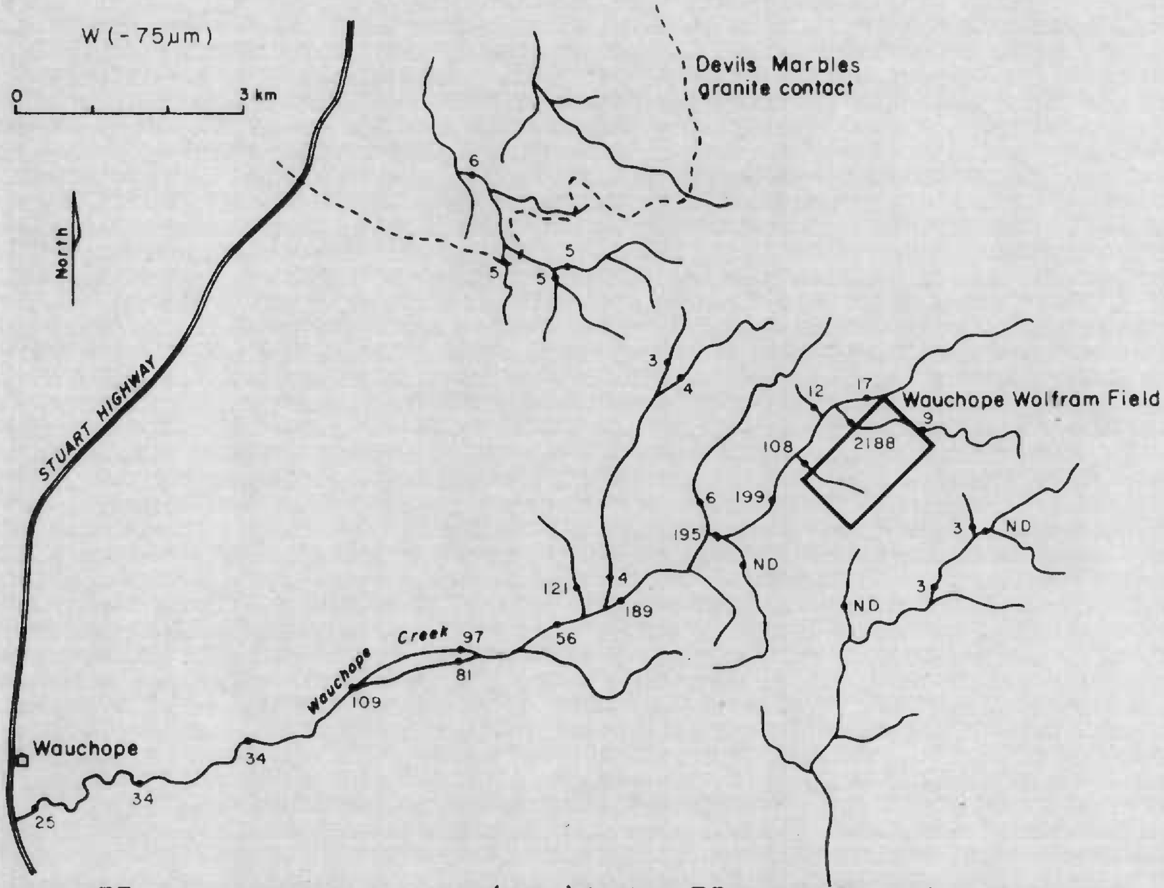

Figure 33: Distribution of tungsten (ppm) in the -75 µm stream sediment fraction, Wauchope Wolfram Field

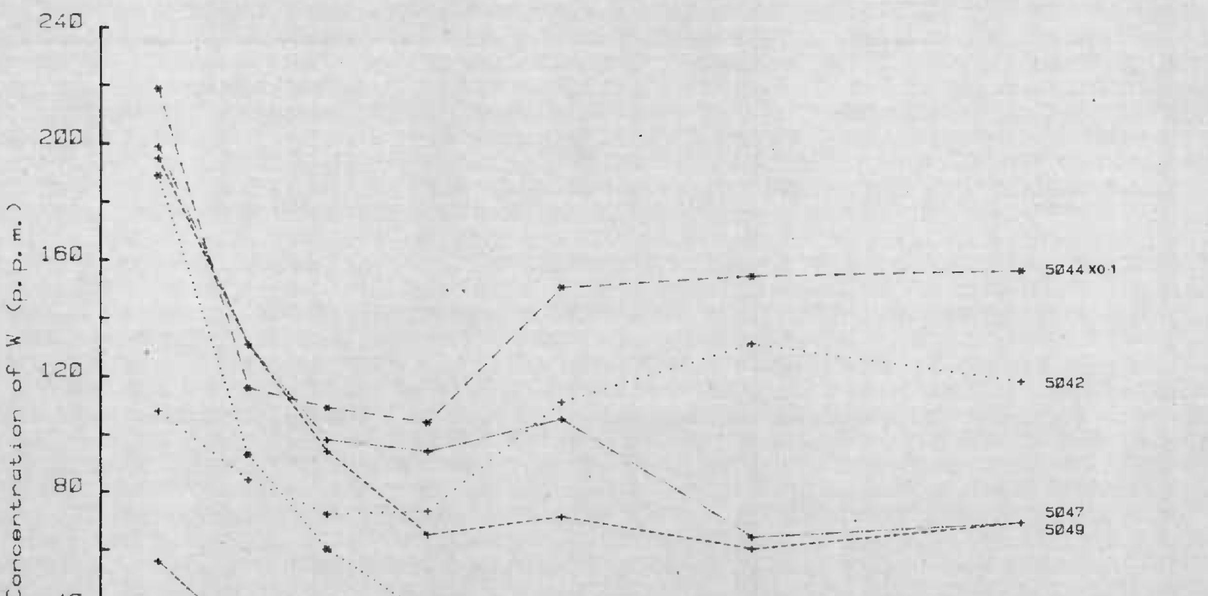

Figure 34: Concentration of tungsten with particle size, Wauchope Wolfram Field

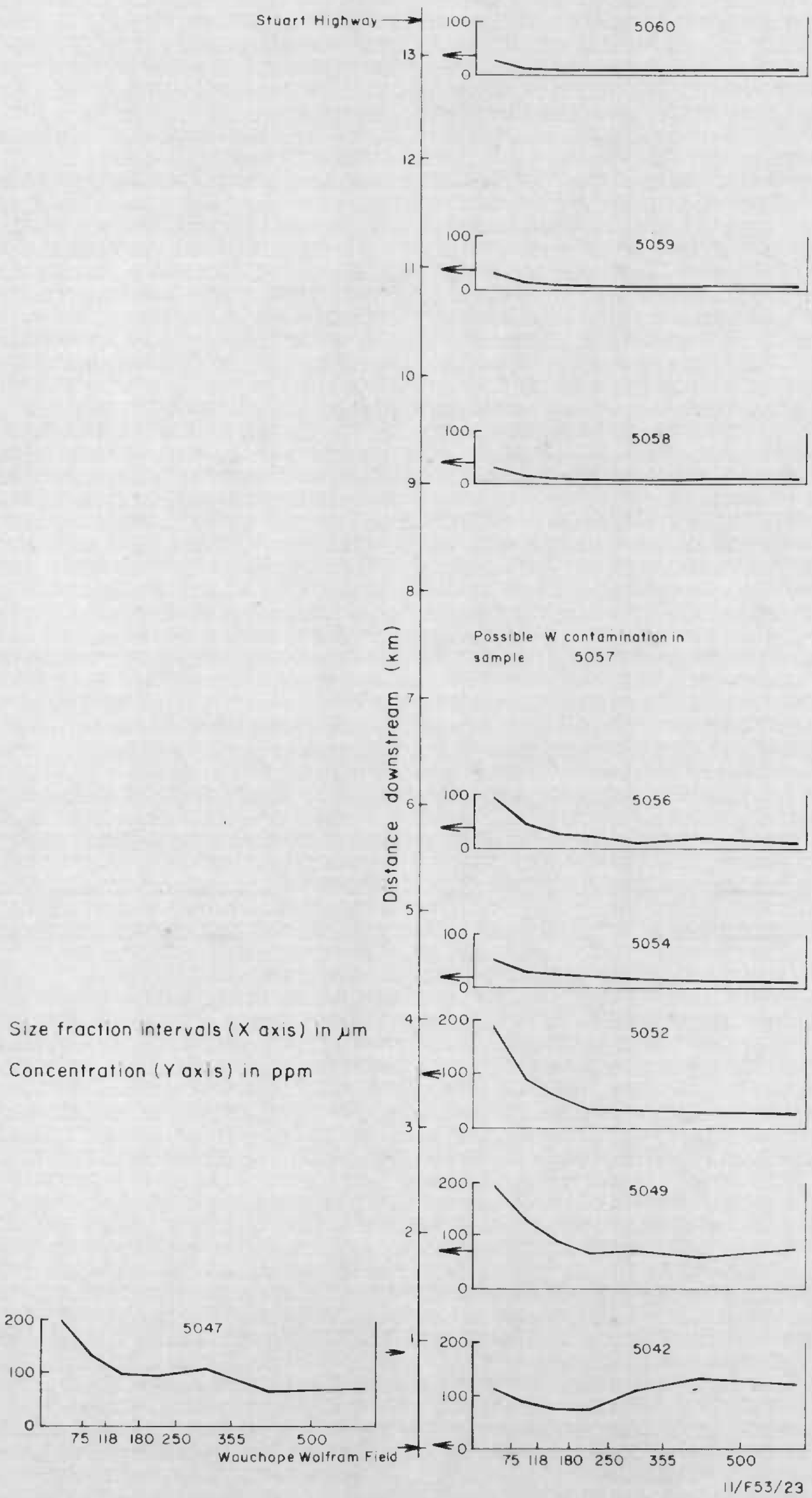

Figure 35: Longitudinal section showing the distribution of tungsten in stream sediment size fractions, Wauchope Creek

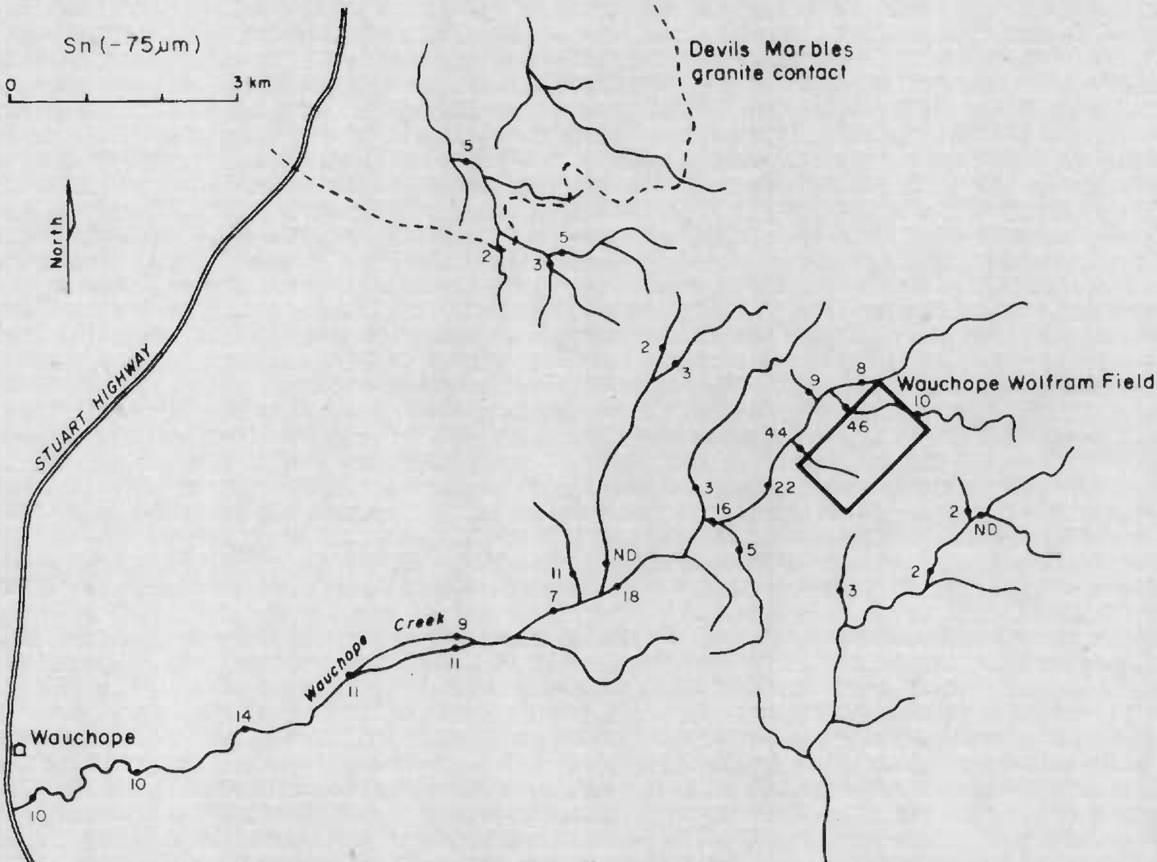

Figure 36: Distribution of tin (ppm) in the −75μm stream sediment fraction, Wauchope Wolfram Field

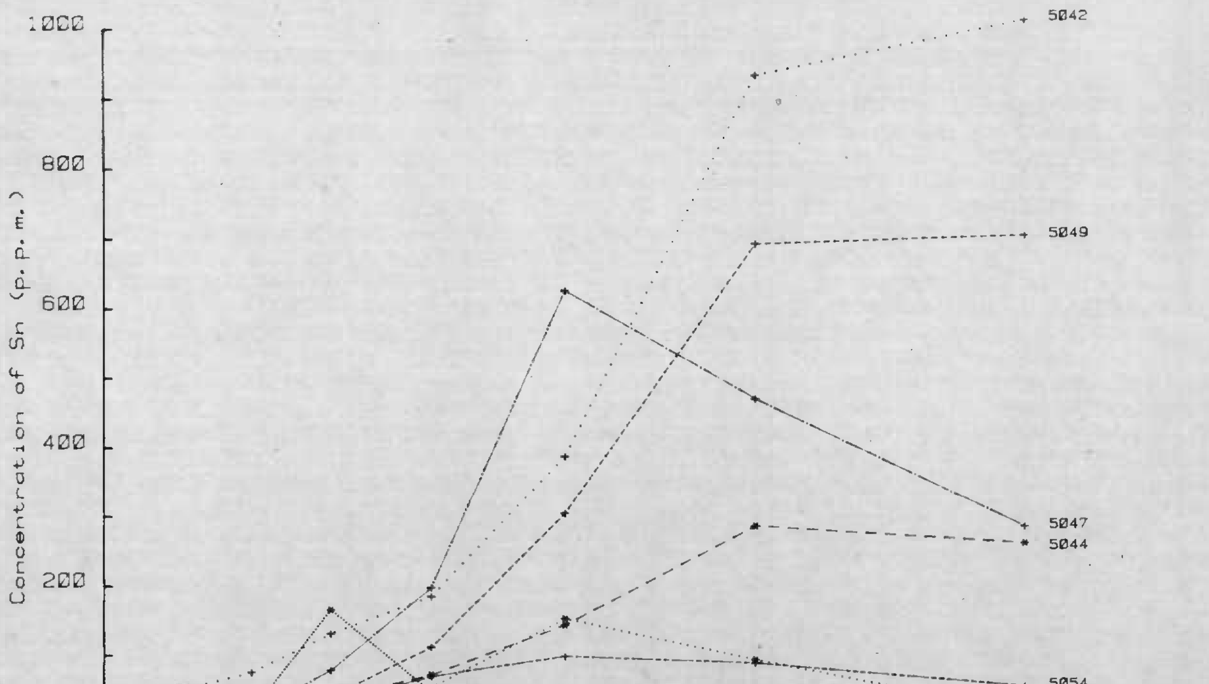

Figure 37: Concentration of tin with particle size, Wauchope Wolfram Field

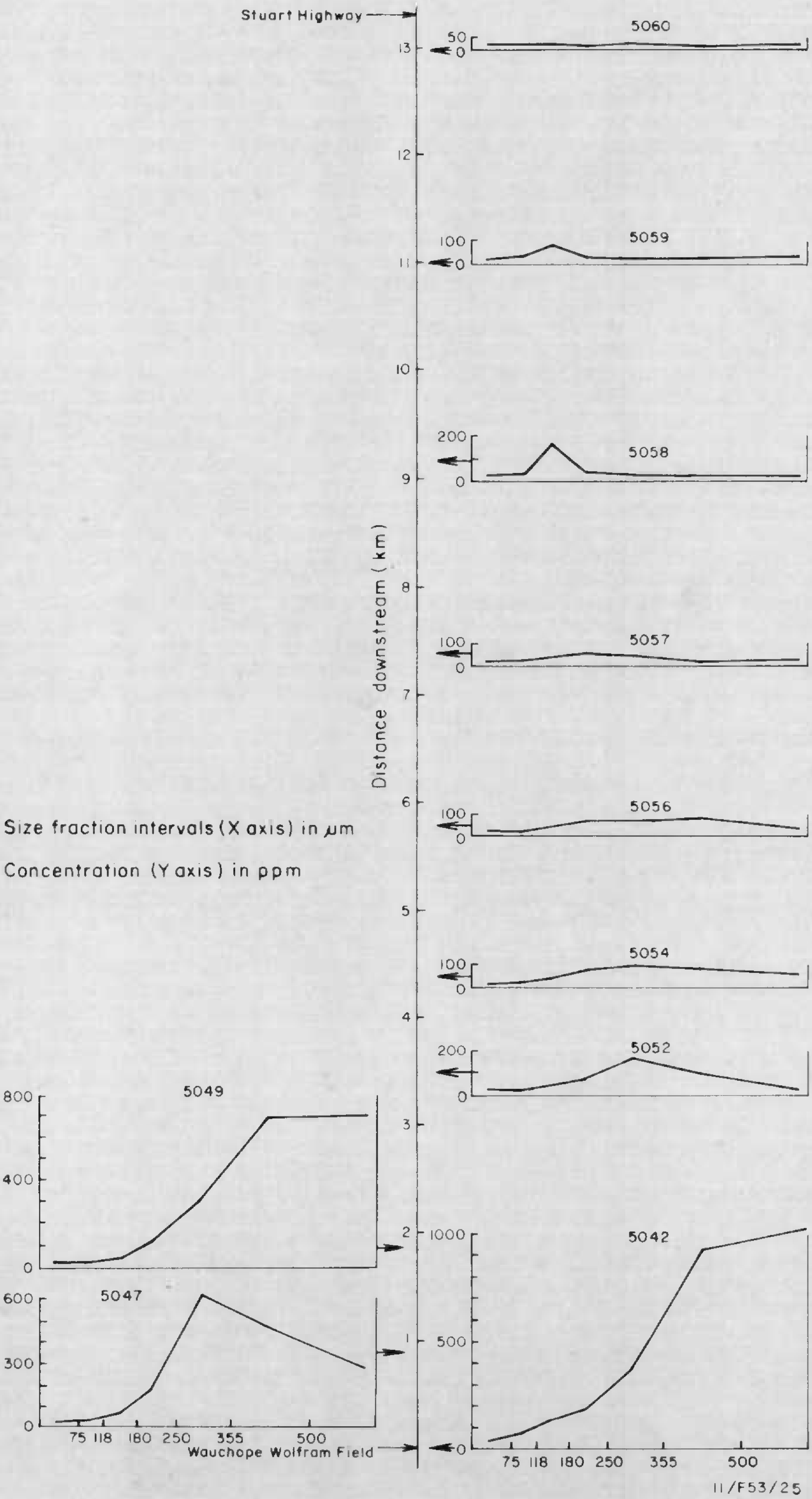

Figure 38: Longitudinal section showing the distribution of tin in stream sediment size fractions, Wauchope Creek

