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A stream-sediment geochemical orientation survey of the Davenport Province, Northern Territory

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A geochemical orientation study in the Davenport Province, Northern Territory, indicates that stream-sediment sampling is an effective geochemical technique for mineral assessment, despite overall poor drainage development.

Bismuth, Mo, Sn and W from vein-type deposits appear to be dispersed by mechanical weathering, giving rise to well-defined anomalies in both sieved samples and heavy mineral concentrates. Dispersion trains exceed 10 km downstream from mineralisation, and for regional surveys the analysis of a coarse sieved fraction at a sample spacing of 1 to 2 km is recommended.

Dispersion of U and Cu appears to be chemically controlled, and anomalies near known mineralisation in both sieved and heavy mineral samples are either less well defined or absent. Dispersion trains rarely extend more than 1 km from mineralisation, and sample spacing of 0.5 to 1 km, or less, would be necessary.

Introduction

A geochemical orientation survey (Hoatson & Cruikshank, 1985) of the Davenport Province study was undertaken as part of a combined Bureau of Mineral Resources (BMR) and Northern Territory Geological Survey (NTGS), to define the province's stratigraphy, structure, sedimentological history, tectonic setting, and economic potential. The aims of this survey were to determine the most suitable geochemical sampling type(s) that characterise the different styles of known Au, Bi, Cu, Mo, Sn, U and W mineralisation, the mechanisms of secondary dispersion, and the characteristics of secondary dispersion including the identification of pathfinder elements, and the sample spacing required to detect mineralisation.

The Davenport Province, about 180 km south of Tennant Creek (Fig. 1) and covering approximately 15 000 km^2, is centred near the conjunction of the Bonney Well, Frew River, Elkedra and Barrow Creek 1:250 000 sheet areas at longitude 135°E and latitude 21°S.

The region has a semi-arid climate with an average annual rainfall of about 300 mm, largely during December to March, and is characterised by marked diurnal and seasonal fluctuations in temperature with average maximum–minimum ranges for December and July of 38–24°C and 24–11°C, respectively (Perry & others, 1962).

The region is dominated by the northwest–southeast trending Murchison and Davenport Ranges, with the Younghusband Range forming a westerly extension of the latter (Fig. 1). The ranges consist of rocky strike ridges rising up to 597 m above sea level at Mt Cairns, and commonly 200 m above the surrounding plains. The ridges are formed of sandstone, quartzite and conglomerate, with intervening flat to gently undulating depressions on carbonate and argillaceous sediments, intermediate-mafic lavas, pyroclastic flows, and intrusions. Granite outcrops commonly have spectacular tor development, most notably at the Devils Marbles National Park on the Stuart Highway (Twidale, 1980).

The two main drainage systems are those of the east-flowing Elkedra River in the south and the north-flowing Frew River on the northeastern flank of the Murchison Range. Drainage elsewhere is largely controlled by long strike ridges of sandstone and quartzite. All drainage terminates in the sandy plains surrounding the ranges. Run off after rain is very rapid, and for most of the year surface water is restricted to semi-permanent waterholes along the main watercourses and to small rockholes in the ranges.

The ranges have a sparse cover of spinifex and small trees (e.g. snappy gum). Isolated stands of acacia and eucalypts occur along drainage channels. Open grasslands are scattered with several varieties of spinifex. Soils are generally immature and poorly developed, varying from shallow and stony on the ridges to either coarse alluvial soils or red aeolian sands on low-lying areas. Aeolian sands cover most of the plains in the Davenport Province.

Geology and mineralisation

Prior to 1981, the geological and economic features of the Davenport Province had been discussed by, amongst others, Sullivan (1952), Ryan (1961), Smith & others (1961), Smith (1964, 1970), Smith & Milligan (1964, 1966), and Roarty (1977). During the BMR–NTGS survey, the province was remapped at 1:100 000 scale, resulting in the publication of four special map sheets: Devils Marbles region (Wyche & others, 1987), Kurundi region (Stewart & Blake, 1986), Hatches Creek region (Blake & others, 1986) and Elkedra region (Blake & Horsfall, 1987), the boundaries of which, along with the generalised geology of the region, are shown in Figure 2. The results of the survey are synthesised in BMR Bulletin 226 and the accompanying 1:250 000 geological map (Blake & others, 1987).

The Davenport Province forms the southern part of the Proterozoic Tennant Creek Inlier, and lies to the north of the Proterozoic Arunta Inlier. The eastern and western margins of the province are masked, respectively, by lower Palaeozoic platform cover of the Georgina and Wiso Basins. The oldest rocks exposed in the Davenport Province are turbidites and minor 1880–1870 Ma felsic volcanics of the Warramunga Group (Blake & Page, 1988; Le Messurier & others, 1990). The Warramunga Group, which extends north to Tennant Creek, consists of tightly folded greywacke and siltstone with subordinate jaspilitic chert and minor felsic volcanics. It was deformed and intruded by granite (Hill of Leaders Granite) before being unconformably overlain by the Hatches Creek Group, a sequence of shallow-water sediments of predominantly quartz arenites, feldspathic quartz arenites, conglomerates and argillites with minor carbonates, interspersed with bimodal mafic–felsic volcanics of both lava flow and pyroclastic origin. Blake & others (1984, 1987) have subdivided the Hatches Creek Group into the Ooradidgee

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Subgroup (lower), the Wauchope Subgroup (middle) and the Hanlon Subgroup (upper), which collectively contain twenty formations totalling about 10 000 m in thickness (Table 1). Uranium-Pb zircon data for felsic extrusives from the Epenarra and Treasure Volcanics formations indicate probable ages of 1820 to 1810 Ma for volcanism in the basal Ooradigee Subgroup (Blake & Page, 1988).

Multiple sill-like intrusions of granophyre, feldspar porphyry and gabbro occur within the Ooradidgee and lower Wauchope subgroups. Small stock-like bodies of granite occur throughout the province, while areally larger muscovite–biotite granites form extensive intrusions marginal to the outcropping area. The larger granite complexes are the Devils Marbles, Hill of Leaders and Elkedra Granites, with the latter two in particular displaying local greisenisation and quartz–aplite veining. Regional metamorphic grade of the Hatches Creek Group is mainly lower greenschist facies, but upper greenschist facies may have been attained locally (Blake & others, 1987).

The Cainozoic surficial sediments consist largely of ferricrete and lateritic gravel, silcrete, calcrete, and poorly consolidated to unconsolidated gravels, sands, silts and clays (Blake & others, 1986). The Fe-rich gravels form cappings up to 3 m thick on Proterozoic and Cambrian rocks and are believed to represent remnants of the upper parts of probable Tertiary weathering profiles. Silcrete occurs on the tops of ridges, hills and mesas. Calcrete, as inorganic cellular limestone, is widespread as patches and probably formed by evaporation of groundwater during the Cainozoic. The poorly consolidated Cainozoic sediments form colluvial, alluvial and aeolian deposits covering most plains and valley floors (Blake & others, 1986).

Gold, Cu, Pb, U and W (± Bi, Cu, Mo and Sn) mineralisation are known in the region, but only Au and W, with minor associated Bi and Cu, have been mined, and this

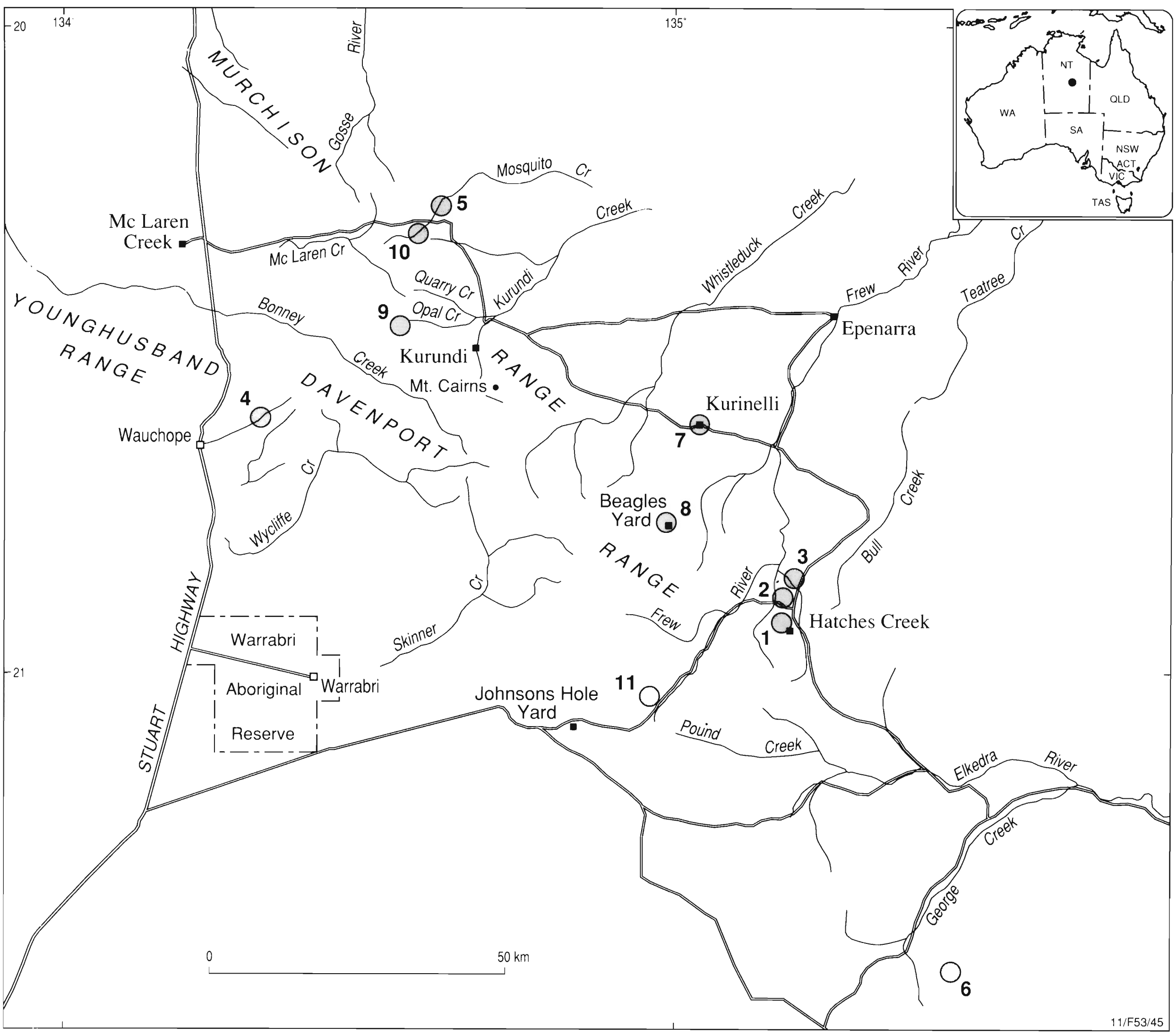

Figure 1. Physiographic map of the Davenport Province showing areas covered in the survey.

(1) Hatches Creek Wolfram Field
(2) Pioneer Mine
(3) Wolfram Hill mines
(4) Wauchope Wolfram Field
(5) Hill of Leaders/Mosquito Creek Wolfram Field
(6) Juggler Wolfram Mine (Elkedra Granite)
(7) Kurinelli Goldfield
(8) Great Davenport Gold Mine and Cairns Gold Prospect
(9) Power of Wealth Gold Mine
(10 Munadgee Uranium Prospect
(11) Silver Valley Lead Prospect

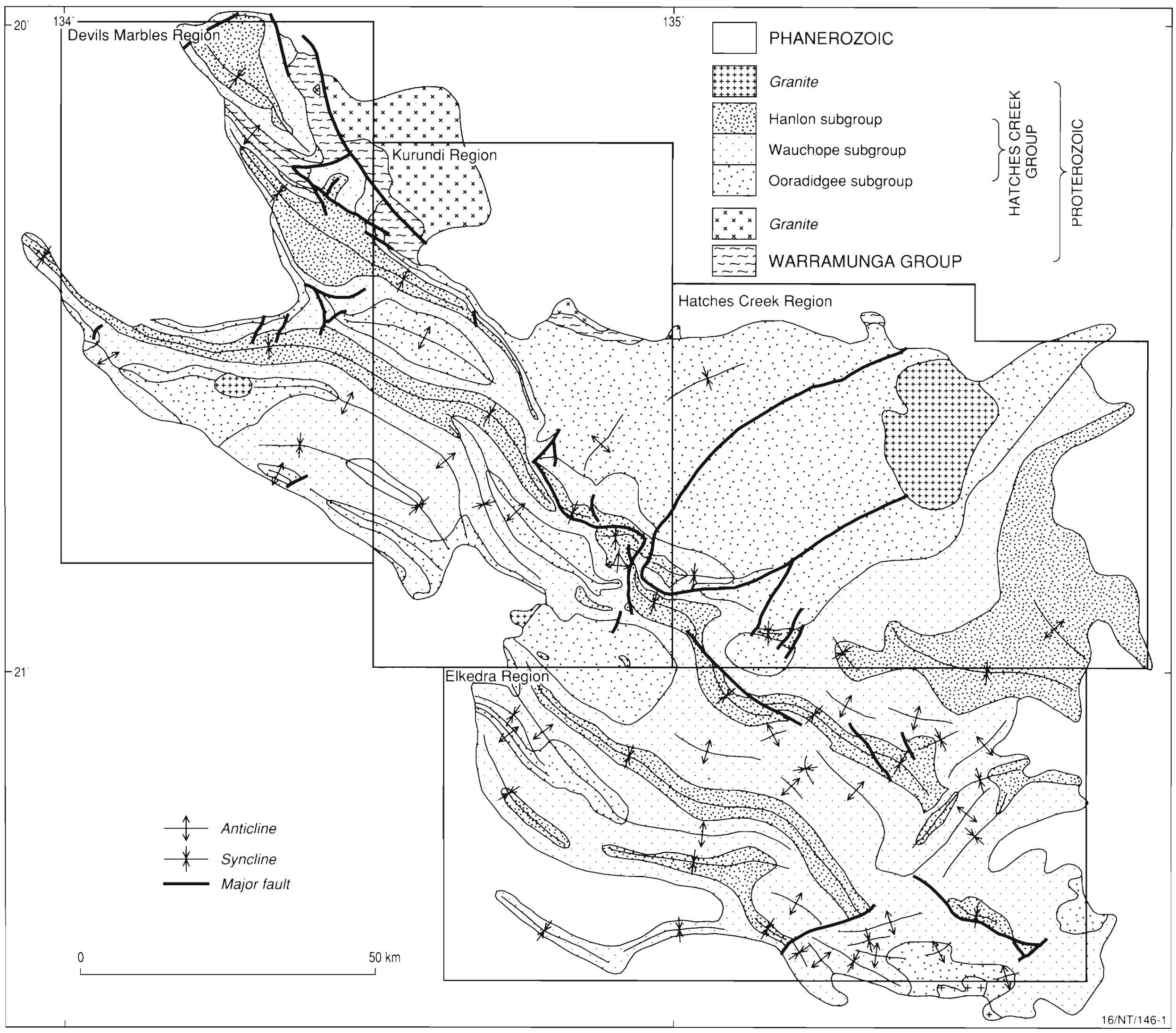

Figure 2. Geological map of the Davenport Province showing the boundaries of the special 1:100 000 map sheet areas.

was intermittent and of small scale. Tungsten mineralisation occurs in a number of styles and settings, ranging from concordant vein swarms within sedimentary–volcanic and/or hypabyssal hosts, to simple vein systems within the upper levels of granitic bodies. Total production of W concentrates from the Hatches Creek and Wauchope Fields has amounted to approximately 4500 tonnes (62–65% WO_3), with about 70 tonnes of Cu and 6 tonnes of Bi concentrates also produced at the Hatches Creek Field (Sullivan, 1952; Ryan, 1961). Other W workings include the Hill of Leaders–Mosquito Creek Field, The Juggler Mine (Elkedra Granite) and the Woodenjerrie Mine (Blake & others, 1987), but no production records are known for these areas.

Gold mineralisation is widely distributed throughout the province but, with the exception of the Kurinelli Goldfield (total recorded production 13.6 kg–Roarty, 1977), the Power of Wealth Gold Mine and the Great Davenport Gold Prospect (Yeaman, 1965: total recorded production 4.7 kg –Smith, 1970; Roarty, 1977), it is isolated and of low tenor.

Minor U mineralisation occurs at the Munadgee Prospect (Lord, 1955; Livingstone, 1957), minor Pb at the Silver Valley Mine/Prospect (Smith & Milligan, 1964), and minor Cu at the Copper Show Mine near Hatches Creek (Ryan, 1961).

Geochemical sampling and analytical procedures

The principal objective of geochemical orientation surveys is to define the patterns of primary and secondary dispersion which occur in the survey area, particularly those of economically or environmentally interesting elements. In geochemical orientation studies, samples from areas of known mineralisation are collected to establish such behaviour, while samples from unmineralised areas are collected to define normal background variations (Hawkes & Webb, 1962). Stream-sediment sampling, involving both sieved fractions and heavy mineral concentrates, is generally considered the most effective technique for regional studies as some form of drainage-dispersal pattern is almost always developed.

In the Davenport Province, stream-sediment sampling was often hindered by confined catchment areas, the restricted length of many streams, and the paucity of fine detritus within the drainage channels because of the dominance of

Table 1. Proterozoic stratigraphy of the Davenport Geosyncline. Data from Blake & others (1987).

Group	*Subgroup*	*Formation (Members)*	*Lithologies*	*Thickness (m)*
		Yaddanilla Sandstone	Quartz arenite, feldspathic quartz arenite	1000?
		Vaddingilla Formation	Siltstone, shale, arenite	ca. 800
		Canulgerra Sandstone	Quartzose-feldspathic arenite, siltstone, mudstone	ca. 500
	Hanlon	Lennee Creek Formation	Siltstone, shale, arenite, calcareous beds	700–1500
		Alinjabon Sandstone	Quartz-feldspathic arenite, siltstone, shale, mafic lava	300–840
		Errolola Sandstone	Quartz-feldspathic arenite	100–1200+
	Conformable contact			
		Kudinga Basalt	Basalt, tuffaceous siltstone, arenite	50–770
		Frew River Formation	Kaolinitic–quartz–feldspathic arenite, dolomite	0–600
		Coulters Sandstone	Quartz–feldspathic–lithic arenite, siltstone, basalt	140–1000+
	Wauchope	Arabulja Volcanics	Felsic lava, tuff	0–500
Hatches Creek		Newlands Volcanics	Dacite, rhyolitic ignimbrite, tuff, agglomerate, arenite	0–2000+
		Yeeradgi Sandstone	Arenite, mudstone, shale, slate, phyllite, felsic lava	0–800
		Unimbra Sandstone	Quartz–lithic arenite, conglomerate	100–1500
	Conformable locally to unconformable contact			
		Mia Mia Volcanics	Felsic ignimbrite, tuff, rhyolitic lava, arenite	2000+
		Treasure Volcanics	Felsic lava, basalt, tuff, arenite	0–1800+
		Taragan Sandstone	Quartz–feldspathic–lithic arenite, siltstone, felsic lava	0–1000+
	Ooradidgee	Edmirringee Volcanics	Basalt, dacite, rhyolite, arenite, siltstone	0–2500
		Kurinelli Sandstone	Feldspathic–lithic–quartzose arenite, siltstone, minor volcanics	0–2600
		Rooneys Formation	Siltstone, arenite, greywacke	0–1200+
		Epenarra Volcanics	Felsic lavas, tuff, agglomerate, arenite	0–3000+
	Unconformity			
Warramunga			Greywacke, siltstone, jasper, chert	10 000+

quartz-rich lithologies throughout the province and the flushing effect of the heavy summer rains. However, soil profiles in areas visited were found to be poorly developed with potentially high aeolian components and this, coupled with the limited mobility of many elements (e.g. Pb, Sn, W, etc) in arid, high pH soils, was considered to preclude soil sampling as part of the regional geochemical survey. Similarly, the style of known mineralisation in the region (i.e. mostly localised small-scale vein systems with weak hydrothermal alteration haloes) renders rock chip sampling impractical because of the high sampling density necessary. Therefore, stream-sediment sampling remains the most effective approach for regional geochemical surveys in the Davenport Province.