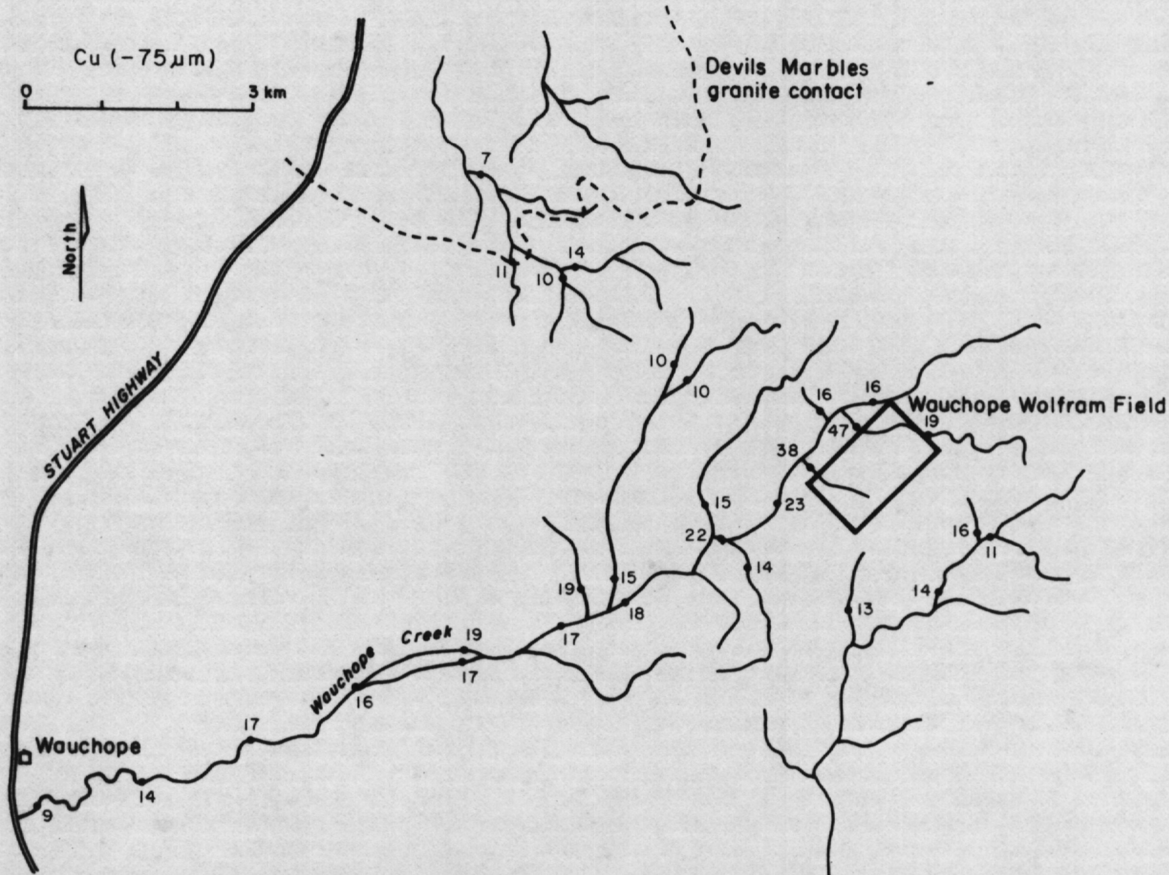

Figure 39: Distribution of copper (ppm) in the -75 µm stream sediment fraction, Wauchope Wolfram Field

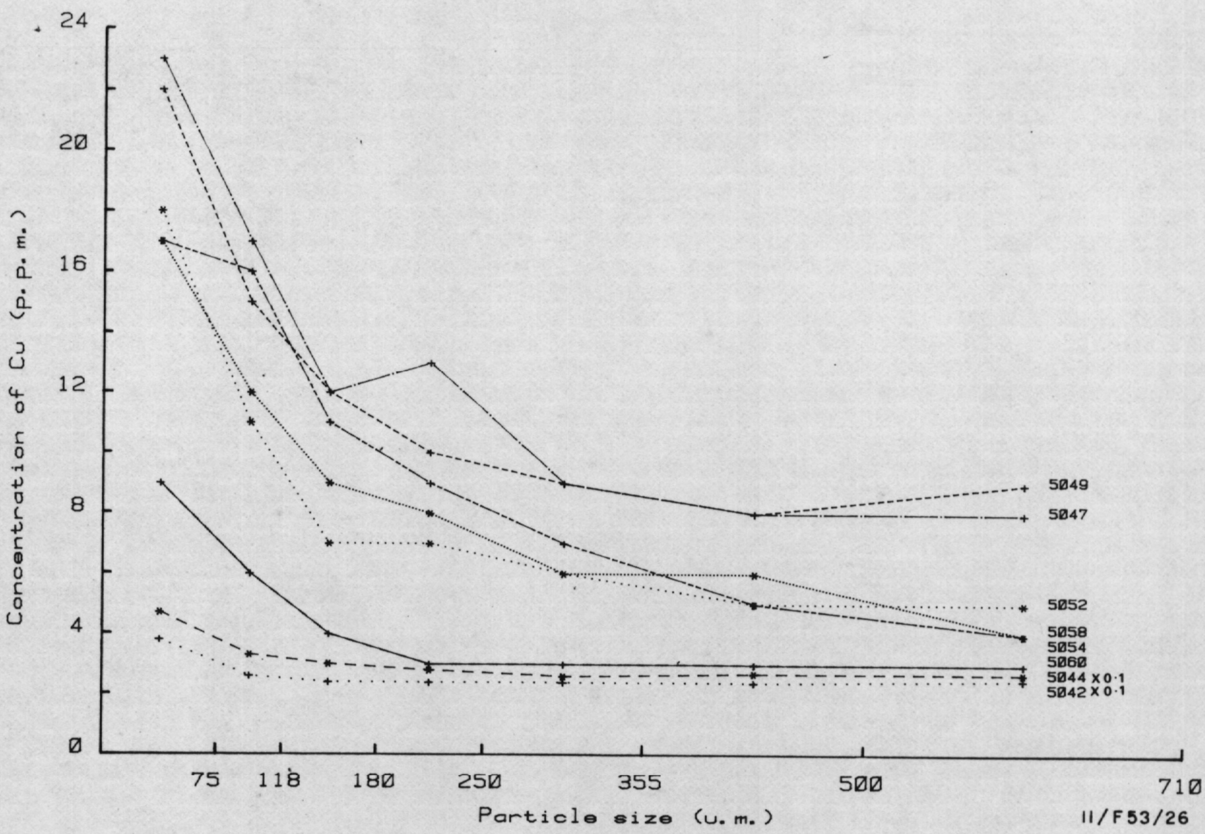

Figure 40: Concentration of copper with particle size, Wauchope Wolfram Field

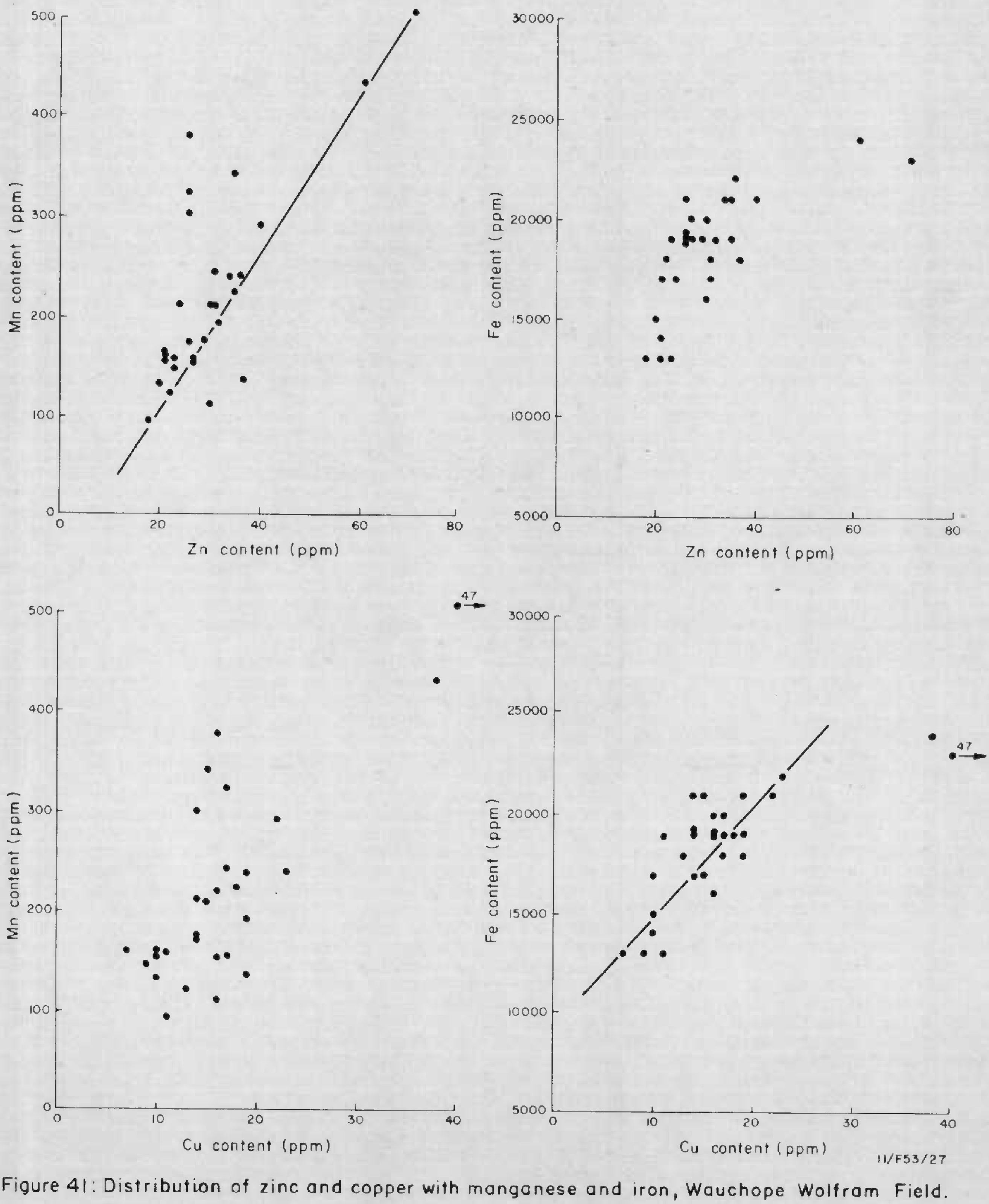

Figure 41: Distribution of zinc and copper with manganese and iron, Wauchope Wolfram Field. Data for the −75 μm fraction

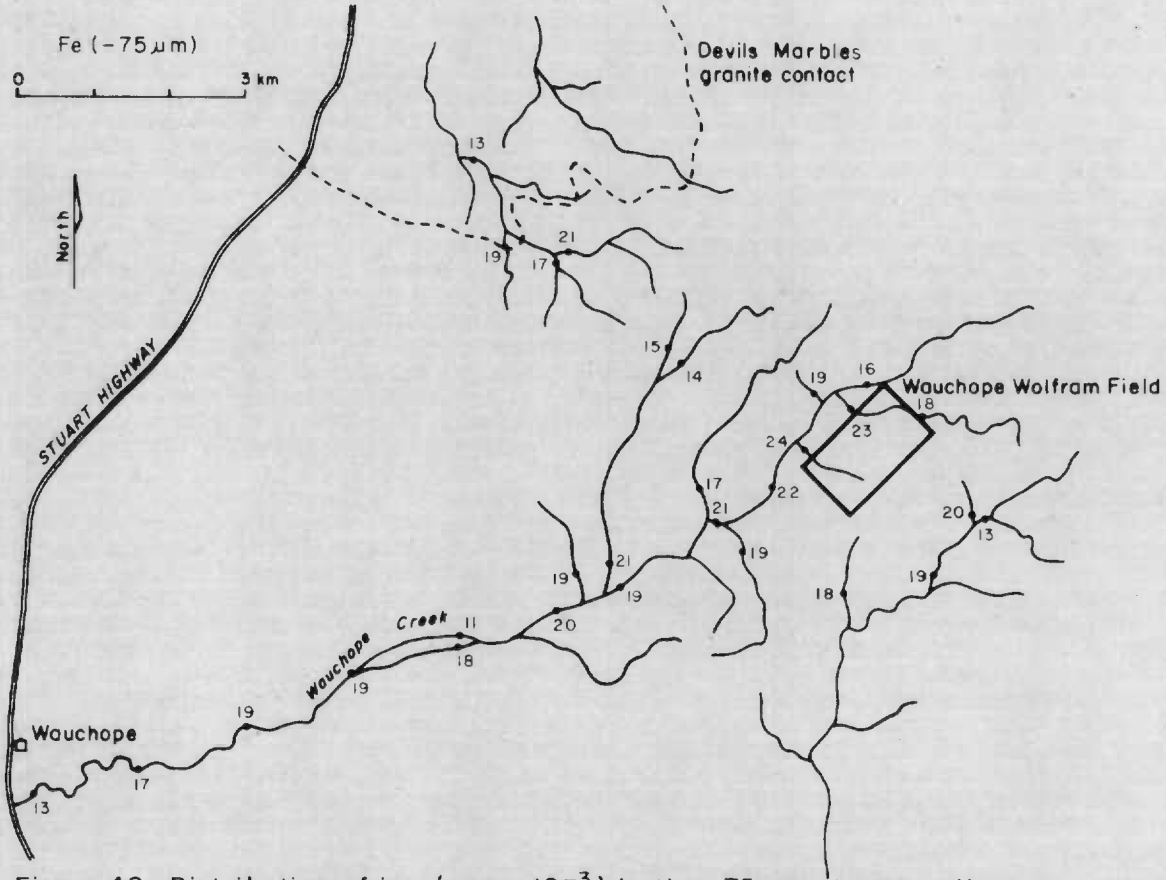

Figure 42: Distribution of iron (ppm x10^{-3}) in the -75 µm stream sediment fraction, Wauchope Wolfram Field

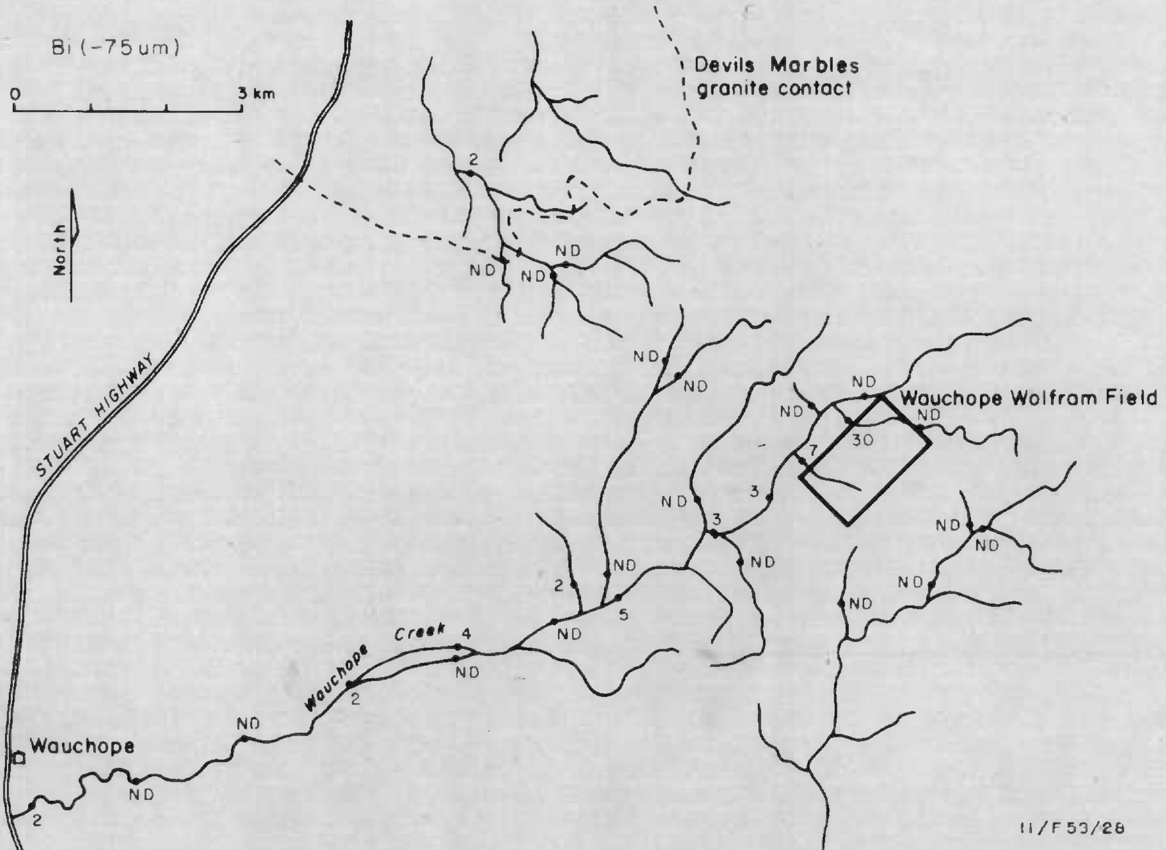

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Figure 43 : Distribution of bismuth (ppm) in the -75 µm stream sediment fraction, Wauchope Wolfram Field