Samples were collected from streams draining mineralisation in Hit or Miss Gully, Treasure Gully, Copper Show Mine and the Wolfram Hill mines in the Hatches Creek Field, the Wauchope Field, the Munadgee Uranium Prospect, the Great Davenport and Cairns Gold Prospects, the Power of Wealth Gold Mine, the Juggler Tungsten Mine and the Elkedra Granite, the Hill of Leaders Granite and associated mines, the unconformity between the Warramunga and Hatches Creek Groups in the northwest of the province, and several unmineralised and potentially mineralised areas. Sampling densities near mineralisation generally were one sample per 0.5–1 km of run in the main drainage channel with most well-defined tributaries also sampled. Remote from mineralisation as well as in unmineralised areas, the density was reduced to one sample per 1–2 km of stream run. The Kurinelli Goldfield was not sampled owing to absence of suitable drainage and dominance of aeolian material.

Samples were collected by teams in 4-wheel drive vehicles, although it was often necessary to walk to the actual sample site. Each sample was a 3–5 kg composite from several sites within the stream bed to minimise the effects of local variations due to stream flow/sedimentation mechanics. Coarse material (i.e. >1 mm) was sieved off and discarded. The samples were sent to BMR's laboratories in Canberra for final sieving, grinding and analysis (Hoatson & Cruikshank, 1985).

To determine the most appropriate grain-size ranges for analysis, several samples from sites close to mineralisation were sieved into eight size fractions using aluminium-bodied sieves fitted with nylon bolting cloth (710 μm, 500 μm, 355 μm, 250 μm, 180 μm, 118 μm and 75 μm mesh sizes). In all samples there was insufficient +710 μm fraction for analysis. Each fraction was finely ground and analysed for As, Bi, Mo, Nb, Pb, Rb, Sn, Sr, Th, U, W, Y and Zr by X-ray fluorescence spectrometry, and for Ag, Be, Co, Cr, Cu, Fe, Li, Mn, Ni and Zn by atomic absorption spectrometry (Table 2). Details of methods are given in Cruikshank & Pyke (1993). The geochemical contrast for most elements was greatest in either the +250–500 µm fraction or the –75 µm fraction (see Results). The remaining samples were sieved for these two grain-size ranges and analysed as above.

The remainder of each sample was passed over a Wilfley table and the light fraction discarded. The resulting concentrate was separated using tetrabromoethane (SG 2.96), after which the heavy fraction was separated on a Carpco Magnetic Separator into magnetic and non-magnetic fractions. Although a low magnet current was used to allow for the moderate magnetic susceptability of wolframite, repeated passes through the separator removed nearly all magnetite, most martite, and also some ilmenite, tourmaline, mica and amphibole. Both the magnetic and non-magnetic fractions were retained for examination under the stereoscopic microscope, and the non- magnetic fraction was also examined under short-wavelength ultraviolet light to check for the presence of scheelite, carbonates, and phosphate- bearing minerals. Grains which could not be identified under the stereoscopic microscope were identified using a petrographic microscope or by X-ray diffraction. Selected samples were qualitatively analysed by optical emission spectrography. The basic technique is labour intensive in comparison to analysis of sieved fractions and requires a high level of skill to identify some minerals, especially when in low abundance.

Results

Stream-sediment sampling effectively defined the area of W and associated Sn (±Bi and Mo) mineralisation at the Hatches Creek and Wauchope Fields where extensive, well-defined dispersion trains were identified. However, there were marked differences in the behaviour of W and Sn due to the mechanical properties of their minerals present in the mineralisation and, therefore, in the stream sediments. Molybdenum and Bi were detected only in close proximity to mineralisation owing to their low abundances in the lodes. Copper, although present in significant concentrations in some ore bodies, showed restricted dispersion, whereas U was not detected even adjacent to exposed, but low-level, U mineralisation. The poor chemical signatures of Cu and U are possibly due to the dominance of chemical weathering processes and greater mobilities of these elements.

The mass of data accumulated during a geochemical survey can be assimilated and interpreted more easily using statistical methods. Such treatments usually assume that sampling is random or unbiased, whereas, in the present orientation survey sampling was deliberately biased towards mineralised areas which have been subjected to mining activity or intensive exploration, thereby greatly increasing the number of 'anomalous' samples, or outliers, in the sample population. Despite this limitation, a number of useful observations can be drawn from an analysis of the available data. Means and standard deviations for the –75 µm fraction are listed in Table 2, and Pearson correlation coefficients in Table 3. A number of elements (i.e. As, Fe, Nb, Pb, Sr, Th, U, Y and Zr) show little variation over the total sample population indicating the absence of 'anomalous' populations of these elements. In contrast, W, Sn and Cu, the principal elements in much of the known mineralisation, show large ranges and standard deviations. Cumulative frequency plots (Sinclair, 1974) of W, Sn and Cu are shown in Figure 3 and suggest background and anomalous populations for each element with threshold values, corresponding to the breaks in slope of the plots, of 7, 4 and 20 ppm, respectively. Threshold values are element concentrations above which geochemical values may be of particular interest for exploration purposes. For Ag, Bi and Mo 'not detected' values (detection limits of 2, 2 and 1 ppm, respectively) formed the greater part of the datasets and hence few parameters have been recorded, but for these elements detected values may be of interest.

Strong mutual correlations ($r>0.60$ and $r<-0.60$) were found between the members of the following three groups:

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

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

(iii) Th, Y, U and Nb

Of these associations, only (i) appears to be of economic significance. Association (ii), and any variation in these elements, appears to be due to the presence of two populations, the low values derived from the ubiquitous quartz–feldspathic sediments and higher values from the mafic volcanics. Association (iii) is usually associated with the presence of resistant detrital minerals, such as monazite and xenotime weathered from granites (Rossiter, 1975).

Heavy mineral concentrates were useful in delineating W-Sn-Cu mineralisation in the province (Hoatson & Cruikshank, 1985). However, because of the complex nature of the bedrock geology, the predominance of quartz-rich arenites (e.g. Unimbra, Errolola, Taragan and Kurinelli Sandstones), and a general absence of diagnostic metamorphic minerals, the heavy mineral samples were not as useful in discriminating geological units in the province as in the Forsayth area of north Queensland (Rossiter, 1983). Heavy minerals of direct economic significance identified in concentrates from the Davenport Province are wolframite, scheelite, cassiterite, bismuthinite, molybdenite, malachite, azurite, chrysocolla, and a molybdenum-bearing variety of scheelite (Table 4), while those of indirect significance are topaz, two varieties of tourmaline, and fluorapatite.

Tungsten

Tungsten mineralisation occurs at Hatches Creek within steeply dipping quartz lodes. The larger deposits (>200 tonnes WO_3) are generally associated with quartz veins cutting the Treasure Volcanics, Kurinelli Sandstone and Taragan Sandstone, dolerite and gabbro, whereas the smaller deposits are usually confined to sedimentary rocks. The lodes are structurally controlled by shears, fracture zones, and intersections of favourable host lithologies. Wolframite is usually the dominant W mineral, but scheelite becomes prominent where gabbro is the host. Associated minerals are tungstite, native bismuth, bismuthinite, bismutite, chalcopyrite, chalcocite, covellite, bornite, tetrahedrite, malachite, azurite, chrysocolla, cuprite, native copper, molybdenite, wulfenite, galena, gold and cassiterite (Ryan, 1961).

At Wauchope, the W mineralisation is in thin quartz veins

Table 2. Summary statistics for analysed elements in all (N = 415) –75 μm fractions of stream-sediment samples collected in the Davenport Province. Concentrations in parts per million (ppm).

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

* Ag content below detection limit (1 ppm) in 347 samples.
** Bi content below detection limit (2 ppm) in 324 samples.
*** Mo content below detection limit (2 ppm) in 408 samples.
# XRFS = X-ray fluorescence spectrometry
AAS = Atomic absorption spectrophotometry
DL = 'Detection Limit' in ppm.

which are generally conformable with bedding in sediments of the Hatches Creek Group. No volcanic rocks or gabbro–dolerite have been recorded. Host rocks belong to the Taragan Sandstone and include gently dipping silty mudstones, laminated siltstones with sandy lenses, arenites and various hornfelsed variants of these. Kaolinisation wallrock alteration is locally intense, and some tourmaline, topaz and hematite have been introduced. Ore minerals are wolframite, trace scheelite, pyrite, chalcopyrite, molybdenite and bismuthinite (Sullivan, 1952).

Stream-sediment samples from the Hatches Creek area (Fig. 4) and from Wauchope Creek downstream from the Wauchope Field (Fig. 5) usually gave W values much higher than the 7 ppm threshold, and the anomaly persisted for at least 10 km down Wauchope Creek. Adjacent to the Wauchope mine, high W values occur in both fine and coarse sieve fractions with a pronounced minimum centred on the 118–180 μm fraction. About 3.5 km downstream from the mine, W has disappeared from the coarser fractions due to the pulverising of the brittle W-bearing minerals during alluvial transport (Fig. 6). Similar profiles were found in size fraction plots for samples from Hit or Miss Gully at Hatches Creek (Fig. 7). This behaviour during transport and the presence of much detrital wolframite and scheelite in heavy mineral concentrates indicates that dispersion occurs by mechanical, rather than chemical, processes (Rossiter, 1975). Wolframite and scheelite are both relatively insoluble under the conditions prevailing in most surface waters (Krauskopf, 1970). Also, in streams draining the Devils Marbles near the Wauchope Field, banks of coarse stream sediment contained copious quantities of unweathered feldspar grains, thus confirming the importance of mechanical weathering processes.

Detrital wolframite was the dominant W mineral in heavy mineral concentrates from Wauchope and Hatches Creek (Table 4). However, where W- rich quartz vein lodes cut granite as at Wolfram Hill (1–2 km north of Hatches Creek), the Hill of Leaders mines in the north of the province, and near the Juggler Mine on the Elkedra Granite in the south, scheelite is the dominant W-bearing mineral.

The strong statistical correlation between W and Cu, Bi, Sn, Mo, Rb, Li and Be (Table 3) is reflected in an equally strong spatial correlation of values for these elements in samples from the Hatches Creek and Wauchope areas (Figs 4 & 5–Li and Be are not shown for Hatches Creek Field). Copper and Bi minerals — and at Hatches Creek, Sn and Mo-bearing minerals — have been identified in the mineralisation (Sullivan, 1952; Ryan, 1961). Correlations with Rb, Li and Be suggest that the mineralisation was derived from a pegmatitic or other fractionated granitic source (Levinson, 1974), as does the widespread occurrence in heavy mineral concentrates from both locations of topaz and two varieties of tourmaline (i.e. schorl and

Table 3. Pearson correlation coefficients (raw data) for elements in the –75 μm fractions of the Davenport stream-sediment samples (N=415). Strong correlations (r>0.60) are in bold and indicate possible geochemical associations.

Th	*Rb*	*Pb*	*Y*	*U*	*As*	*W*	*Bi*	*Sr*	*Sn*	*Nb*	*Zr*	*Mo*	*Ag*	*Be*	*Co*	*Cr*	*Cu*	*Fe*	*Li*	*Mn*	*Ni*	*Zn*	
	0.25	0.42	**0.80**	**0.70**	0.18	0.05	–.03	0.08	0.13	**0.67**	0.53	0.03	0.04	0.19	–.08	–.20	–.02	0.00	0.16	–.01	–.23	–.04	Th
		0.20	0.27	0.19	0.05	0.51	**0.67**	0.35	**0.82**	0.44	–.13	0.43	0.12	**0.86**	0.19	–.07	**0.70**	0.39	**0.72**	0.41	–.07	**0.65**	Rb
			0.46	0.38	0.34	0.23	0.18	0.34	0.17	0.39	0.05	0.24	0.11	0.18	0.27	–.02	0.02	0.19	0.30	0.19	0.00	0.18	Pb
				0.70	0.23	0.07	0.09	0.10	0.16	**0.64**	0.48	0.07	0.07	0.22	0.10	–.12	0.07	0.19	0.17	0.19	–.13	0.10	Y
					0.25	0.10	0.06	0.04	0.12	0.54	0.48	0.10	0.01	0.12	–.08	–.15	0.01	–.03	0.15	0.03	–.19	–.07	U
						0.25	0.01	0.28	0.03	0.30	0.05	0.15	0.21	0.01	0.20	0.04	–.03	0.23	0.25	0.14	0.04	0.10	As
							0.67	0.51	**0.65**	0.31	–.03	**0.84**	0.08	0.43	0.06	–.02	0.30	0.13	**0.73**	0.24	–.02	0.35	W
								0.29	**0.77**	0.25	0.04	**0.64**	0.02	**0.61**	0.08	–.04	**0.67**	0.24	0.53	0.29	–.04	0.55	Bi
									0.41	0.30	–.16	0.41	0.11	0.32	0.31	0.06	0.11	0.22	0.56	0.31	0.10	0.29	Sr
										0.33	0.01	**0.60**	0.05	**0.73**	0.09	–.05	**0.68**	0.27	0.09	0.35	–.06	0.56	Sn
											0.40	0.24	0.07	0.41	0.03	–.19	0.15	0.16	0.38	0.16	–.20	0.23	Nb
												–.01	–.08	–.11	–.29	–.18	0.01	–.25	–.15	–.14	–.22	–.18	Zr
													0.02	0.37	0.04	–.02	0.30	0.13	0.51	0.18	–.02	0.30	Mo
														0.05	0.08	0.00	0.00	0.05	0.17	0.10	–.03	0.07	Ag
															0.23	–.02	**0.65**	0.42	**0.63**	0.46	0.00	**0.66**	Be
																0.55	0.18	**0.74**	0.27	**0.67**	**0.85**	0.50	Co
																	0.05	0.42	0.07	0.36	**0.94**	0.16	Cr
																		0.38	0.38	0.39	0.06	**0.62**	Cu
																			0.31	**0.67**	0.51	**0.68**	Fe
																				0.45	0.08	0.50	Li
																					0.42	**0.64**	Mn
																						0.23	Ni
																							Zn

dravite). The two tourmalines appear to coexist, and topaz is abundant, only near W–Sn mineralised areas at Hatches Creek and Wauchope. They are probably derived from wall rock alteration (e.g. greisenisation) associated with the hydrothermal veining. The schorl–dravite–topaz association, therefore, appears to be a useful indicator for W–Sn mineralisation.

Tungsten values are low (20–25 ppm) immediately downstream from the Hill of Leaders Field and the Juggler Mine. At Hill of Leaders, strong spatial and statistical correlations were apparent between W, Sn, Bi and Cu, but these associations are weaker and more diffuse at the Juggler Mine. Scheelite was the dominant W mineral in heavy mineral concentrates from both areas and while schorl and dravite were abundant, topaz was rare or not observed. Fluorapatite was confined to samples from these areas and, although its relationship to the mineralisation is not clear, it appeared to be associated with scheelite. No enrichment in Sn, Cu, Bi, Mo, Rb, Li or Be was evident in stream sediments from Hill of Leaders. Low level Sn, Bi and Be anomalies occurred over the Elkedra Granite, although not immediately downstream from the Juggler Mine.

Sampling programs for W can be based on collection and analysis of fine (–75 μm) or coarse (+180 –500 μm) sieved sediment, or on visual examination of heavy mineral concentrates for W-bearing and associated minerals. Visual examination of heavy mineral concentrates is labour intensive and, therefore, analysis of the fine sieved fraction is probably the most efficient and economical approach. Given the rather lengthy dispersion trains from the Wauchope and Hatches Creek Fields, a sample spacing of 1 to 2 km should be adequate to define W mineralisation in the province.

Tin

The dispersion of Sn is also controlled by the mechanical and chemical stability of its major mineral, cassiterite. Cassiterite is abundant and widespread in heavy mineral concentrates from Wauchope, and from Treasure Gully at Hatches Creek. At both locations, Sn initially concentrates in the coarser fractions of the sieved sediments, but moves to finer fractions with transport as shown down Wauchope Creek (Fig. 8), due to the mechanical pulverising of the cassiterite grains.

Although there is a shift in abundance of Sn to finer fractions with distance from mineralisation, the highest values were found in the coarser fractions. Thus, a program seeking Sn mineralisation should be based on coarse sediment (+180 –500 μm) sampling at spacing of 1 to 2 km. Visual examination of heavy minerals for cassiterite can also be used, but is considered to be less economical.

Bismuth and molybdenum

Bismuthinite and minor amounts of molybdenite were observed in heavy mineral concentrates from Hit or Miss Gully at Hatches Creek. Bismuth and Mo concentrated in the coarser fractions of the sieved sediments regardless of distance from mineralisation, possibly because of the ductility of the minerals. At Wauchope, Bi and Mo values are much lower than in Hit or Miss Gully, although anomalous levels of Bi persisted for some 3 to 4 km down Wauchope Creek.

The coarser fractions of sieved sediments are necessary for Bi (+250 –500 μm) and Mo (+180 –500 μm). Bismuthinite and molybdenite are easier to identify in heavy mineral concentrates than wolframite, scheelite and cassiterite because of their platy form and metallic lustre.

Other elements associated with W mineralisation

Rubidium, Li and Be display similar distribution patterns to W and, along with Sn, Bi, Mo, and, to a lesser extent Cu (see below), can be used as pathfinder elements for W mineralisation. These elements are more prominent in the