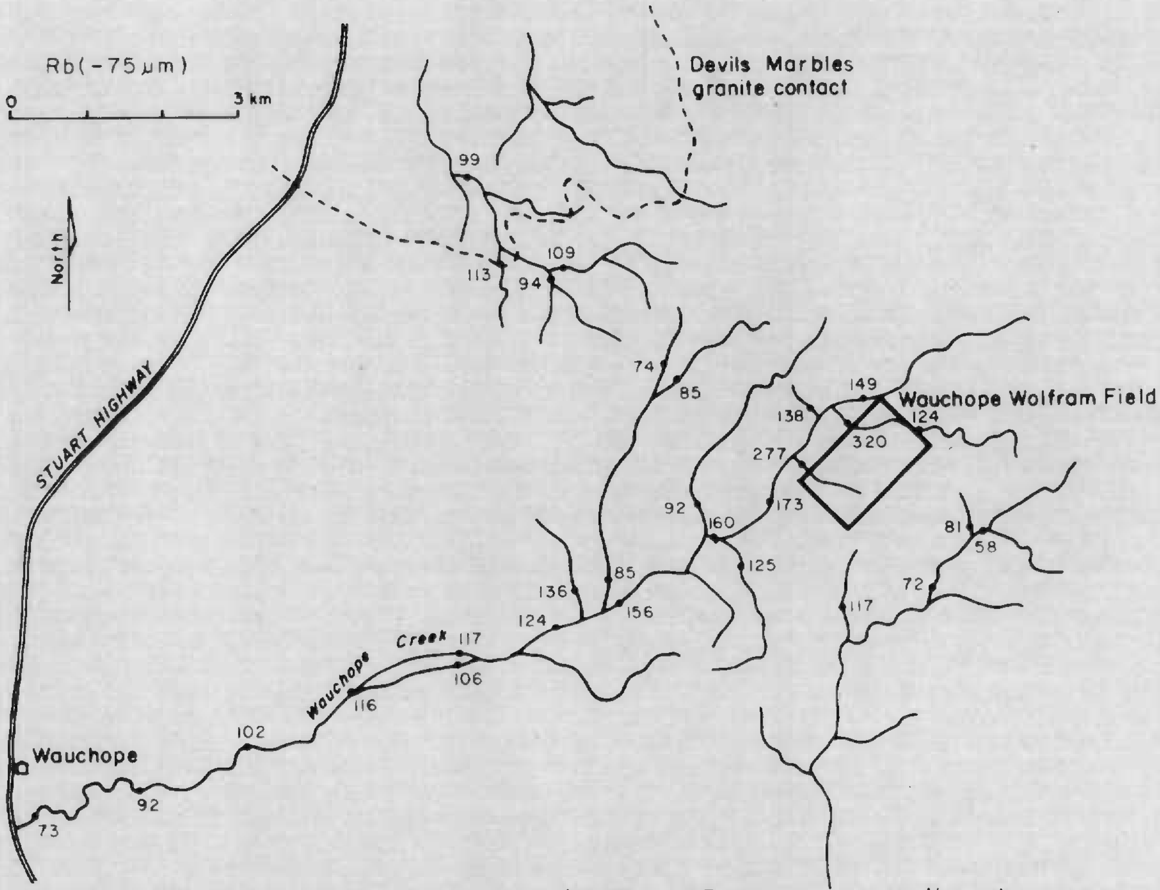

Figure 44: Distribution of rubidium (ppm) in the −75 µm stream sediment fraction, Wauchope Wolfram Field

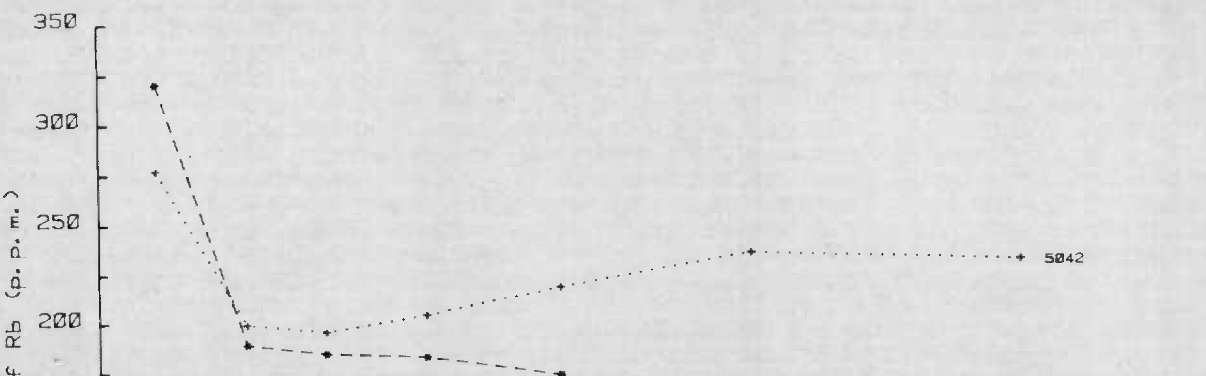

Figure 45: Concentration of rubidium with particle size, Wauchope Wolfram Field

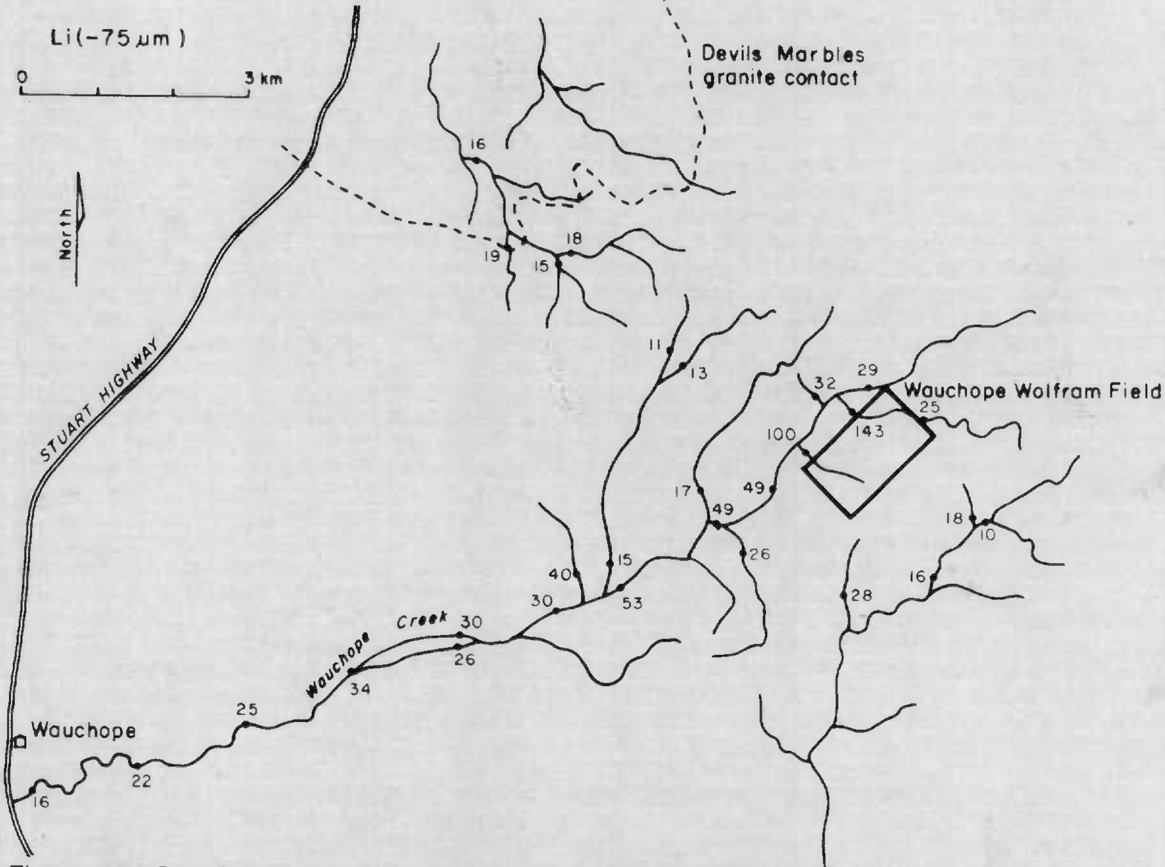

Figure 46: Distribution of lithium (ppm) in the -75µm stream sediment fraction, Wauchope Wolfram Field

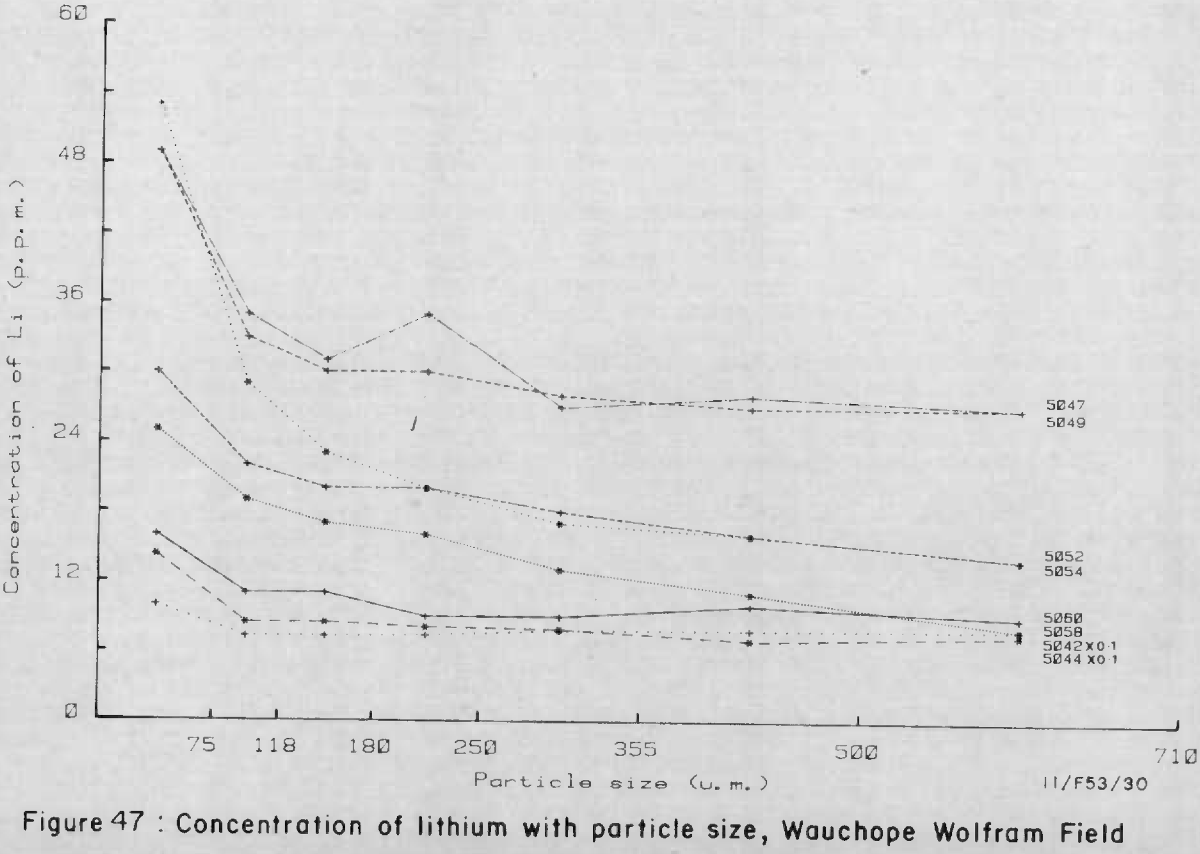

Figure 47 : Concentration of lithium with particle size, Wauchope Wolfram Field

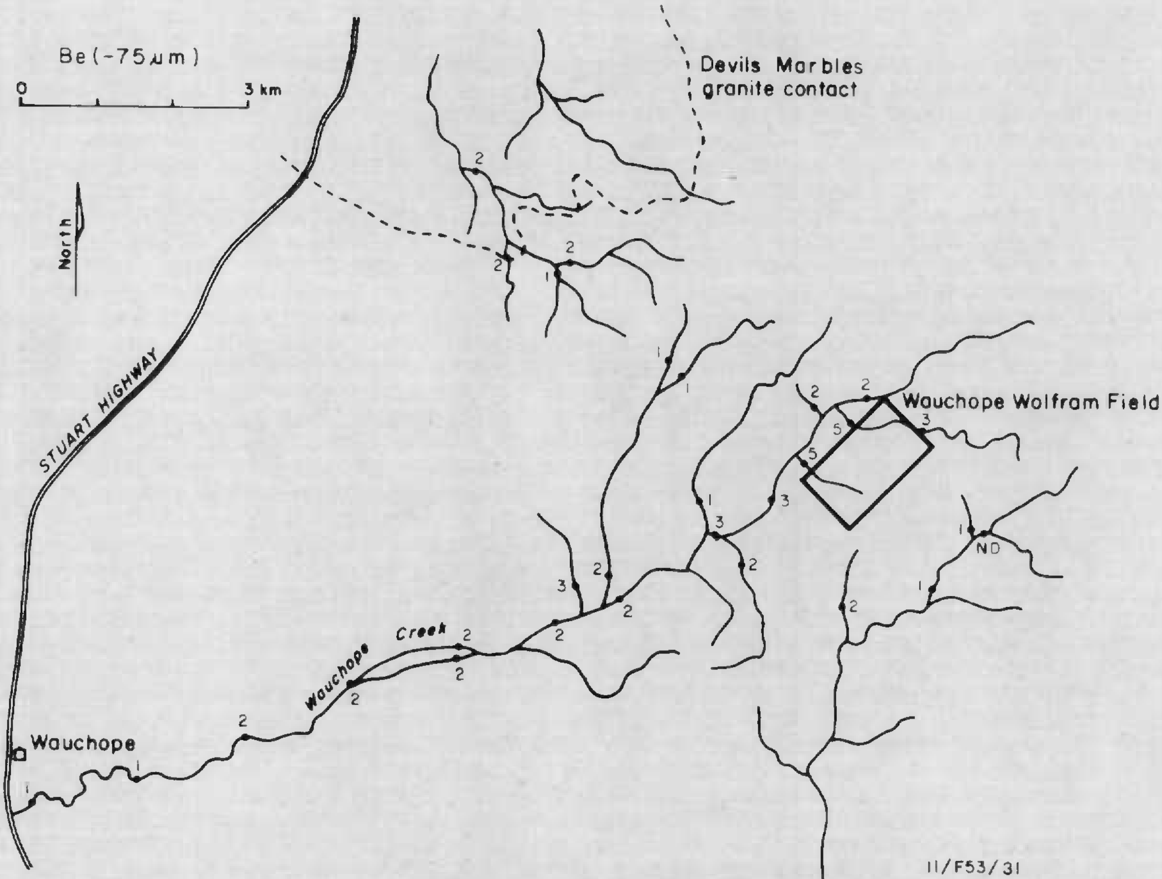

Figure 48: Distribution of beryllium (ppm) in the −75µm stream sediment fraction, Wauchope Wolfram Field