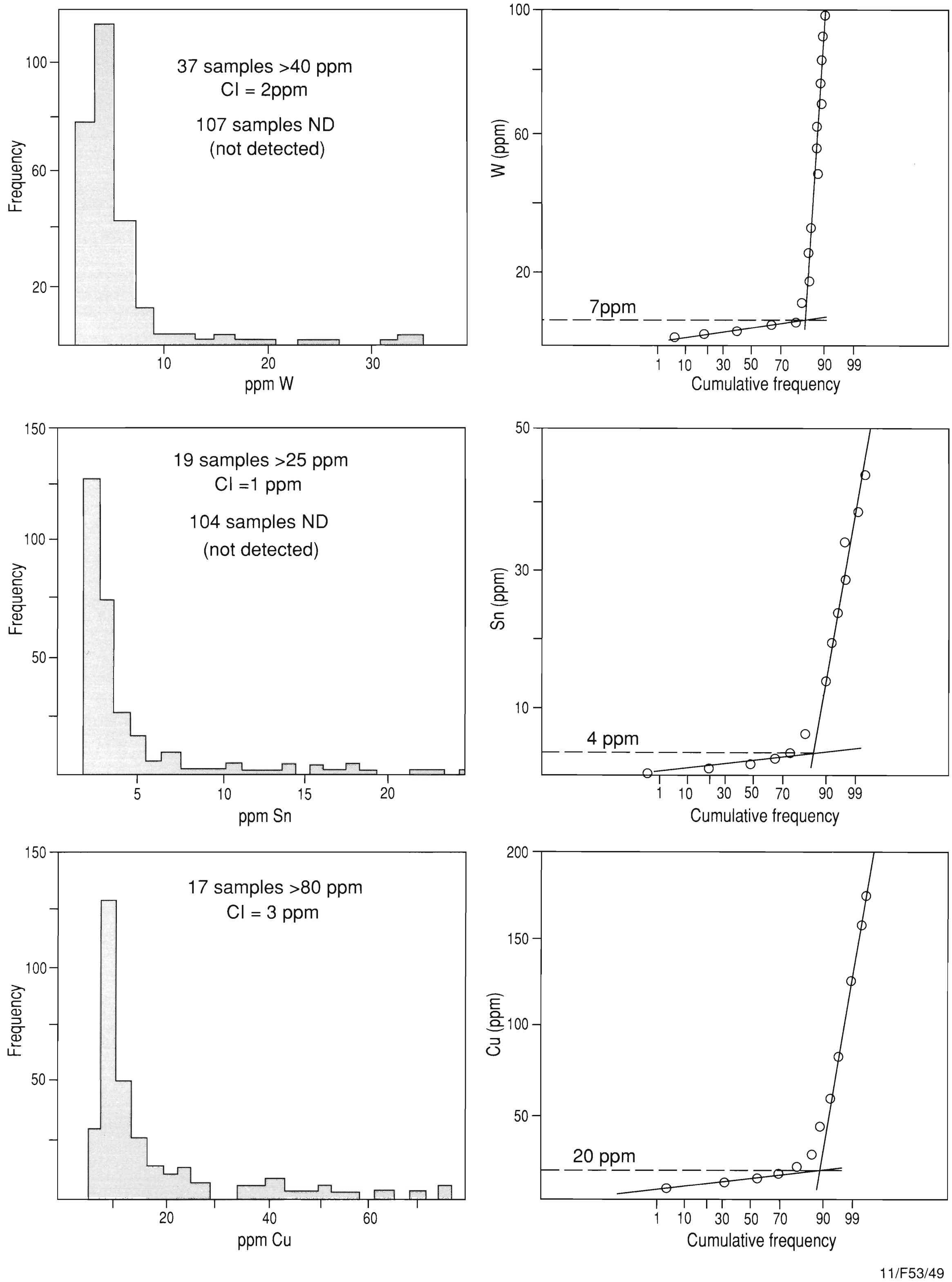

Figure 3. Histograms and cumulative frequency plots for W, Sn and Cu in the –75 µm fraction of all sieved stream-sediment samples collected. The break in the slope of the cumulative frequency plots is the 'threshold' value.

Table 4. Distribution of heavy minerals of economic significance.

Mining Centre	*Wolframite*	*Scheelite*	*Cassiterite*	*Bismuthinite*	*Molybdenite*	*Malachite*	*Azurite*	*Chrysocolla*	*Schorl*	*Dravite*	*Topaz*	*Fluorapatit*
(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/0	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

coarser sieved fractions (Table 5).

Copper

Copper mineralisation is scattered throughout the Davenport Province but, apart from the southern part of the Hatches Creek Field, the reported occurrences are of little economic significance. Copper minerals have been observed in vesicles in Kudinga Basalt, 19 km southeast of Kurundi Homestead (Smith, 1970). Secondary Cu minerals occur in quartz veins 19 km east of Murray Downs Homestead (Smith & Milligan, 1964), and a narrow vein of chalcocite has been reported west of Elkedra station (Smith & Milligan, 1966). Turquoise has been mined at the Tosca Mine in the Elkedra area (Blake & Horsfall, 1987).

Downstream from the Copper Show Mine at Hatches Creek (Fig. 4), and in Wauchope Creek (Fig. 5), Cu has a relatively short dispersion train of 2 km or less, beyond which values fall below the threshold value of 20 ppm. Proximal Cu values were low in both, surprisingly so near the Copper Show Mine (2.5–4.5 times threshold), although azurite, malachite and chrysocolla were identified in heavy mineral concentrates from these two areas (Table 4). No detrital Cu sulphide minerals were observed. The short dispersion train and low initial values could be due to Cu, released during oxidation of ore-body sulphide minerals, being largely flushed out during the wet season as these sediments appear to have little finely divided material (clays or hydrated oxides) to adsorb the Cu ions. The secondary minerals are very friable and would be quickly pulverised during alluvial transport.

During the survey, a small pocket of secondary Cu minerals was found in siltstones of the Rooneys Formation, close to the Elkedra Granite. Even though the mineralisation was exposed, no Cu anomaly was detected in a stream sediment less than 1 km downstream. The mineralisation has little economic significance, but its presence underlines the potential difficulties in interpretation caused, firstly, by such small pockets of mineralisation and, secondly, by the limited secondary dispersion of Cu.

Copper background levels are variable, with values usually less than 10 ppm in areas draining sedimentary rocks and felsic volcanics and 10 to 20 ppm where mafic volcanics are present.

In the immediate vicinity of mineralisation, Cu is equally present in both coarse and fine fractions of the sieved sediment — but at a distances greater than 1 km, the Cu response is very muted and virtually confined to the fine (–75 μm) fraction. For this reason, the fine fraction should be sampled at sample spacings of 0.5 to 1 km, or less. Heavy mineral concentrates are more useful, because the secondary Cu carbonate minerals are readily identified by their vivid colours (Table 6).

Gold

Gold-bearing quartz lodes are restricted to the Kurinelli Sandstone, Rooneys Formation and Epenarra Volcanics of the Hatches Creek Group, and to dolerite, gabbro and granophyre bodies intruding these units. Stream-sediment sampling was carried out downstream from the Great Davenport Mine and Cairns Prospect (Fig. 9), and the Power of Wealth Mine (Fig. 10).

At Great Davenport, patchy flake and coarse gold, the latter associated with pyrite and oxidised pyritic boxworks, occur in quartz veins cutting the Kurinelli Sandstone (Yeaman, 1965). At the Cairns Prospect, 6 km to the southeast, thin quartz and quartz–hematite–magnetite veins cut altered porphyritic granophyre, and arenite and siltstone of the Kurinelli Sandstone. The mineralisation at the Power of Wealth Mine is in intense quartz veining within the Kurinelli Sandstone and Epenarra Volcanics. Surface expression of the mineralisation is poor, and even at the 30 m level, where the highest grades occur, the mineralisation is patchy and discontinuous.

No free gold was observed in streams draining Great Davenport and the Cairns Prospect (Fig. 9). However, Au was detected by optical emission spectrographic analysis of heavy mineral concentrates from streams draining both prospects. Interesting near Great Davenport is the concentration of low-level Au values to the southwest of the mine in streams draining rhyolite of the Treasure Volcanics and arenite of the Taragan Sandstone and Unimbra Sandstone. Of the other elements analysed, only As has any obvious spatial correlation with Au. Arsenic shows weak anomalies (up to 9 ppm) close to the mineralisation, but falls to background levels (3–4 ppm) within 1–2 km of the mineralisation. Hence, As appears to have limited application as a pathfinder for Au.

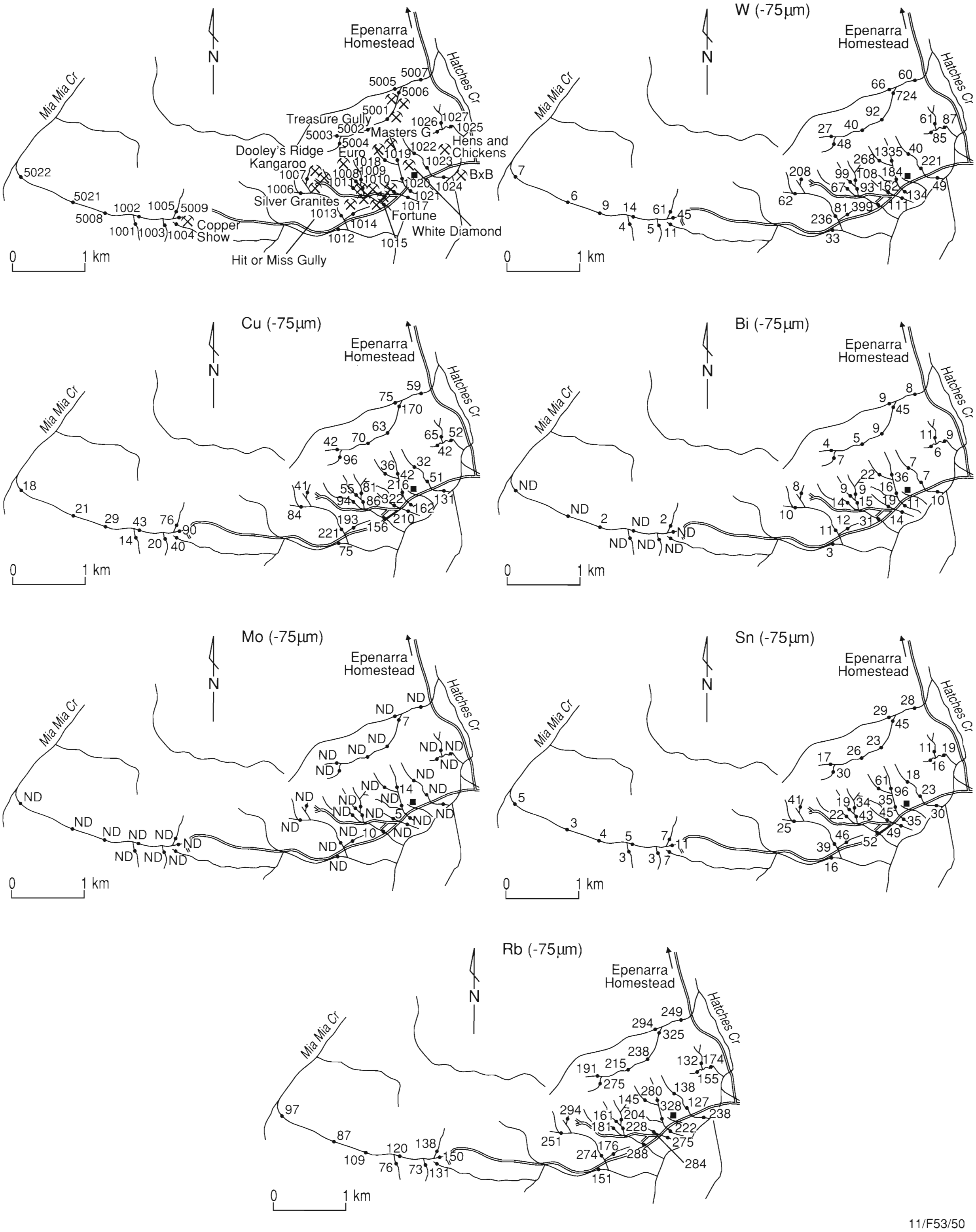

Figure 4. (a) Location of mines and sample sites in the area of the Hatches Creek Field. (b-g) Values for W, Cu, Bi, Mo, Sn and Rb, respectively. ND = 'Not detected'

Gold was also detected by emission spectrography in heavy mineral concentrates from streams draining the Power of Wealth Mine, in the headwaters of Opal Creek and in several streams draining the area of intense quartz veining (Fig. 10). Arsenic remains at background levels (3– 4 ppm) in all samples from the survey area with no obvious enrichment near the Power of Wealth Mine. This is not surprising since the sulphide content of the Power of Wealth lode is much lower than the Great Davenport lode. Moderate local Cu anomalies (>10 ppm) are probably related to the Edmirringee and Kudinga Basalts, as samples from streams draining the Kurinelli Sandstone Formation and Epenarra Volcanics rarely exceed 10 ppm Cu.