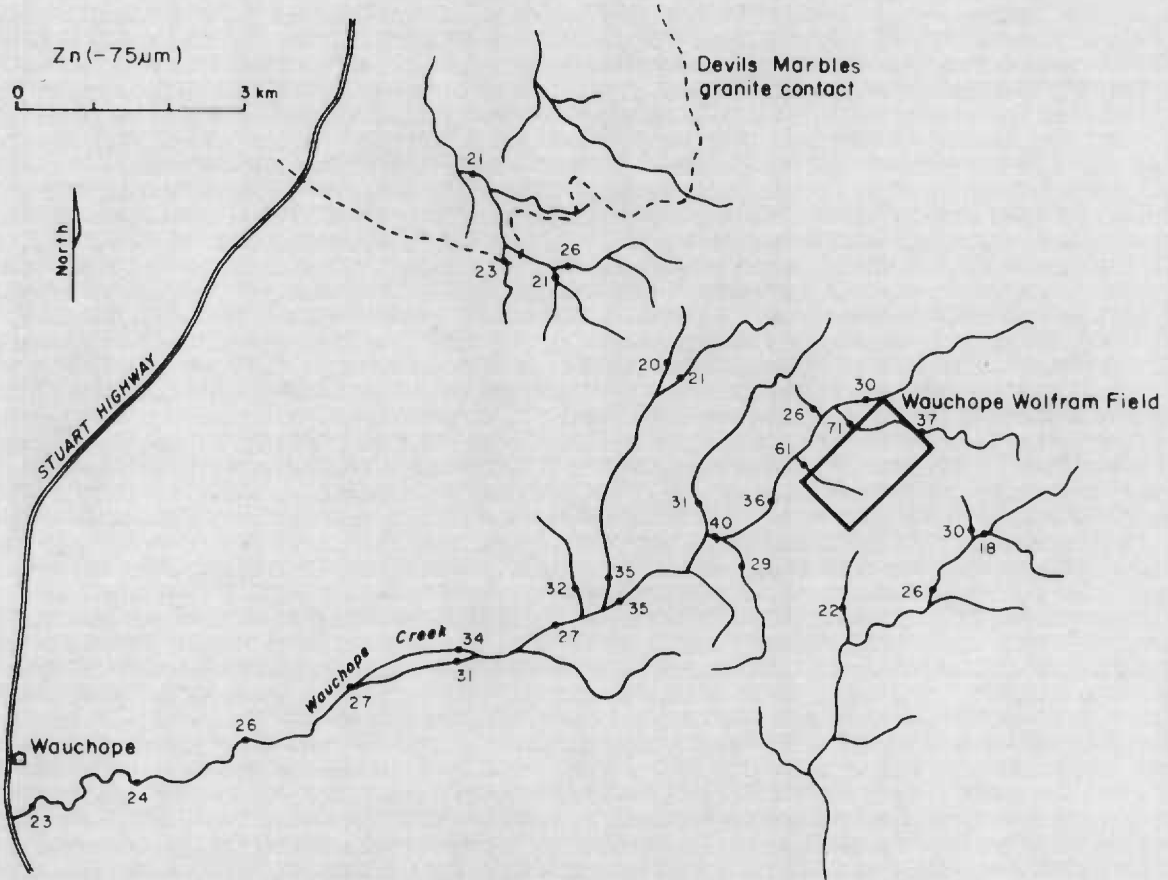

Figure 49: Distribution of zinc (ppm) in the -75 µm stream sediment fraction, Wauchope Wolfram Field

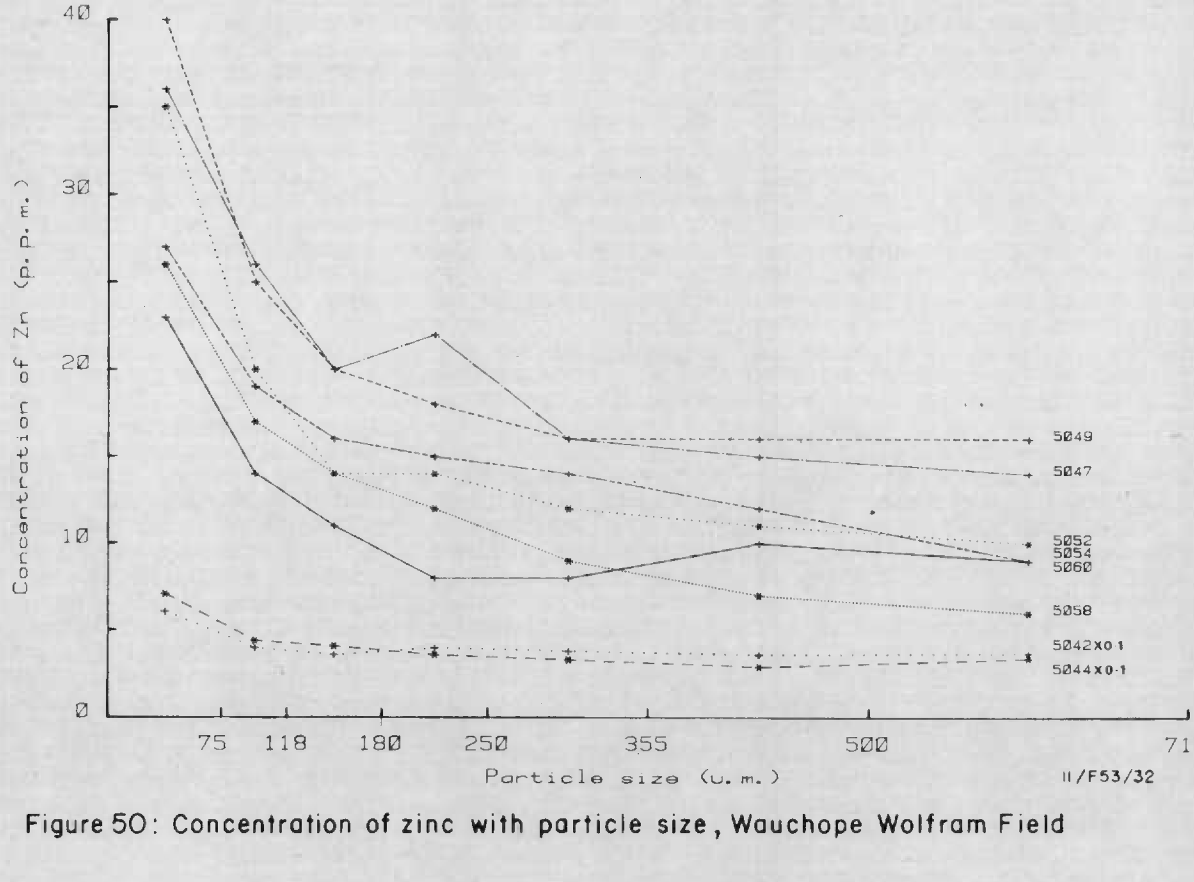

Figure 50: Concentration of zinc with particle size, Wauchope Wolfram Field

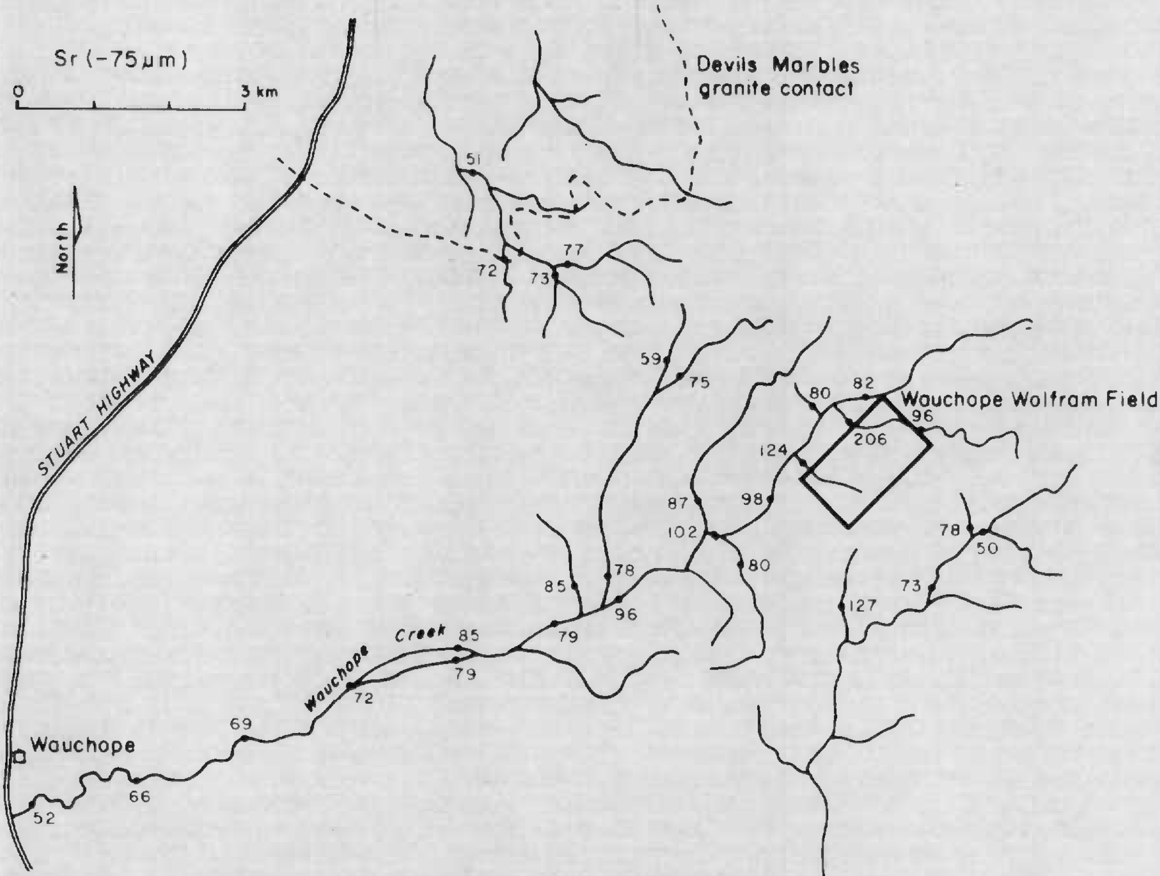

Figure 51 : Distribution of strontium (ppm) in the -75µm stream sediment fraction, Wauchope Wolfram Field

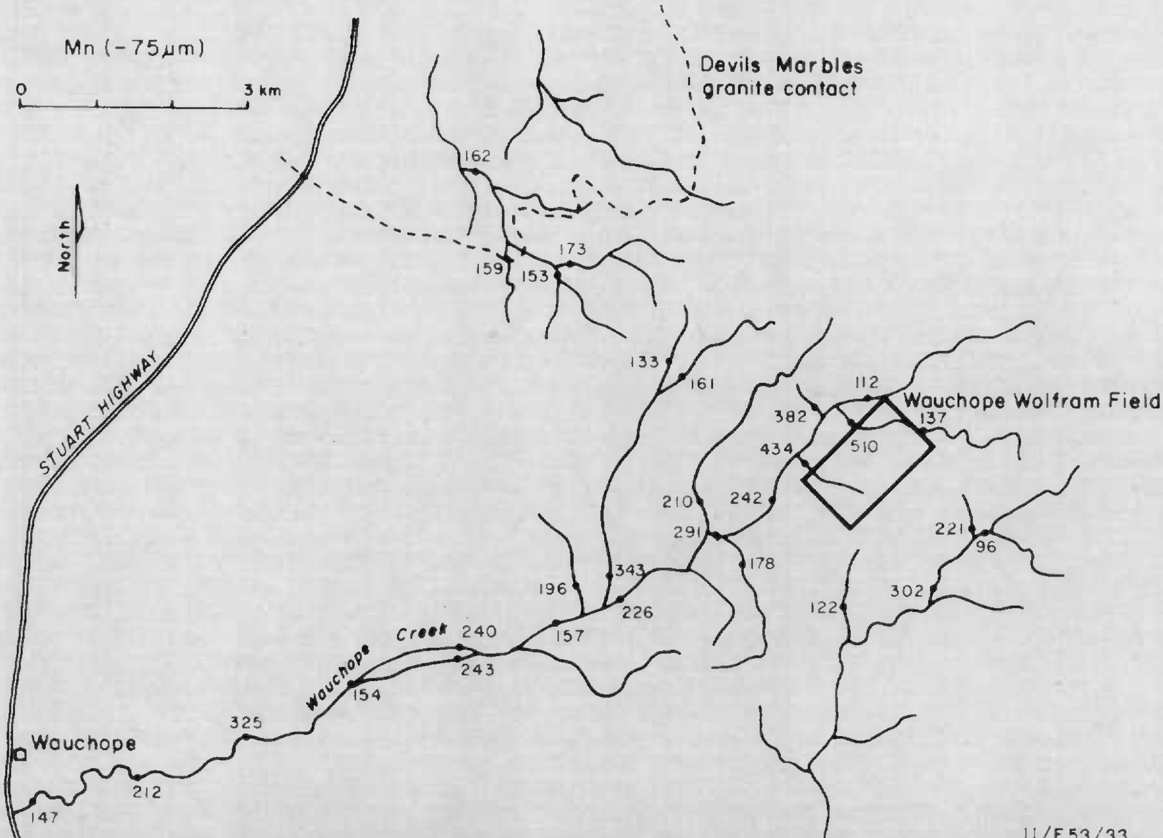

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Figure 52 : Distribution of manganese (ppm) in the -75 µm stream sediment fraction, Wauchope Wolfram Field

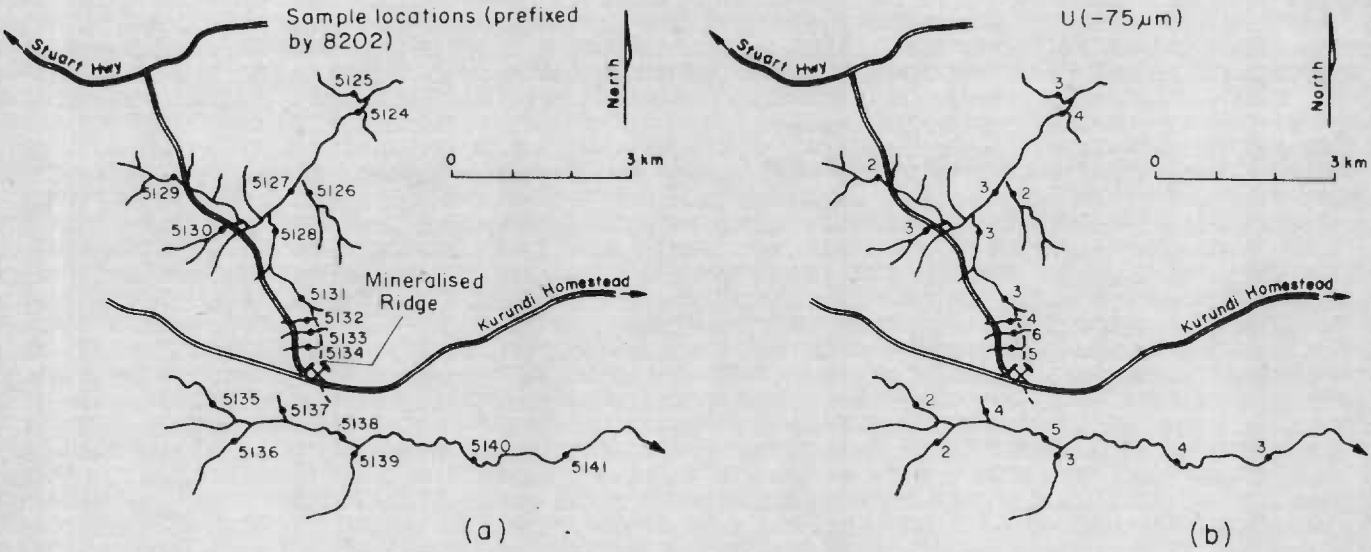

Figure 53 : Sample locations and distribution of uranium (ppm) in the -75µm stream sediment fraction, Munadgee Uranium Prospect

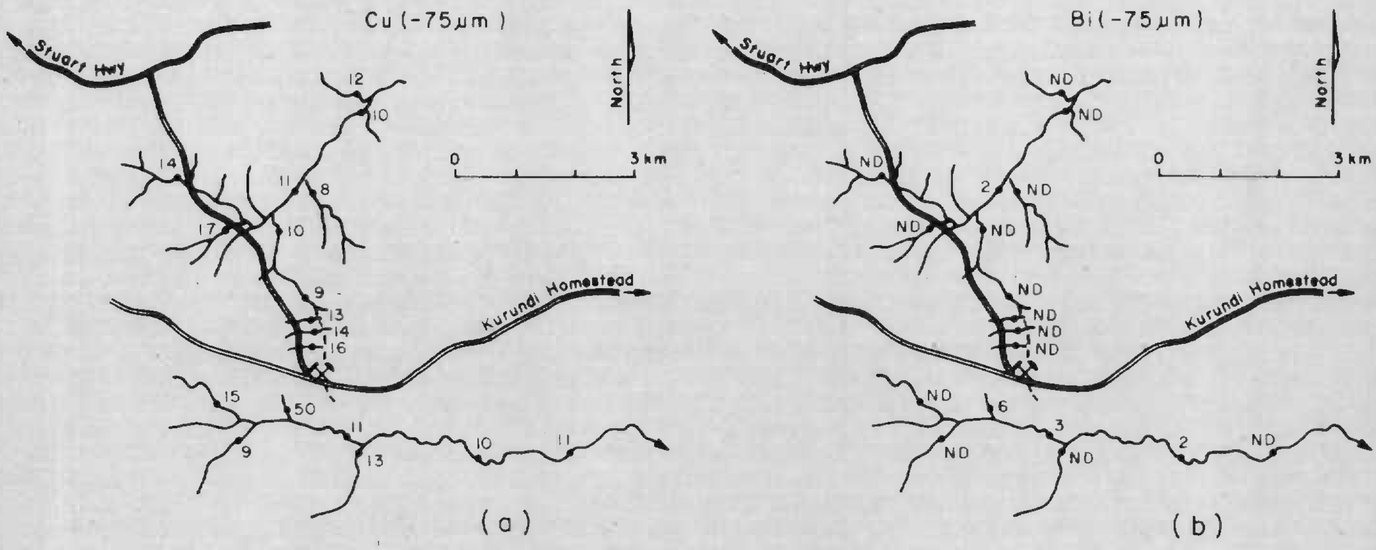

Figure 54 : Distribution of copper and bismuth (ppm) in the -75µm stream sediment fraction, Munadgee Uranium Prospect

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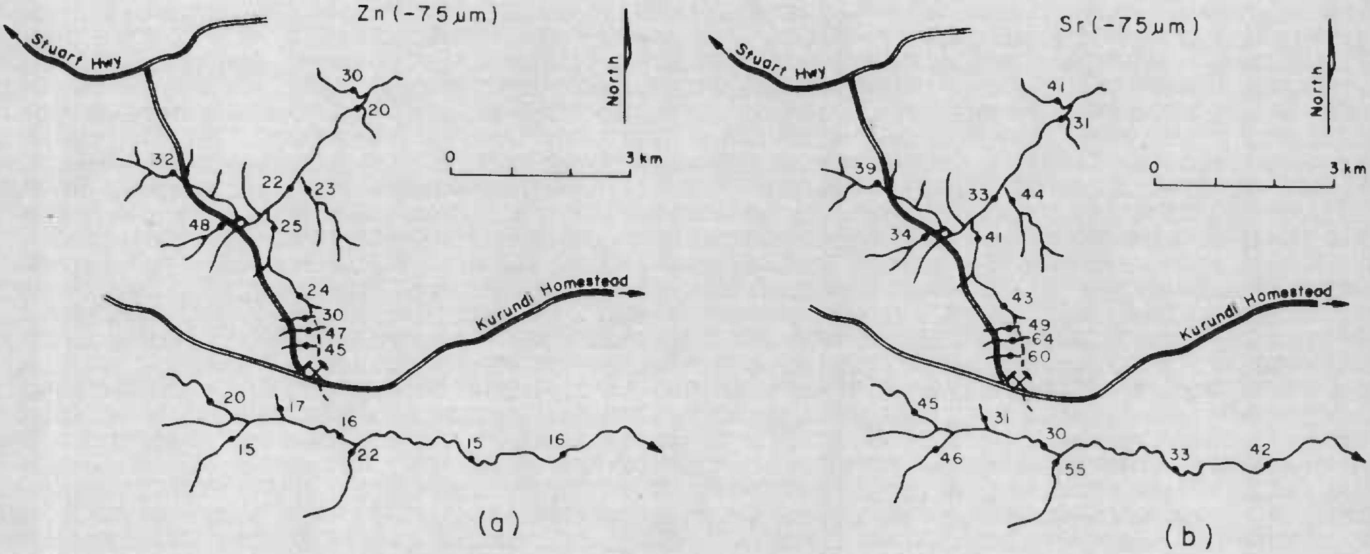

Figure 55: Distribution of zinc and strontium (ppm) in the $-75 \mu m$ stream sediment fraction, Munadgee Uranium Prospect

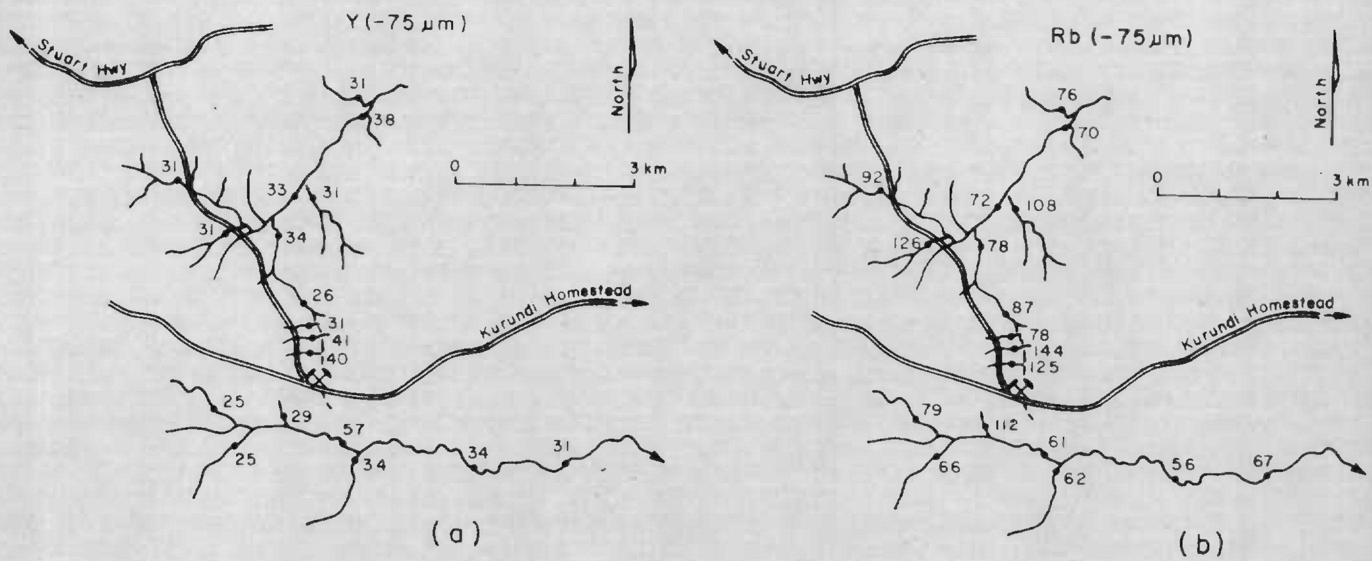

Figure 56: Distribution of yttrium and rubidium (ppm) in the $-75 \mu m$ stream sediment fraction, Munadgee Uranium Prospect

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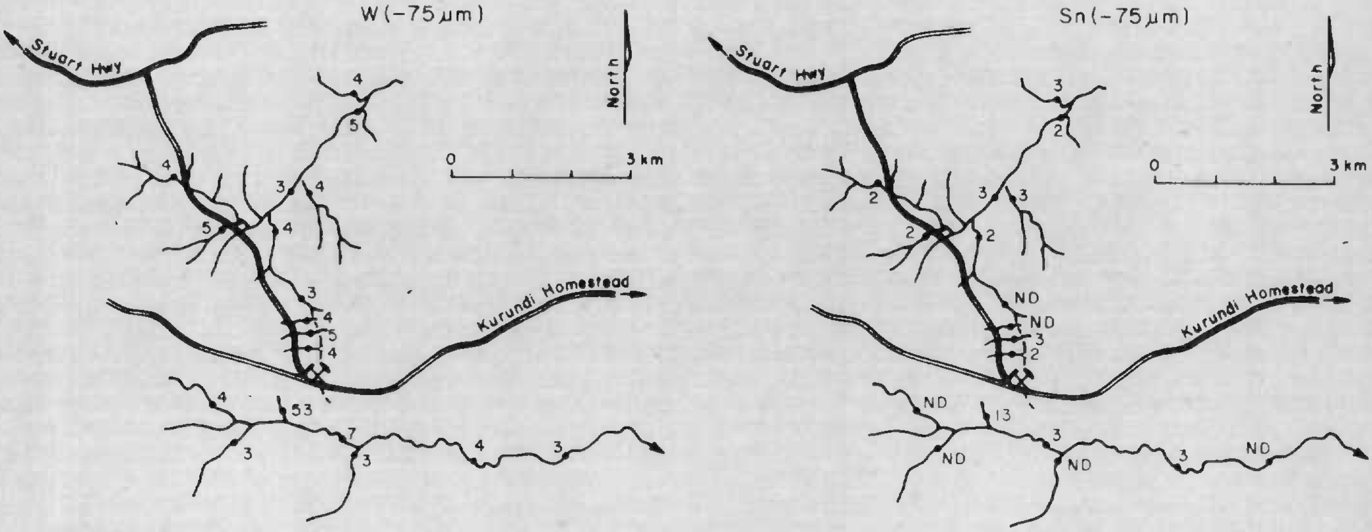


Figure 57: Distribution of tungsten and tin (ppm) in the -75µm stream sediment fraction, Munadgee Uranium Prospect

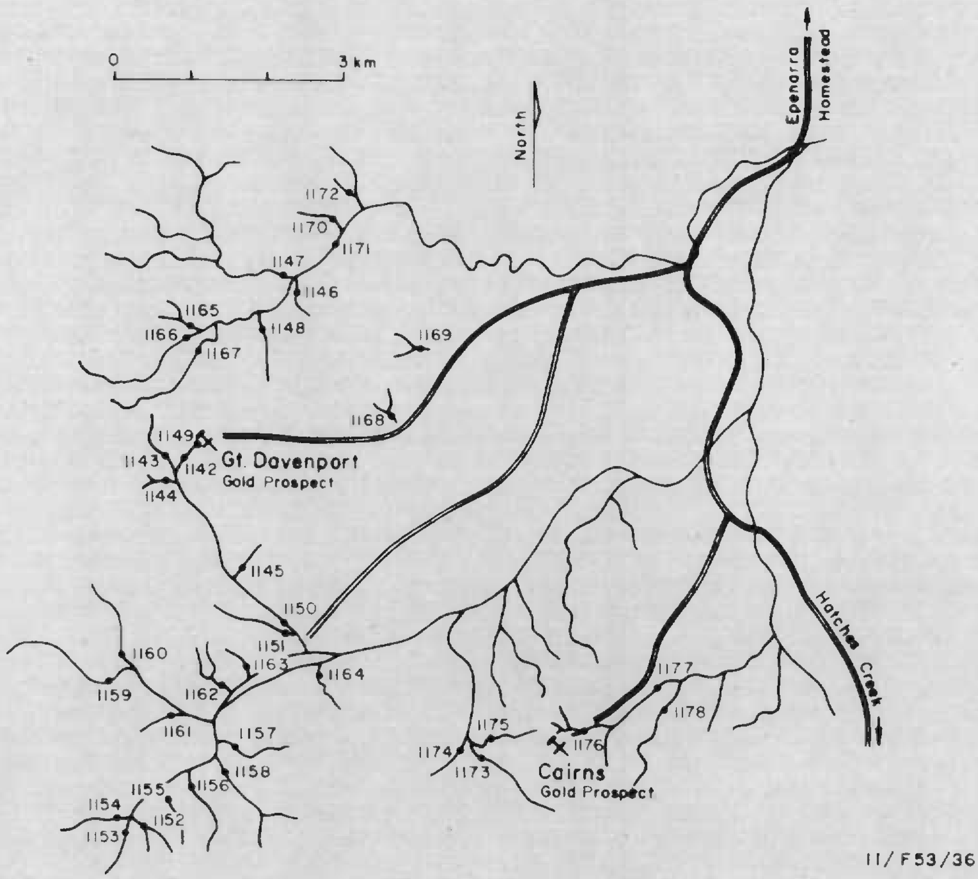


Figure 58: Sample locations (prefixed by 8202), Great Davenport Gold Prospect

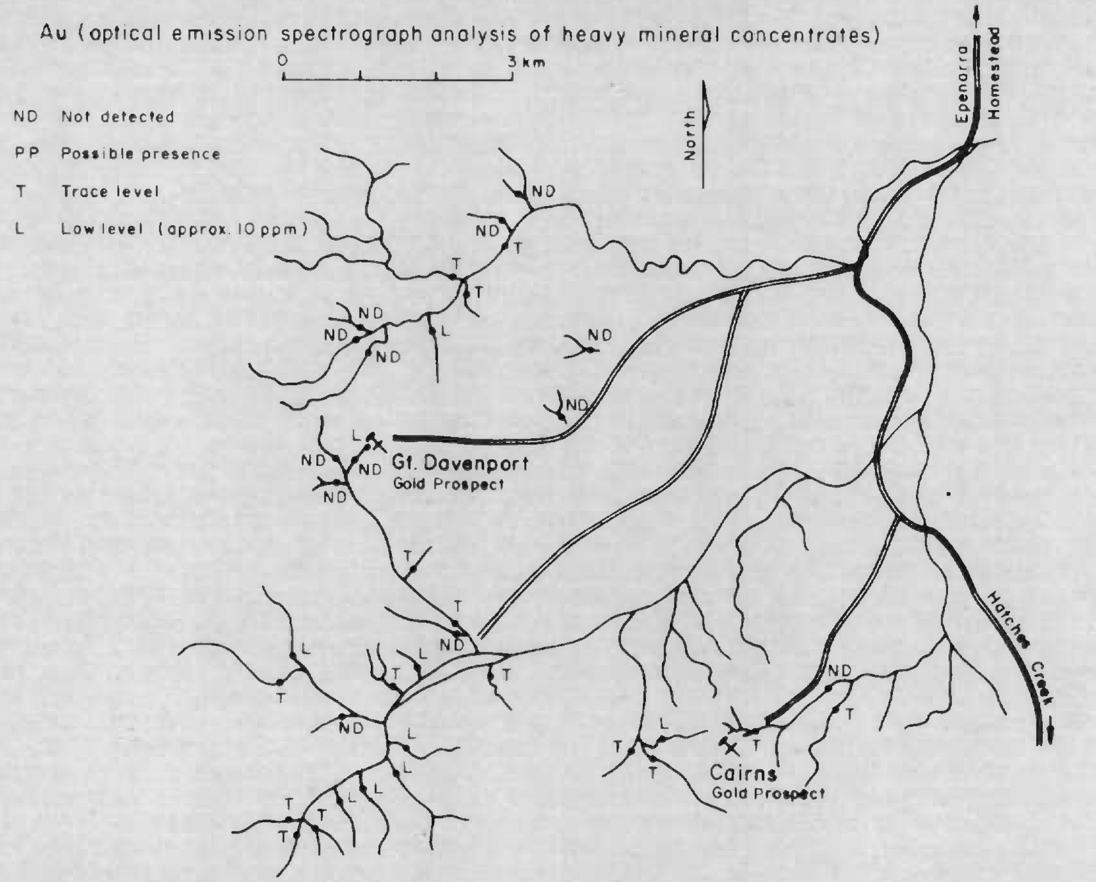


Figure 59: Distribution of gold in heavy mineral concentrates, Great Davenport Gold Prospect

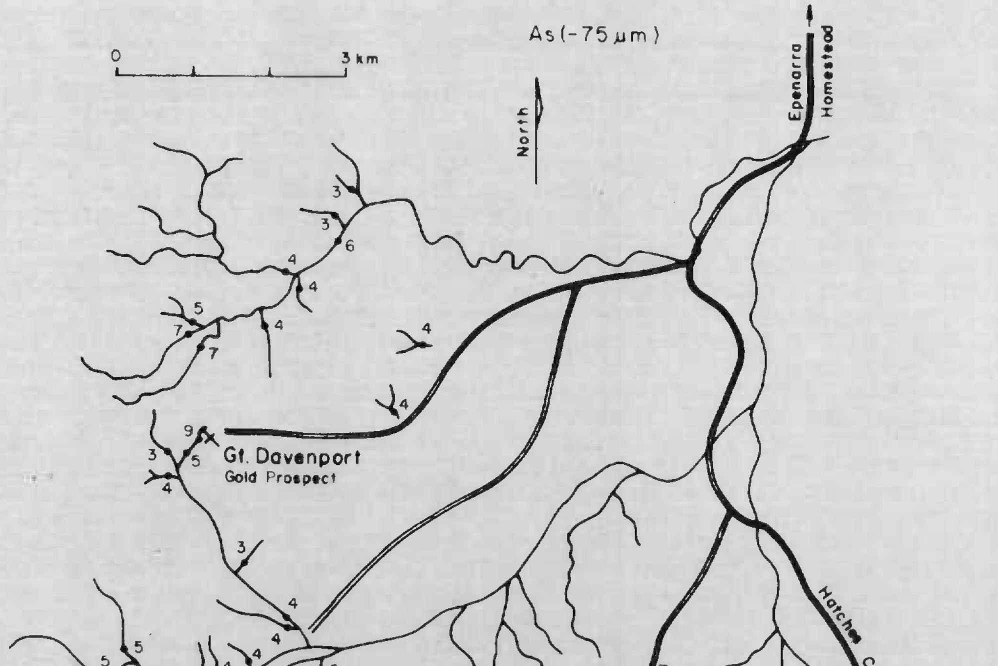


Figure 60: Distribution of arsenic (ppm) in the -75µm stream sediment fraction Great Davenport Gold Prospect

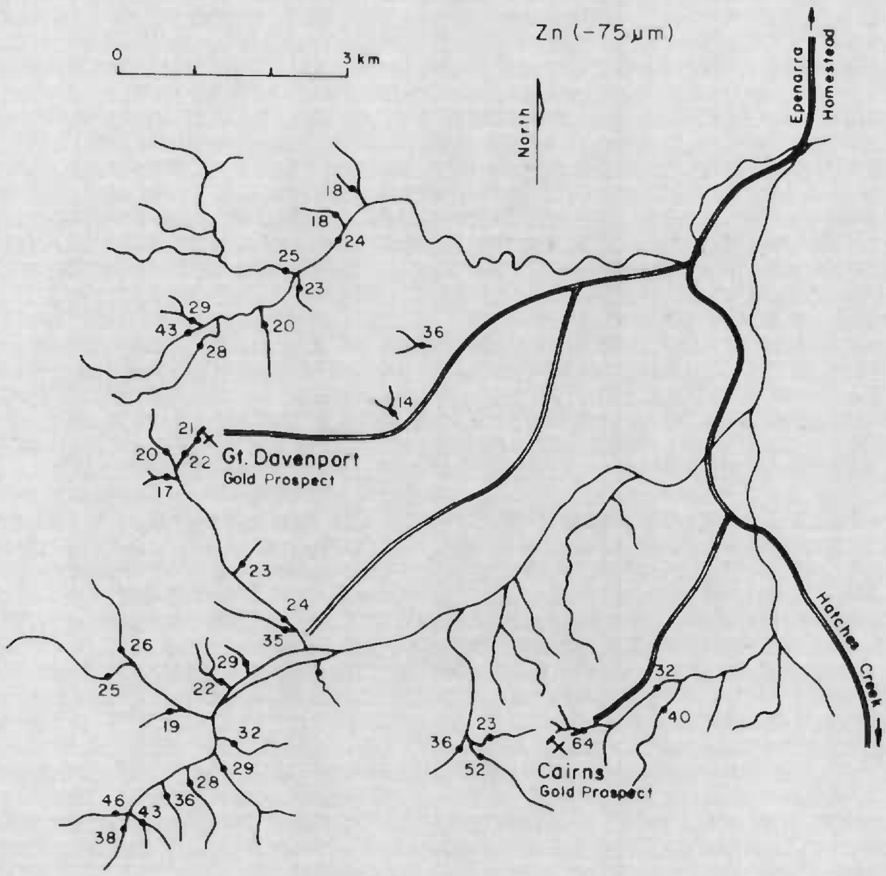
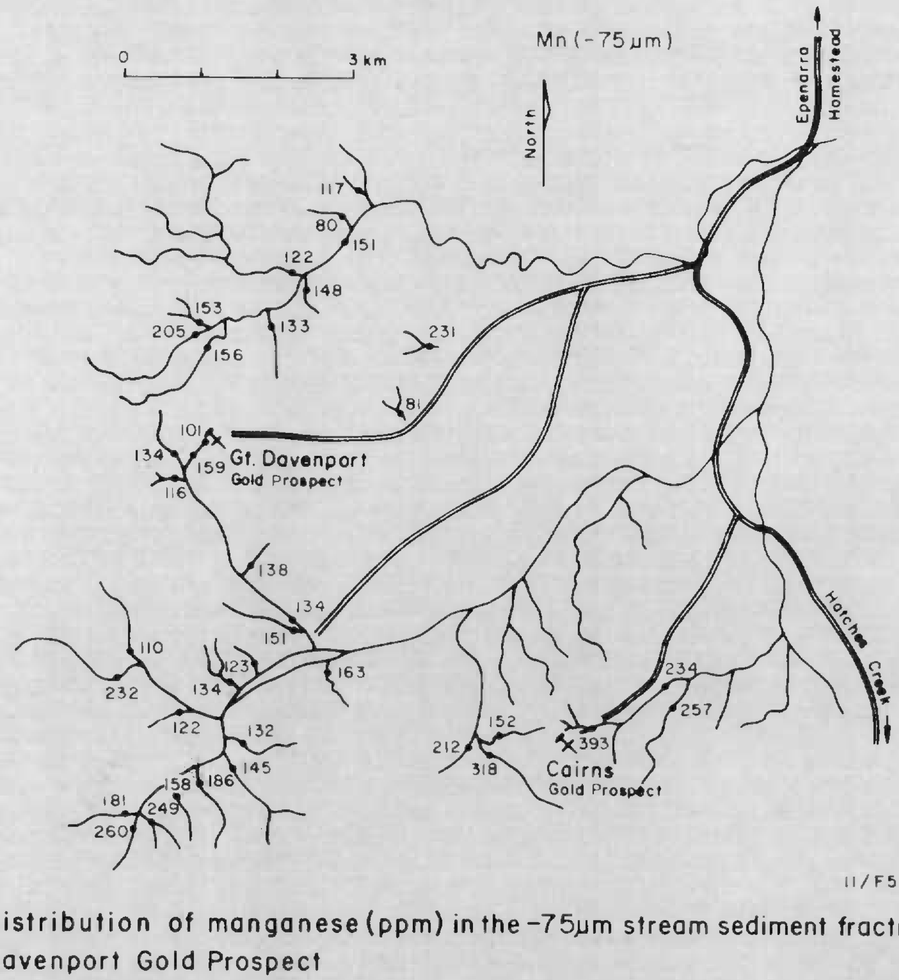