Uranium

Autunite, torbernite and carnotite mineralisation occurs within a sheared porphyry intruding the Warramunga Group at Munadgee. The mineralisation occurs on a ridge, drained by short gullies on its western side only (Fig. 11). Uranium in all size fractions was low (generally <3 ppm), with slightly anomalous values (4 to 6 ppm) in some

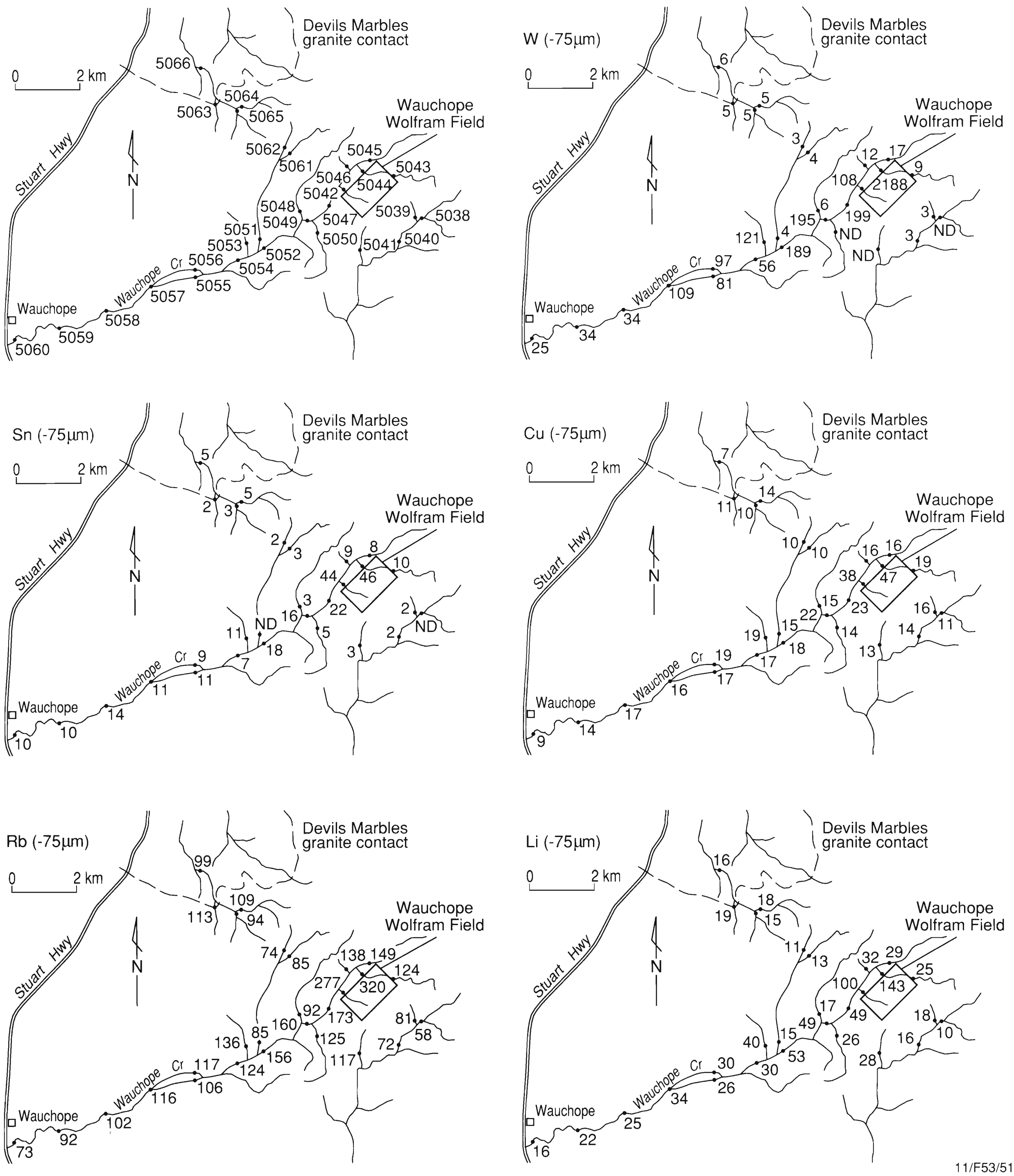

Figure 5. (a) Location of mineral field and sample sites in the area of the Wauchope Field. (b-f) Values for W, Sn, Cu, Rb and Li, respectively.

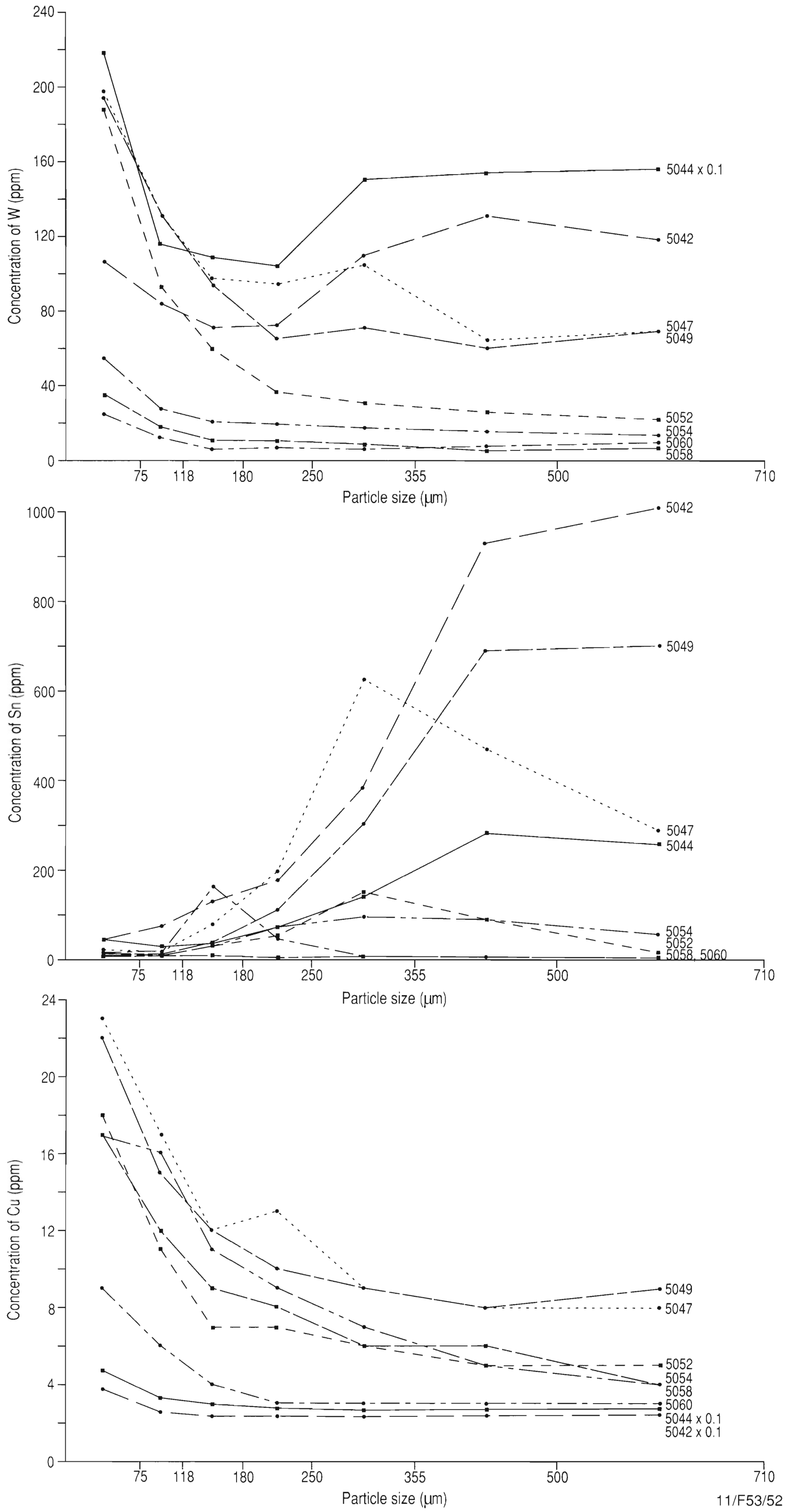

Figure 6. Concentration/particle size plots for the Wauchope Field for W (a), Sn (b), and Cu (c).