Figure 61 : Distribution of zinc (ppm) in the -75 µm stream sediment fraction, Great Davenport Gold Prospect



11/F53/38

Figure 62 : Distribution of manganese (ppm) in the -75µm stream sediment fraction, Great Davenport Gold Prospect

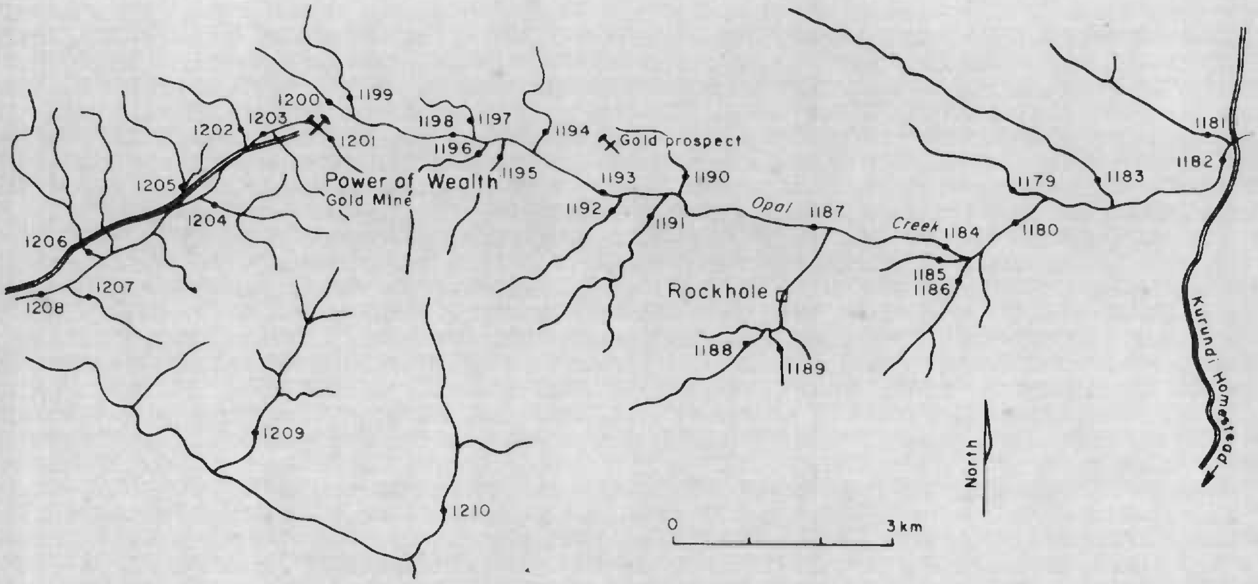
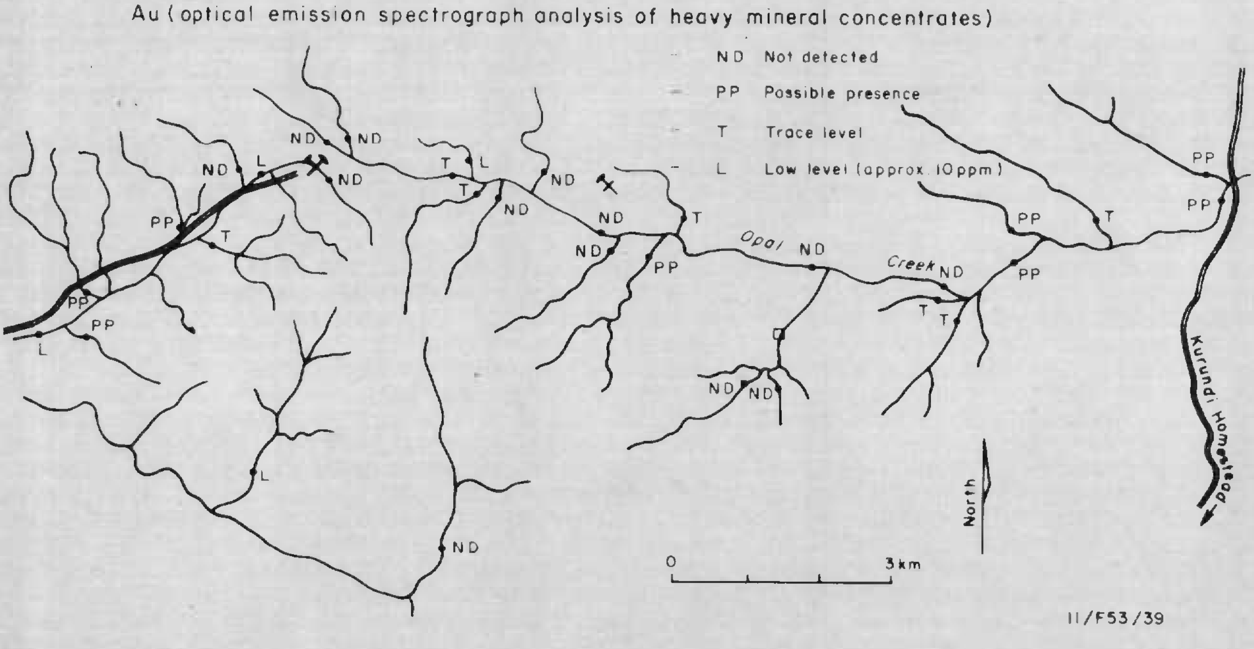


Figure 63 : Sample locations (prefixed by 8202), Power of Wealth Gold Mine



11/F53/39

Figure 64: Distribution of gold in heavy mineral concentrates, Power of Wealth Gold Mine

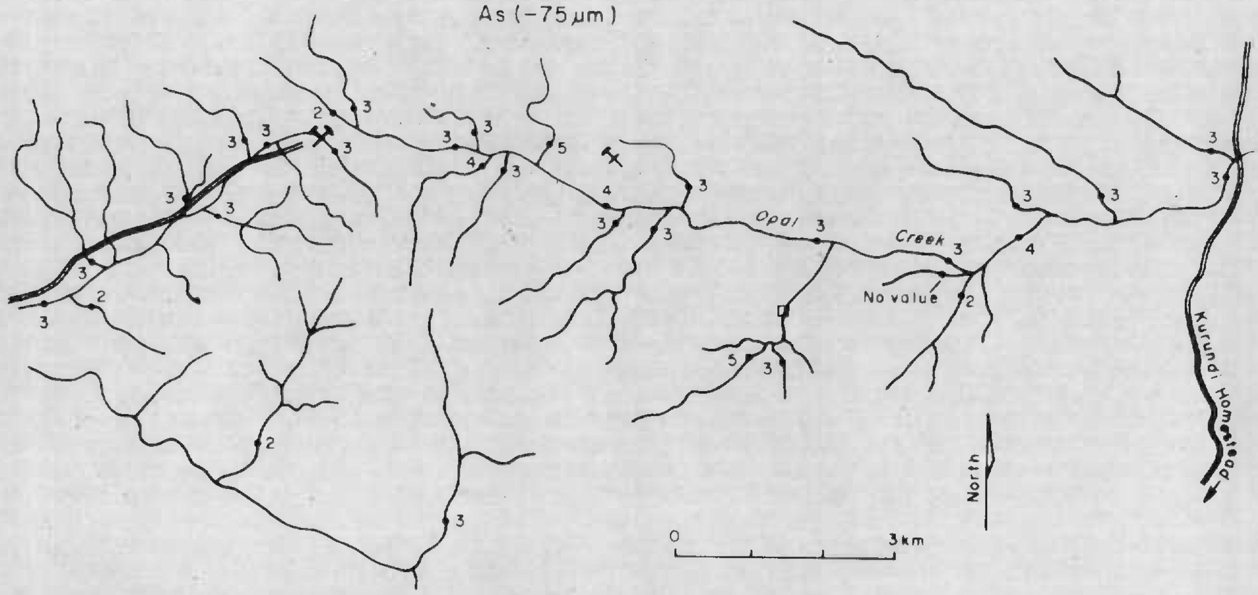
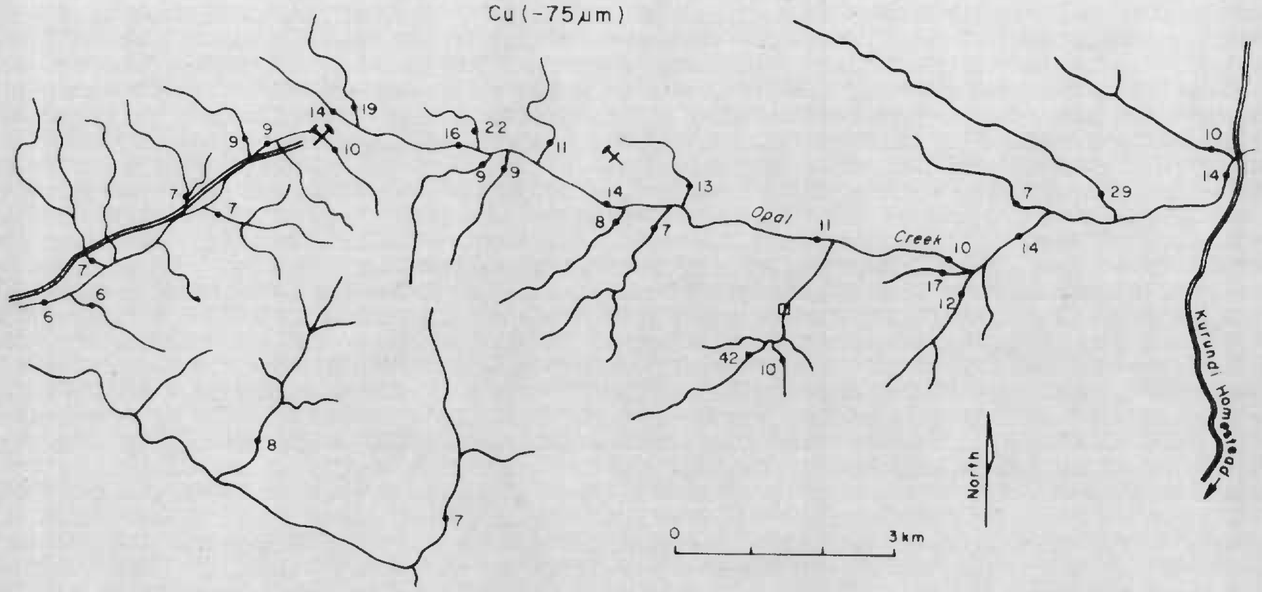


Figure 65: Distribution of arsenic (ppm) in the -75 µm stream sediment fraction, Power of Wealth Gold Mine



11/F53/40

Figure 66: Distribution of copper (ppm) in the -75 µm stream sediment fraction, Power of Wealth Gold Mine

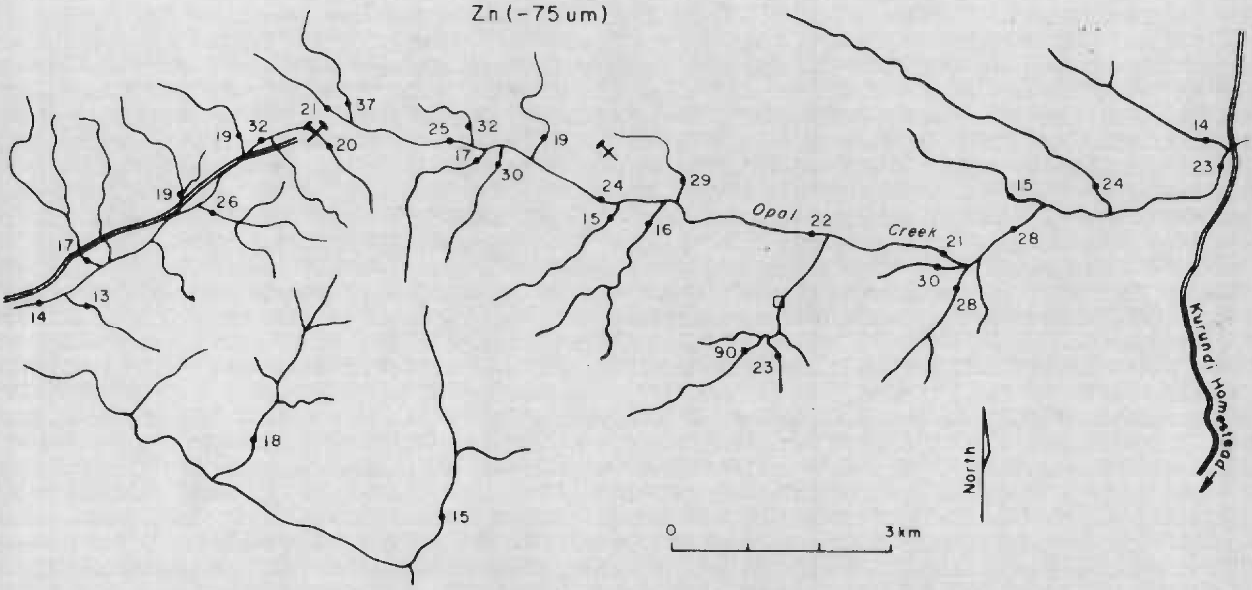


Figure 67: Distribution of zinc (ppm) in the -75 µm stream sedimen fraction, Power of Wealth Gold Mine

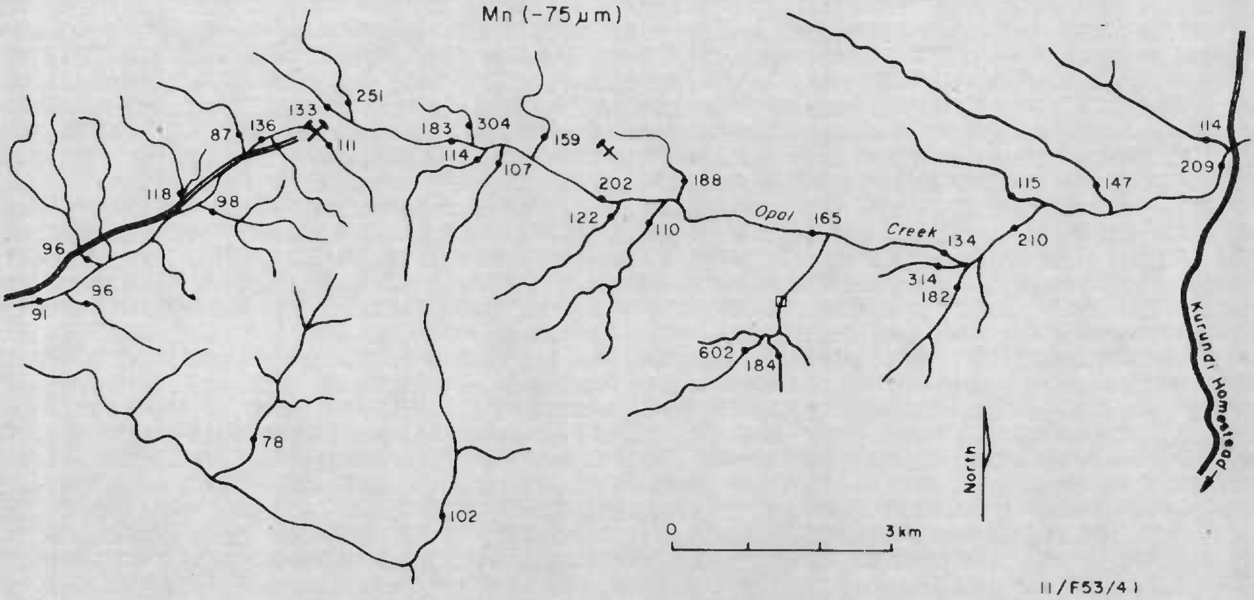


Figure 68 : Distribution of manganese (ppm) in the -75 µm stream sediment fraction, Power of Wealth Gold Mine

Table 1. Details of the geochemical survey.

Sub-area. (see Figure 1 for location)	Sample number (prefixed by 8202)	1:100 000 Map sheet	Reason for program.
(1) Hatches Creek Wolfram Field including Copper Show Mine	1001-1027 5001-5009 5021-5022	Hatches Creek	Study mineral/element dispersion from a mineralised environment (W, Cu, Bi, Mo and Sn).
(2) Northeast Hatches Creek including Wolfram Hill Mines	1028-1102	Hatches Creek	Define Hatches Creek type mineralisation along inferred subsurface granite contact.
(3) Northeast Pioneer Mine	1103-1141	Hatches Creek	Investigate possibility of stratiform scheelite (W) mineralisation.
(4) Great Davenport and Cairns Gold Prospects	1142-1178	Kurundi and Hatches Creek	Study mineral/element dispersion from a mineralised environment (Au) and along geological strike from the mineralisation.
(5) Power of Wealth Gold Mine	1179-1210	Kurundi	As for (4).
(6) Elkedra Granite	1211-1218 5190-5198	Elkedra	Study mineral/element dispersion from the Juggler Mine (W) and the Elkedra Granite.
(7) Southwest Hatches Creek			Investigate base metal potential of Frew River Formation.
(north of Murray Downs road)	5069-5091	Hatches Creek	
(south of Murray Downs road)	1219-23 & 5199-203	Elkedra	
(8) Mia Mia Dome	5010-5037	Hatches Creek	Investigate reported radiometric anomalies
(9) Wauchope Wolfram Field	5038-5068	Devils Marbles	Study mineral/element dispersion from a mineralised environment (W) and the Devils Marbles Granite.
(10) Hill of Leaders/Mosquito Creek Wolfram Mines	5092-5125	Kurundi	Study mineral/element dispersion from a mineralised environment (W) and the Hill of Leaders Granite
(11) Munadgee Uranium Prospect	5126-5141	Kurundi	As for (1) (U).
(12) Northwest Davenport			Compare mineral/element dispersion from the Hatches Creek and Warramunga Groups.
(Gilbert Creek)	5152-5183	Devils Marbles	
(Little Edinburgh Creek)	5184-5189	Devils Marbles	

Table 2. Operating conditions for atomic absorption spectrophotometric analyses.

Element	Line (nm)	Slit (nm)	Lamp current (mA)	NAA correction	Flame* type	Flame stoichiometry	Detection limit (ppm)[2*]
Ag	328.1	0.20	3	No	AA	oxidising	2
Be	234.9	0.50	5	No	NOA	reducing	1
Co	240.7	0.20	8	Yes	AA	oxidising	2
Cr	357.9	0.20	5	No	NOA	reducing	4
Cu	324.7	0.50	3	No	AA	oxidising	2
Fe	372.0	0.20	6	No	AA	oxidising	-
Li	670.8	0.50	5	No	AA	oxidising	2
Mn	279.5	0.20	5	No	AA	oxidising	-
Ni	232.0	0.50	8	Yes	AA	oxidising	2
Zn	213.9	0.50	6	Yes	AA	oxidising	1

* AA = Air/Acetylene NOA = Nitrous oxide/Acetylene

2* for A<0.005 absorbance units (equivalent to 99% transmission)

Table 3. Analytical conditions for X-ray spectrometric analyses.

PROGRAM 1. Tube - Mo target Voltage - 90 kV Current - 30 mA
Compton scatter mass absorption correction.

Element	Line	Peak 2θ	Background 2θ	Peak time(secs)	Collimator	Crystal (LiF)	Counter	Corrected for:-	Detection Limit(ppm
Th	Lα	27.46	+-0.20	40	fine	200	scint	Pb, Bi	2
Rb	Kα	26.58	+-0.30	20	fine	200	scint	Pb	2
Pb	Lβ	28.25	+-0.27	40	fine	200	scint	Th	2
Y	Kα	33.84	+-0.43	20	fine	220	scint	Rb, Pb, Th	1
U	Lα	37.30	+-0.25	100	fine	220	scint	Rb	1
As	Kα	33.98	+-0.44	40	fine	200	scint+flow	Pb	1
W	Lα	62.49	+-0.75	100	fine	220	scint+flow	-	3
Bi	Lα	33.00	+-0.60	40	fine	200	scint+flow	Pb, Th, As	2
M.A.	MoKα (Compton)	30.14	-1.82	40	fine	220	scint	Y	-

PROGRAM 2. Tube - Au target Voltage - 90 kV Current - 30 mA
Compton scatter mass absorption correction.

Element	Line	Peak 2θ	Background 2θ	Peak time(secs)	Collimator	Crystal (LiF)	Counter	Corrected for:-	Detection Limit(ppm)
Sr	Kα	35.80	+-0.43	20	fine	220	scint	-	2
Sn	Kα	19.84	+-0.45	100	fine	220	scint	-	2
Nb	Kα	21.37	+-0.37	40	fine	200	scint	-	2
Zr	Kα	22.52	+0.38-0.32	20	fine	200	scint	Sr	2
Mo	Kα	28.85	+0.33-0.18	100	fine	220	scint	Zr	3
M.A.	AuLα (Compton)	53.28	-0.90	40	fine	220	scint+flow		-

Table 4. Proterozoic stratigraphy of the Davenport Geosyncline. Data from Blake and others (1983a).

Group	Subgroup	Formation (Members)	Lithologies	Thickness (m)
		Yaddanilla Sandstone	Quartz arenite, feldspathic quartz arenites.	300+
		Vaddingilla	Siltstone, shale, arenite.	ca. 800
		Canulgerra Sandstone	Quartzose-feldspathic arenites, siltstone, mudstone.	ca. 500
	Hanlon	Lennee Creek	Siltstone, shale, arenite, calcareous beds.	ca. 1500
		Alinjabon Sandstone	Quartz-feldspathic arenites, siltstone, shale, mafic lavas.	750
		Errolola Sandstone	Quartz-feldspathic arenites.	1200
	Conformable			
		Kudinga Basalt	Basalt, tuffaceous siltstone, arenite	800
		Frew River	Kaolinitic-quartz-feldspathic arenites, dolomite.	ca. 500
		Coulters Sandstone	Quartz-feldspathic-lithic arenites, siltstone, basalt	3000(?)
	Wauchope	Arabulja Volcanics	Felsic lavas, tuffs.	ca. 700
Hatches Creek		Newlands Volcanics	Dacite, rhyolitic ignimbrite, tuff, agglomerate, arenite.	2000+(?)
		Yeeradgi SAndstone	Arenite, mudstone, shale, slate, phyllite, felsic lavas.	800
		Unimbra Sandstone	Quartz-lithic arenites, conglomerate beds.	1500+
	Conformable to Disconformable			
		Mia Mia Volcanics	Felsic ignimbrite, tuff, rhyolitic lavas, arenite.	2000+(?)
		Treasure Volcanics	Felsic lavas, basalt, tuff, arenite.	3500(?)
		Taragan Sandstone	Quartz-feldspathic-lithic arenite, siltstone, felsic lava.	1200
		Warnes Sandstone	Quartzose arenite.	ca. 500
	Ooradidgee	Endurance Sandstone	Greywacke, siltstone, arenite.	ca. 500
		Kurinelli Sandstone	Feldspathic-lithic-quartzose arenites, siltstone, volcanics.	3000+
		Rooneys	Siltstone, arenite, greywacke.	ca. 1200
		Edmirringee Volcanics	Basalt, dacite, rhyolite, arenite, siltstone.	ca. 2500
		Epenarra Volcanics	Felsic lavas, tuff, agglomerate, arenite.	3000+(?)
	Unconformable			
Warramunga			Greywacke, siltstone, jasper, chert.	?

Table 5. Distribution of mineralisation with stratigraphy. Mines and major prospects, Davenport Province.

Stratigraphy	Tungsten (+-Cu, Bi, Mo)																			Gold				Copper, Lead, Uranium		
	Pioneer	Endurance	Rickety Kate	Black Diamond	Bonanza	Green Diamond	Treasure Group	Masters Gully	White Diamond	Hen and Chickens	BxB	Kangaroo Group	Euro	Hit or Miss Group	Silver Granites	Wauchope Field	Hill of Leaders	Juggler Mine	Woodenjerrie	Kurinelli Field	Crystal	Great Davenport	Power of Wealth	Cairns Prospect	Copper Show	Murray Downs	Munadgee
Granite																	I	I									
Granophyre																											
Gabbro, dolerite	I	I																									
Yaddanilla Sandstone																											
Vaddingilla																											
Canulgerra Sandstone																											
Lenee Creek																											
Alinjabon Sandstone																											
Errolola Sandstone																											
Kudinga Basalt																											
Frew River																											
Coulters Sandstone																											
Arabulja Volcanics																											
Newlands Volcanics																											
Yeeradgi Sandstone																											
Unimbra Sandstone																											
Mia Mia Volcanics																									I		
Treasure Volcanics							I	I	I	I	I			I	I												
Taragan Sandstone												I	I			I											
Kurinelli Sandstone	I	I	I	I	I	I															I	I	I	I			
Rooneys																				I							
Edmirringee Volcanics																										I	
Epenarra Volcanics																											
Porphyry																											I
Warramunga																			I								
	←Hatches Creek Field→																										

Table 6. Comparison of channel and bank samples (-75 um fraction), Wauchope Wolfram Field and Copper Show Mine (Hatches Creek Wolfram Field). Results in ppm.

	Bank A (north side)	Bank B (south side)	Channel
Wauchope Creek - W			
5047	10	12	199
5049	108	19	195
5052	11	9	189
5054	6	105	56
5057	34	71	109
Copper Show - W			
1002	11	4	14
1004	14	12	11
1005	301	16	61
5008	6	5	9
5021	7	5	6
Wauchope Creek - Sn			
5047	7	22	22
5049	12	18	16
5052	7	15	18
5054	9	4	7
5057	19	7	11
Copper Show - Sn			
1002	2	2	5
1004	5	5	7
1005	3	8	7
5008	2	2	4
5021	1	1	3
Wauchope Creek - Cu			
5047	11	10	23
5049	11	8	22
5052	8	10	18
5054	10	10	17
5057	11	13	16
Copper Show - Cu			
1002	23	26	43
1004	26	48	40
1005	206	31	76
5008	22	12	29
5021	20	19	21

Table 7. Element concentration - size fraction trends.

	Th	Rb	Pb	Y	U	As	W	Bi	Sr	Sn	Nb	Zr	Mo	Ag	Be	Co	Cr	Cu	Fe	Li	Mn	Ni	Zn
Hatches Creek Field:																							
Treasure Gully	A	A	C	A	L	L	A	A	C	A	A	C	A	L	A	A	A	A	A	A	A	C	A
Hit or Miss Gully	A C	A	C	A C	L	L	A	A	C A	A	A	C	E	L	A	C A	A C	A	A	A	A	C	A
Copper Show Mine	C A	A	C	A C	L	L	A	L	C	A D	A C	C	L	L	L	L	C A	A C	A C	C	A C	C A	A C
Wauchope Field:	C	C	C	C	L	L	C	B	E	C	C	C	L	L	C	C	C	C	C	C	C	C	C

A - "Davenport Dip": Increasing concentration either side of the 75-118um size fraction.

B - Displaced "Davenport Dip" to increasing size fractions.

C - Decreasing concentration with increasing size fractions.

D - Increasing concentration with increasing size fractions.

E - Complex.

L - Concentrations too low to determine trend.

Table 8. Geochemical summary of other survey areas.

Survey Area. (see Fig.1. for locations.)	Geochemical Results and Observations. (Sample numbers are prefixed by 8202 and all concentrations are in ppm and in the -75 um fraction unless stated otherwise.)
2. Wolfram Hill mines and northeast Hatches Creek region.	Element dispersion trends and concentrations - W(range 181-246), Cu(94-191), Bi(20-48), Mo(4-8: in 250-500 um), Sn(14-22: in 250-500um) - at the Wolfram Hill mines are similar to those at the Hit or Miss Gully at Hatches Creek, except for higher Bi and lower Sn. Associated anomalous elements include Rb(158-227), Li(15-20), Be(2-3), Cr(41-44), Mn(208-339), Ni(14-23) and Zn(62-73).
3. Northwest Pioneer Mine	W(<5) was not anamalous in the area, possibly indicating low potential for stratiform exhalative type scheelite mineralisation. Local high Cr(578), Cu(38) and Ni(178) in the 250-500 um fraction of one sample ( ) may be related to mafic rock types of the Treasure Volcanics.
6. Juggler Mine and Elkedra Granite	Low levels of W(21), Sn(12) and Bi(4) occur in the coarse fractions downstream from the Juggler Mine, with low order W(18), Sn(21), Bi(4), Nb(21), U(6) and Be(6) anomalies along the southern, central contact region of the Elkedra Granite.
7. Southwest Hatches Creek	Weak anomalies for Cu(up to 42 in 250-500 um) draining Frew River Formation are associated with high Co and Mn and probably are related to Mn scavenging. Zn, Ag and Pb levels are near background for all samples indicating that the Frew River Formation has little potential for base-metal mineralisation. The Coulters Sandstone has no economic significance.
8. Mia Mia Dome	U(<6) and Th(<21) are at background levels for all samples draining the radiometric anomalies reported for Area 3 of BMR REcord 1957/80 (Livingstone, 1957). The source of these anomalies, located on the northern margin of the Mia Mia Felsic Volcanic complex is not known. High Sn(42), W(11) and Bi(3) in the 250-500 um fractions of 2 samples suggests a proximal source, possibly the altered granite at GR 186805.
10. Hill of Leaders - Mosquito Creek Tungsten Mines	Low order W(23, in 250-500 um) anomalies persist for more than 1 km downstream from the Hill of Leaders - Mosquito Creek Mineral Field. Element associations differ from those at Hatches Creek and Wauchope Fields with some enrichment of U(9) and background levels of Li, Be, Cu, Bi, Mo and Sn characterising the W mineralisation. The Hill of Leaders Granite appears to be weakly enriched in Y and U, and depleted in Rb, Bi and Nb relative to the Elkedra and Devils Marbles Granites.
12. Northwest Davenport	The geochemical differences between the Hatches Creek and Warramunga Groups reflects the different lithologies of the groups. The feldspathic and quartz arenites of the Unimbra, Coulters and Errolola Sandstone Formations (Hatches Creek Group) are characterised by lower Rb, Li, Be, Mn, Cu, Zn and, in particular, Fe contents than for the phyllitic, haematitic greywacke and chert sediments of the Warramunga Group. Zr appears to be the only element (related to the detrital zircon contents of the arenites) showing greater concentration levels in the Hatches Creek Group then in the Warramunga Group.

Table 9. Summary statistics for all (N = 415) -75 um fractions of stream sediment samples collected in the Davenport Province. Concentrations in ppm.

Element	Arithmetic Mean(AM)	Standard Deviation(SD)	Geometric Mean(GM)	Geometric Deviation(GD)	Range (R)	Median (M)	Inter-element correlations r>0.90*	r=0.81-0.90*	r=0.71-0.80*	r=0.60-0.70
Th	16.0	4.24	15.4	1.369	3-44	16		Y		U,Nb
Rb	96.6	49.0	87.1	1.640	-328	80		Sn,Be	Cu,Li	Bi,Zn
Pb	12.5	2.72	12.1	1.299	0-25	12				
Y	36.7	8.50	35.4	1.387	-83	36		Th		U,Nb
U	3.85	1.19	3.67	1.390	0-9	4				Th,Y
As	3.30	1.26	3.12	1.390	0-12	4				
W	24.4	136.2	4.34	3.980	0-2188	4		Mo	Li	Bi,Sn
Bi*	-	-	-	-	0-48	-			Sn	Rb,W,Mo,Be,Cu
Sr	59.0	20.4	56.4	1.385	-282	56				
Sn	4.41	10.0	2.72	2.558	0-96	2		Rb	Bi,Be	W,Cu,Li
Nb	11.6	2.20	11.3	1.248	-24	11				Th,Y
Zr	1297	364.9	1228	1.586	-3320	1250				
Mo**	-	-	-	-	0-14	-		W		Bi
Ag***	-	-	-	-	0-2	-				
Be	1.67	1.19	1.46	1.648	0-10	1		Rb	Sn	Bi,Cu,Li,Zn
Co	6.99	3.53	6.29	1.658	0-26	7			Fe	Mn,Ni
Cr	35.0	28.1	30.9	1.510	14-286	28	Ni			
Cu	21.5	32.3	15.2	1.917	6-322	13			Rb	Bi,Sn,Be,Zn
Fe	19000	5026	18410	1.284	7000-58000	17500			Co	Mn,Zn
Li	14.2	10.6	12.5	1.572	6-143	12			Rb,W	Sn,Be
Mn	203.9	100.0	184.4	1.550	66-897	179				Co,Fe,Zn
Ni	11.2	9.84	9.33	1.720	3-88	9	Cr			Co
Zn	30.8	13.9	28.5	1.463	8-115	28				Rb,Be,Cu,Fe,Mn

* - Bi content below detection limit (2ppm) in 324 samples.
** - Mo content below detection limit (2ppm) in 408 samples.
*** - Ag content below detection limit (1ppm) in 347 samples.

Table 10. Arithmetic mean and standard deviation of -75 um fractions of stream sediment samples from mineralsied areas. Concentrations are in ppm.