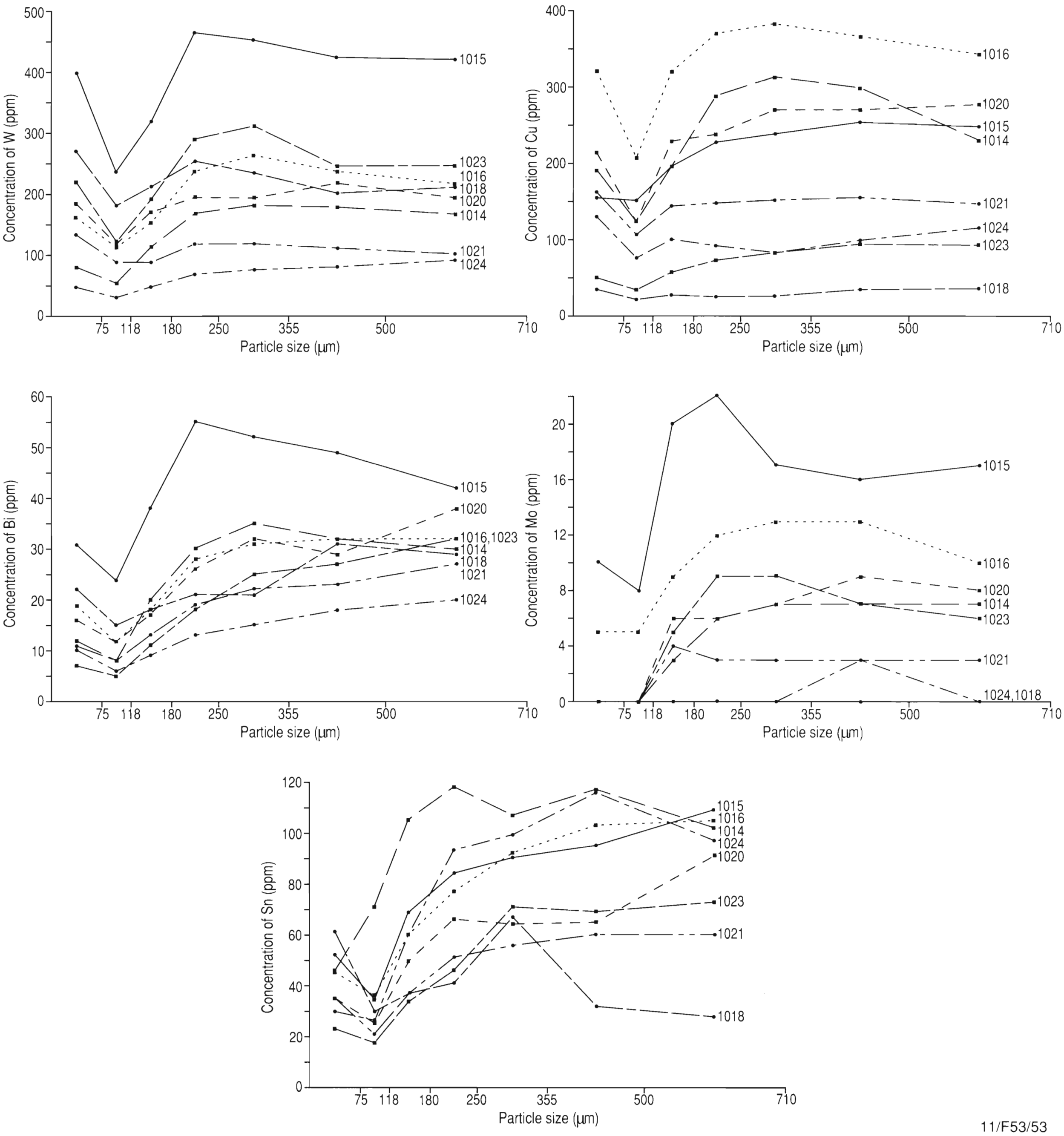

Figure 7. Concentration/particle size plots for the Hatches Creek Field for W (a), Cu (b), Bi (c), Mo (d), and Sn (e).

samples draining the ridge. The low levels in the sieved fractions can be attributed to the limited surface expression of the mineralisation and to the extreme solubility and mobility of the UO_{22+} ion in arid environments (Hawkes & Webb, 1962). Pathfinder elements characteristic of vein-type U deposits, such as As, Bi, Co, Cu, Mo and Ni (Levinson, 1974), give little indication of the Munadgee U mineralisation. No secondary U minerals were observed in the heavy mineral concentrates, and scans of the concentrates with a scintillometer gave no response.

One sample, from about 1 km to the southwest of the prospect, showed anomalous values for Bi, Cu, Sn and W, but the U value was about average for the area. The source of this anomaly is not known.

Neither sieved sediments nor heavy mineral concentrates defined the known mineralisation adequately or unambiguously, even in close proximity to the exposed mineralisation. Sample spacings of less than 0.5 km for fine (–75 μm) sieved sediments would be necessary to have any chance of detecting mineralisation.

Discussion

Despite limitations imposed by restricted drainage, stream-sediment sampling is a useful geochemical exploration technique in the Davenport Province. Both sieved fractions

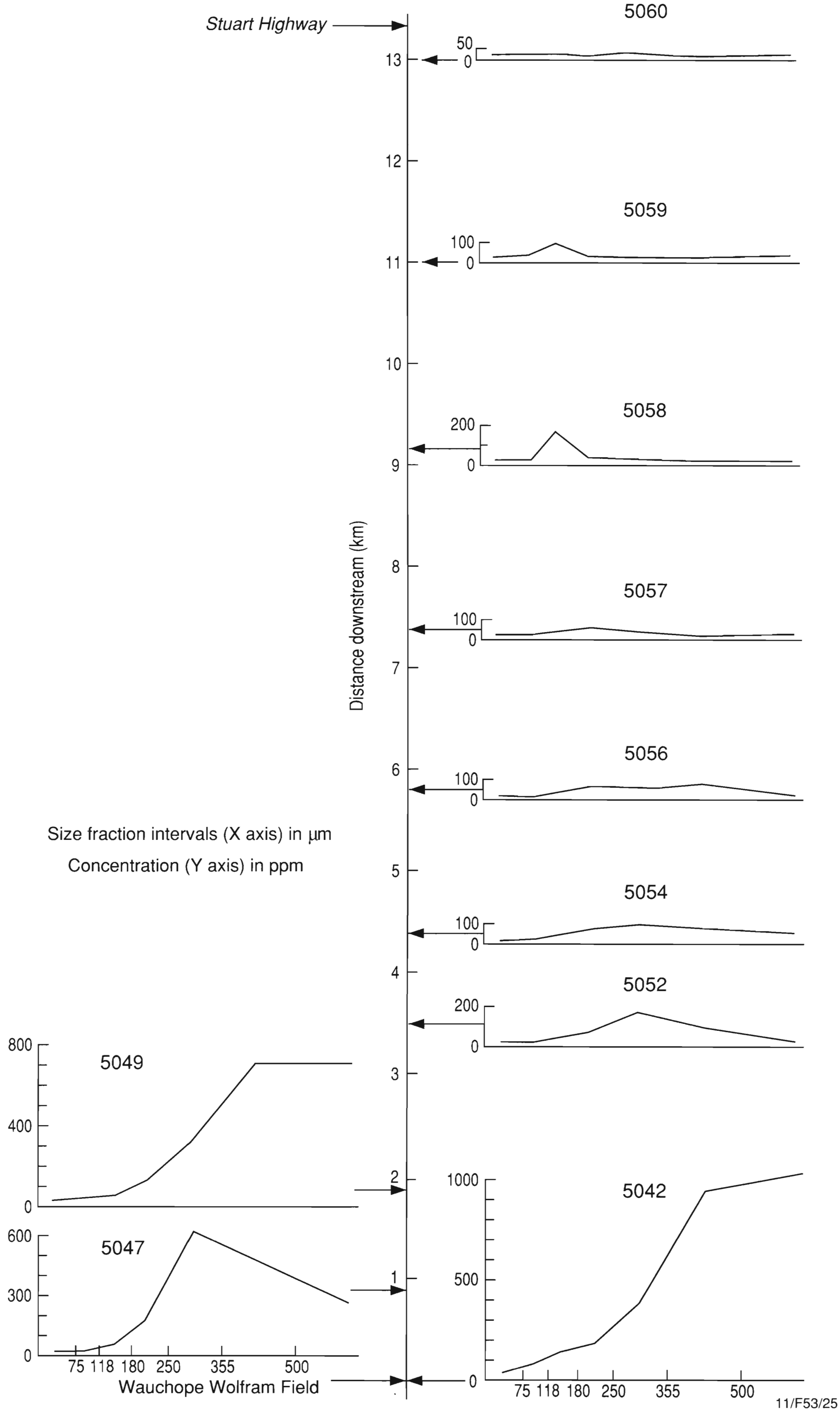

Figure 8. Longitudinal section showing the distribution of Sn in stream-sediment size fractions along Wauchope Creek. Arrows indicate approximate positions of samples downstream from the Wauchope Wolfram Field. Size fraction intervals (X-axis) in µm; concentration (Y-axis) in ppm.

Table 5. Summary of the stream-sediment geochemical survey, Davenport Province.

Styles of mineralisation	*Useful element associations*	*Optimum sieve fractions(μm)* Near source	Remote from	*Heavy mineral indicators (in order of frequency)*	*Application of heavy minerals*
(1) Wolframite/scheelite vein-type in sediment, or mixed sediment–volcanic/intrusive host	Cu, Bi, Mo, Sn, Be, Rb and Li	W –75, +180–500 Cu –75, +180–500 Bi +500 Mo +180–500 Sn +180–500 Li +180–500 Be +180 Rb +180	–75 (>13 km) –75 (1 km) –75 (3 km) +180–500 (>13 km) –75 (>13 km) –75 (3 km) –75 (>13 km)	Wolframite Malachite Cassiterite Topaz Schorl Dravite Scheelite Azurite Bismuthinite Molybdenite	Malachite and azurite readily identified by vivid green–blue colours: metallic lustre of the bismuth–molybdenum minerals assists rapid identification: cassiterite and topaz diagnostic of sediment host and, because of stability in secondary dispersion, are excellent indicators
(2) Scheelite vein, disseminated type, in granite host	Sn, U, Nb, and Bi	Sn +250–500 U –75 Nb –75 Bi +250–500		Scheelite Schorl Dravite Fluorapatite Topaz Wolframite Cassiterite (?)	Scheelite and fluorapatite readily identified by fluorescence under short wave length UV light
(3) Vein–type gold (Au) in sediment host	As (?)	As –75		Dravite (?) Schorl	Little application
(4) Vein–type gold (Au) in granophyre-sediment host	As(?)	As –75		–	

and heavy mineral concentrates should be considered.