Element	All Samples AM	All Samples SD	Hatches Creek AM	Hatches Creek SD	Wauchope AM	Wauchope SD	Hill of Leaders AM	Hill of Leaders SD	Great Davenport AM	Great Davenport SD	Power of Wealth AM	Power of Wealth SD	Elkedra Granite AM	Elkedra Granite SD
Th	16.0	4.24	14.6	3.19	18.3	3.39	19.5	6.45	14.9	2.12	15.3	4.34	22.2	4.59
Rb	96.6	49.0	109.9	63.7	122.0	54.7	86.5	23.7	75.3	9.44	63.6	15.2	124.1	18.0
Pb	12.5	2.72	11.7	2.04	14.4	2.07	13.8	3.99	13.8	2.11	11.6	2.73	13.9	2.09
Y	36.7	8.50	35.2	7.47	37.4	4.99	42.1	14.1	35.8	7.12	33.7	8.65	43.2	5.21
U	3.85	1.19	3.24	0.93	4.39	1.12	4.68	1.62	3.95	0.85	4.13	1.21	5.00	0.94
As	3.30	1.26	2.92	0.91	4.32	1.66	2.68	0.62	4.73	1.76	3.00	0.88	3.41	0.71
W	25.2	136.1	35.6	124.6	113.9	389.8	6.58	7.51	1.84	1.77	0.81	1.62	7.41	3.36
Sr	59.0	20.4	60.4	22.1	82.7	29.3	43.8	8.81	60.9	7.68	45.9	11.5	62.4	7.48
Sn	4.91	9.74	7.61	13.6	9.65	10.8	2.62	2.17	1.03	1.26	0.88	1.10	5.65	1.66
Nb	11.6	2.20	11.3	1.71	12.5	2.55	11.3	2.17	11.6	1.26	10.1	2.25	17.0	2.83
Zr	1297	364.9	1207	267.0	1185	279.4	1493	534.4	1340	267.0	1554	550.5	1581	413.7
Be	1.68	1.16	2.08	1.45	2.00	1.07	1.18	0.44	1.19	0.57	1.03	0.18	2.47	1.07
Co	7.04	3.43	7.55	3.21	7.03	2.37	5.82	2.94	6.95	2.71	5.38	4.99	6.94	2.63
Cr	35.0	28.1	41.4	41.3	32.7	6.08	27.5	5.85	32.1	7.91	26.6	7.03	29.2	8.23
Cu	21.5	32.3	32.5	46.9	16.5	7.95	13.0	6.25	14.7	4.78	12.3	7.41	11.6	3.22
Fe	19000	5030	20260	4620	18320	2810	17440	4200	19080	5600	16720	8780	20530	4690
Mn	203.9	100.0	238.7	109.1	217.6	97.8	165.3	78.6	169.4	65.9	164.4	99.7	231.1	75.3
Ni	11.2	9.84	14.1	13.6	10.7	3.22	7.12	2.44	9.76	3.10	8.13	6.34	8.71	4.01
Zn	30.8	13.9	36.6	16.3	30.6	11.1	24.2	8.72	29.4	10.6	24.3	13.5	30.6	10.8
N =	415		178		31		50		37		32		17	

Table 11. Heavy minerals of economic significance.

Mining Centre	Wolframite	Scheelite	Cassiterite	Bismuthinite	Molybdenite	Malachite	Azurite	Chrysocolla	Schorl	Dravite	Topaz	Fluorapatite
1) Hatches Creek Hit or Miss Gully	A	M	M	R	M	C	R	N/O	C	M	C	N/O
Treasure Gully	M	N/O	A	N/O	N/O	N/O	N/O	N/O	M	M	M	N/O
Copper Show Mine	M	R	R	N/O	N/O	M	M	R	R	R	N/O	N/O
2) Wolfram Hill	C	A	N/O	R	M	M	C	N/O	M	M	N/O	N/O
3) Wauchope	A	R	A	N/O	N/O	R	R	N/O	M	R	A	R
4) Hill of Leaders	R	A	N/O	N/O	N/O	N/O	N/O	N/O	A	C	N/O	R
5) Juggler Tungsten Mine	N/O	A	N/O	N/O	N/O	N/O	N/O	N/O	A	M	R	M
6) Power of Wealth Gold Mine	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	R	M	N/O	N/O
7) Great Davenport Gold Prospect	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	C	A	N/O	N/O

A - abundant
C - common
M - minor
R - rare
N/O - not observed

Table 12. Areas of potential mineralisation defined by heavy mineral studies.

Heavy minerals of economic interest	Stream sediment sample no.	Area	Associated heavy minerals	Geology of drainage area	Stream sediment values	Comments	Follow up priority
Wolframite Scheelite Cassiterite Copper carbonates	1005	Copper Show Mine	Pyrite, magnetite, ilmenite, zircon, epidote and topaz	Andesites, rhyolites, tuffs (Treasure Volcanics) and arenites and conglomerate (Taragan Sandstone)	108ppm W 45ppm Sn 82ppm Cu	Source may be related to extension of Copper Show mineralisation	High
Wolframite Cassiterite	1025 1026	Hit or Miss Gully	Tourmaline, apatite, zircon and magnetite	As above.	132ppm W 120ppm Sn 52ppm Cu	Eastern end of Hit or Miss Gully; possibly of Treasure Gully mineralisation style	High
Wolframite	5137	Munadgee Uranium Prospect	Magnetite, epidote and psilomelane(?)	Greywacke and cherts (Warramunga Group)	86ppm W 11ppm Bi 28ppm Sn 4ppm Mo 92ppm Cu	Proximal to Munadgee Uranium Prospect. Mineral-isation of Hatches Creek style	Medium
Scheelite	1028 1029	Wolfram Hill	Tourmaline, zircon, magnetite, ilmenite and apatite(?)	Arenites, felsic volcanics (Kurinelli Sandstone), and dolerite and gabbro	150ppm W 60ppm Bi 19ppm Sn 60ppm Zn 200ppm Cu	Sample 1028 maybe draining Ricketty Kate Mine	Medium
Scheelite	5068	Devils Marbles Granite Complex	Mica, topaz, zircon, fluorapatite, ilmenite and tourmaline	Biotite-muscovite granite	7ppm W	Scheelite likely to be granite hosted as veins or disseminations	Low
Scheelite	1212 1214 1215 5190	Elkedra Granite	Tourmaline, zircon, mica, ilmenite, apatite and fluorapatite	Biotite-muscovite tourmaline granite	14ppm W 6ppm U 22ppm Sn 459ppm Rb 4ppm Bi 28ppm Li	Multiple source of scheelite along southern central margin of granite complex	Medium
Scheelite	5195 5197	Elkedra Granite	Hornblende and tourmaline	Biotite-muscovite tourmaline granite and arenites and schists (Rooneys Formation)	11ppm W 10ppm Sn 56ppm Zn	Source within granite or sediments along western contact of granite	Low
Scheelite	5018 5020	Mia Mia Dome	Tourmaline, apatite, zircon, magnetite and epidote	Felsic tuff, arenites (Mia Mia Volcanics) and arenites (Unimbra Sandstone)	11ppm W 3ppm Bi	Mineralisation related to altered granite body occuring at GR 186805	Low
Cassiterite	5012	Mia Mia Dome	Tourmaline and magnetite	Arenites (Unimbra Sandstone)	42ppm Sn	As above.	Medium
Cassiterite	5041-5059 5062 5064	Wauchope Wolfram Field	Topaz, tourmaline, zircon, ilmenite, epidote and apatite	Arenites and conglomerate (Taragan Sandstone)	1010ppm Sn	Cassiterite not reported from this area; multiple sources spatially close to wolframite mineralisation	High

Table 13. Distribution of heavy minerals related to styles of W mineralisation.

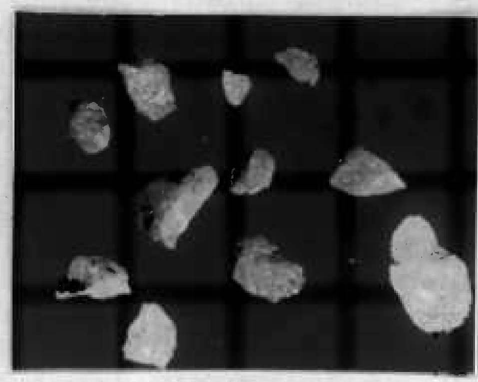
Styles of W mineralisation	Heavy minerals of economic significance											
	Wolframite	Scheelite	Cassiterite	Bismuthinite	Molybdenite	Malachite	Azurite	Chrysocolla	Schorl	Dravite	Topaz	Fluorapatite
1) Wolframite +- scheelite in steeply dipping quartz vein stockworks, within volcanics e.g. Hit or Miss Gully, Treasure Gully and Copper Show Mine	A	M	C	R	R	C	M	R	M	M	C	N/O
2) Wolframite + scheelite in moderately dipping quartz vein stockworks, within sediments of Kurinelli Sandstone e.g. Wauchope	C	A	N/O	R	M	M	C	N/O	M	M	N/O	N/O
3) Wolframite in shallow dipping veins within Taragan Sandstone sediments e.g. Wauchope	A	R	A	N/O	N/O	R	R	N/O	M	R	A	R
4) Scheelite in tourmaline-quartz veins within altered granite e.g. Hill of Leaders and Elkedra Granites	R	A	N/O	N/O	N/O	N/O	N/O	N/O	A	C	R	R
5) Scheelite draining arenites and felsic tuffs of Unimbra Sandstone and felsic volcanics of Mia Mia Volcanics e.g Mia Mia Dome	N/O	M	N/O	N/O	N/O	N/O	N/O	N/O	M	R	N/O	N/O

A - abundant
C - common
M - minor
R - rare
N/O - not observed

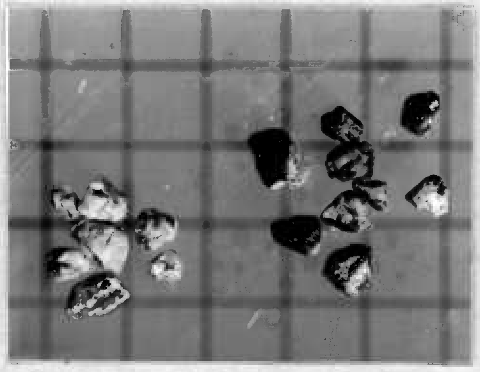
Table 14. Summary of the stream sediment geochemical survey, Davenport Province.

Styles of W, Au and U mineralisation	Useful element associations	Optimum sieve fractions(um) Proximal	Distal	Heavy mineral indicators (in order of frequency)	Application of heavy minerals
1) Wolframite +- scheelite vein type (W+-Cu+-Bi+-Mo +-Sn) in mixed sediment-volcanic-intrusive host	Cu, Bi, Mo, Sn, Li, Be, Rb and Pb	-75, +180-500 W -75, +180-500 Cu +500 Bi +180-500 Mo +180-500 Sn +180-500 Li +180 Be +180 Rb -75 Pb		Wolframite Malachite Cassiterite Topaz Schorl Dravite Scheelite Azurite Bismuthinite Molybdenite	Malachite and azurite can be readily identified by their vivid green-blue colours while the metallic lustre of the bismuth-molybdenum minerals assists rapid identification
2) Wolframite vein type (W+-Sn) in sediment host	Sn, Cu, Bi, Li, Be, Rb, Co and Zn	-75, +180-500 W +355 Sn -75 Cu -75, +500 Bi -75 Li -75 Be -75 Rb -75 Co -75 Zn	-75 W (>13km) +180-500 Sn(>13km) -75 Cu(1km) -75 Bi(3km) -75 Li(>13km) -75 Be(3km) -75 Rb(>13km) -75 Co(1km) -75 Zn(4km)	Wolframite Cassiterite Topaz Schorl Dravite Malachite Fluorapatite Scheelite	Cassiterite and topaz are diagnostic of this style of W mineralisation and combined with their stability during secondary dispersion makes them excellent indicators
3) Scheelite vein (W), disseminated type, in granite host	Sn, U, Nb and Bi	+250-500 Sn -75 U -75 Nb +250-500 Bi		Scheelite Schorl Dravite Fluorapatite Topaz Wolframite Cassiterite(?)	Scheelite and fluorapatite can be readily identified by their fluorescence under short wavelength UV light
4) Vein type gold (Au) in sediment host	As	-75 As		Dravite(?) Schorl	Little application
5) Vein type gold (Au) in granophyre-sediment host	As and Zn(?)	-75 As -75 Zn		-	
6) Vein and secondary coatings uranium (U) in porphyry host	Zn and Y	-75 Zn -75 Y		-	

Bladed wolframite from Copper Show Mine (sample 1005).



Irregular grains of scheelite from Wolfram Hill (sample 1095)



Subrounded cassiterite from Treasure Gully (sample 5002). Grains at bottom left corner are coated with metallic tin from zinc plate method

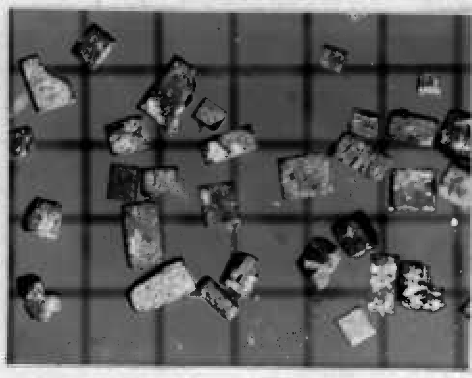
Deformed plates of molybdenite from Hit or Miss Gully (sample 1017)

Equigranular topaz from Dooley's Ridge (sample 1025)

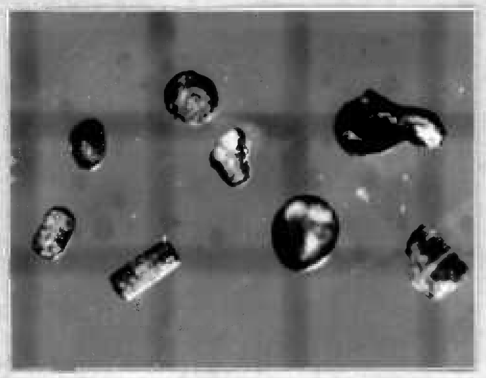
Earthy malachite from Hit or Miss Gully (sample 1010)

Plate 1. Heavy mineral grains from the Hatches Creek Wolfram Field. All grains are superimposed on a 1 mm graticule grid.

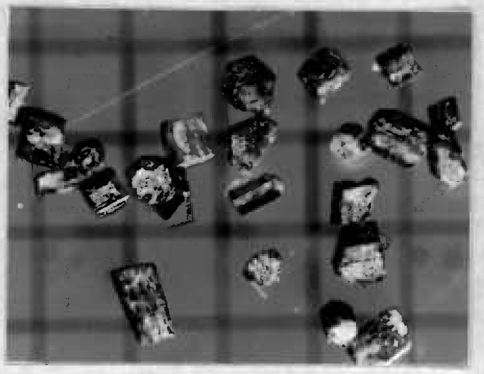
Octahedral martitic magnetite from Copper Show Mine (sample 1004).



Limonite pseudomorphs after pyrite (sample 1043) northeast of Hatches Creek Field

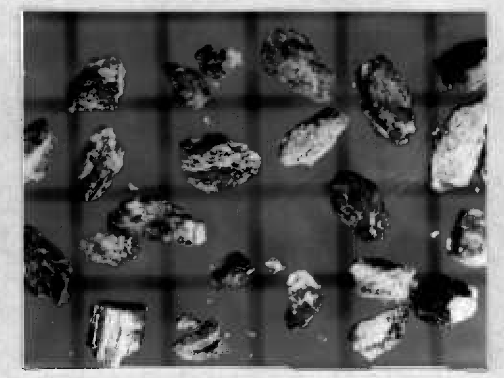


Rounded (?) dravite tourmaline from Northwest Pioneer Mine (composite sample)



Euhedral prismatic (?) schorl tourmaline from Hatches Creek Field (composite sample)

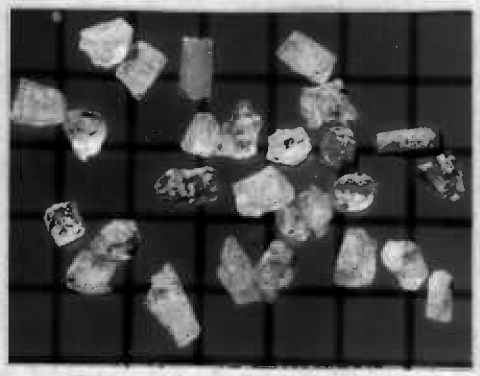
Epidote showing various stages of alteration. From Northwest Pioneer Mine (composite sample)



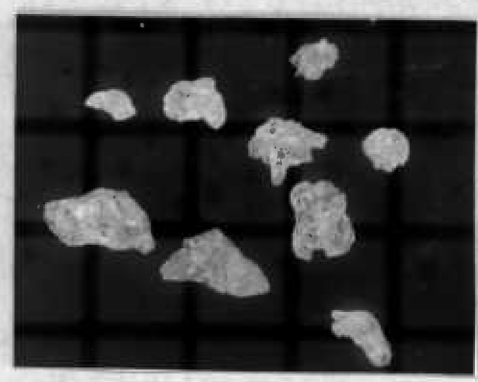
Secondary amphibole showing cleavage partings. From North-west Pioneer Mine (samples 1052 and 1053)

Plate 2. Heavy mineral grains from the Hatches Creek Region. All grains are superimposed on a 1 mm graticule grid.

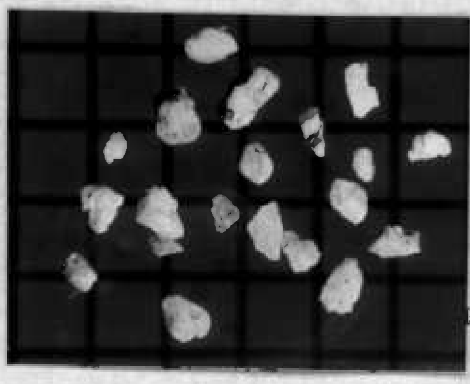
Polychromic prismatic cassiterite from the Wauchope Wolfram Field (sample 5042)



Euhedral topaz from the Wauchope Wolfram Field (samples 5042 and 5056)



Irregular scheelite from the Hill of Leaders Granite (sample 5096)



Small fluorapatite grains from the Elkedra Granite (sample 5198)

Plate 3. Heavy mineral grains from the Wauchope Wolfram Field, and the Hill of Leaders and Elkedra Granites. All grains are superimposed on a 1 mm graticule grid.