Sieved fractions

Mechanical weathering processes appear dominant in the dispersion of W, Sn, Bi and Mo. This is indicated by the presence of W and Sn in the coarser of the sieved fractions in samples from near mineralisation and by their subsequent movement to the finer fractions during alluvial transport. Wolframite, scheelite and cassiterite are all relatively stable under the prevailing weathering conditions, but wolframite and scheelite are very brittle due to their perfect cleavage. Cassiterite is more resistant than the W minerals; hence Sn is less prominant in the finer fractions than W. Grains of wolframite in heavy mineral concentrates frequently show little evidence of rounding or solution. Tungsten and Sn have dispersion trains which persisted for more than 13 km down Wauchope Creek (Fig. 5), although the lengths of the trains were no doubt enhanced by the mining activity upstream. Bismuth and Mo appear to remain in the coarser fractions, possibly because their major minerals (bismuthinite and molybdenite) are ductile and hence not easily pulverised during transport, although they are relatively unstable in the weathering environment and may be oxidised releasing soluble Bi and Mo species. In the Davenport Province, stream-sediment samples at 1 to 2 km spacings along a drainage system should detect the presence of the W-Sn-Bi-Mo mineralisation, especially if more than one size fraction (e.g. –75 μm and +250 –500 μm) was separated and analysed.

Chemical processes appear to be dominant in the dispersion of Cu and U, as shown by relatively low values for these elements in stream sediments close to mineralisation and by short dispersion trains. This is evident at the Copper Show Mine where stream-sediment Cu values are surprisingly low, and at the Munadgee Uranium Prospect where no U anomalies were clearly defined, even adjacent to exposed mineralisation. These elements are probably taken into solution during weathering and flushed out of the stream sediment during the wet season. This effect would be compounded by the relative paucity in the sediments of finely divided clay material, organic matter, and hydrated oxides of Fe and Mn which otherwise might concentrate these elements by either adsorption or coprecipitation as in more tropical climates (Rossiter, 1975). Relatively high, but not anomalous, levels of Cu and U are found in many streams draining mafic volcanics and granites, respectively. Since Cu and U levels associated with mineralisation are only slightly anomalous, this factor tends to complicate delineation of anomalies. Hence, Cu and U anomalies are more difficult to detect than W or Sn anomalies, and their detection requires denser sample spacings of 0.5 to 1 km, or less.

Pathfinder elements are limited to Be, Li and Rb for W and Sn mineralisation and possibly As for Au mineralisation, especially for sulphide-bearing lodes.

A summary of the stream-sediment geochemistry is given in Table 5.

Heavy mineral concentrates

Heavy mineral concentrates are a valuable tool for defining W, Sn and Cu mineralisation in the Davenport Province (Hoatson & Cruikshank, 1985). The observed distribution of heavy minerals of economic importance is summarised in Table 4, together with that of a number of heavy minerals of indirect economic importance, namely topaz, two varieties of tourmaline and fluorapatite. Heavy minerals associated with each style of mineralisation are summarised in Table 5, and descriptions of typical grains of these minerals are given in Table 6. Gold was not observed in any of the heavy mineral concentrates, including those from streams draining Au mines or prospects. Similarly, no secondary U minerals were found in concentrates from streams draining the Munadgee Prospect.

Table 6. Descriptions of heavy minerals found in concentrates from the Davenport region.

Mineral	*Description*
W minerals	
Wolframite	Grains generally brownish–black to black with brownish black streak and weakly magnetic. Grains from Hatches Creek commonly elongated (up to 3 mm in length) with a 'splintery' appearance. Grains from Wauchope have shorter and more prismatic, tabular habit. Small grains showed no evidence of rounding.
Scheelite	Forms small (generally less than 1 mm), irregularly shaped, honey-brown (volcanic hosts) to milky white (granitic hosts) grains with uneven fracture and vitreous lustre. Fluoresces blue-white and at Hatches Creek, yellowish blue (indicating a molybdic variety).
Cu minerals	
Malachite	Forms small (generally less than 1 mm) irregular, vivid green grains, easily seen under the microscope. Often with limonitic fragments.
Azurite	As for malachite except coloured blue.
Sn minerals	
Cassiterite	Grains prismatic in habit about 1 mm long; well shaped near the source, subrounded downstrean, indicating strong resistance to chemical and mechanical weathering. Colour ranges from almost colourless, through pinkish-red, reddish-brown and brownish-black to black. Some grains are colour zoned.
Bi and Mo minerals	
Bismuthinite	Rare, brittle platy grains found proximal to mineralisation.
Molybdenite	Rare, occurring as small (less than 1 mm), scaly plates which have burred, compressed margins due to abrasion during transport.
Minerals of indirect economic interest	
Tourmaline	Two types (schorl and dravite) noted. Schorl (Fe–rich) is invariably dark-brown to black and strongly pleochroic from reddish-brown to bluish-green (under polarising microscope). Dravite (Mg-rich) is clear to tan-brown and moderately pleochroic from yellow to brown. Grains near source are elongate, prismatic, have striated faces and are rarely terminated.
Topaz	Grains about 1 mm across; readily identified by coarse, blocky shape, frosted appearance and yellow, orange or red colour, or are colourless and glassy. Distinguished from ferruginised quartz by subhedral shape and coarser grain size.
Fluorapatite	Rare, readily identified by strong pale yellow to golden fluorescence, small irregular grains, usually transparent to milky white.

Conclusions

Stream-sediment sampling is an effective exploration technique for Au, Bi, Mo, Sn and W mineralisation in the Davenport Province, less effective for Cu mineralisation, and ineffective for U mineralisation.

For Bi, Mo, Sn and W, parallel analysis of the +180 –500 µm and –75 µm sieved fractions would be most informative, but would double the cost of any sampling and analytical program. On balance, the coarser (+180 –500 µm) sieved fraction at a spacing of one sample every 1 to 2 km of stream run is preferred. These elements appear to be dispersed by mechanical processes and enter the sediment in the coarser fractions but, with the exception of Sn, concentrate in finer fractions at distance from the source (Table 5). Prospective areas may be defined by Be, Li and Rb highs, indicating the possible presence of pegmatitic or fractionated granites.

While visual examination of heavy mineral concentrates is also a very effective technique, it is considered to be less cost effective than analysis of sieved fractions due to the level of skill necessary to identify the W and Sn minerals and the general labour intensiveness of the technique.

Stream-sediment sampling is less effective for Cu and U, which appear to be dispersed by chemical processes. For Cu, the fine (–75 µm) sieved fraction is preferred at a close spacing of one sample per 0.5 to 1 km, or less, of stream run. The vividly coloured secondary Cu minerals are easily identified in heavy mineral concentrates and this technique may be cost effective, if only to confirm sieved fraction anomalies. Uranium mineralisation could not be definitely defined by either sieved fractions or heavy mineral concentrates.

Free gold was not found in any of the heavy mineral concentrates, but was detected by optical emission spectrographic analysis of concentrates. Although not carried out in this study, it is considered that bulk cyanide leach followed by a sensitive analytical technique, such as either graphite furnace atomic absorption spectrophotometry (GF–AAS) or inductively coupled plasma-mass spectrometry (ICP–MS), would be highly effective for samples from the province. Arsenic is a pathfinder for gold/sulphide mineralisation.

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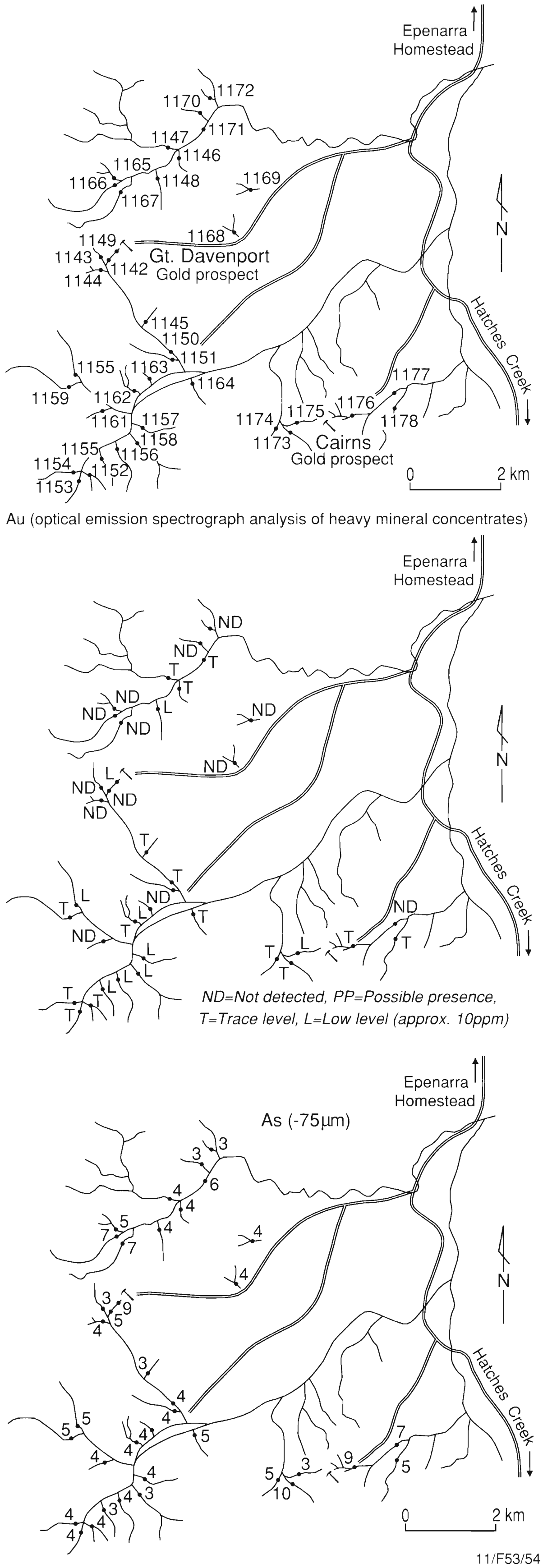

Figure 9. (a) Location of mines and sample sites in the Great Davenport area. (b & c) Values for Au and As, respectively.

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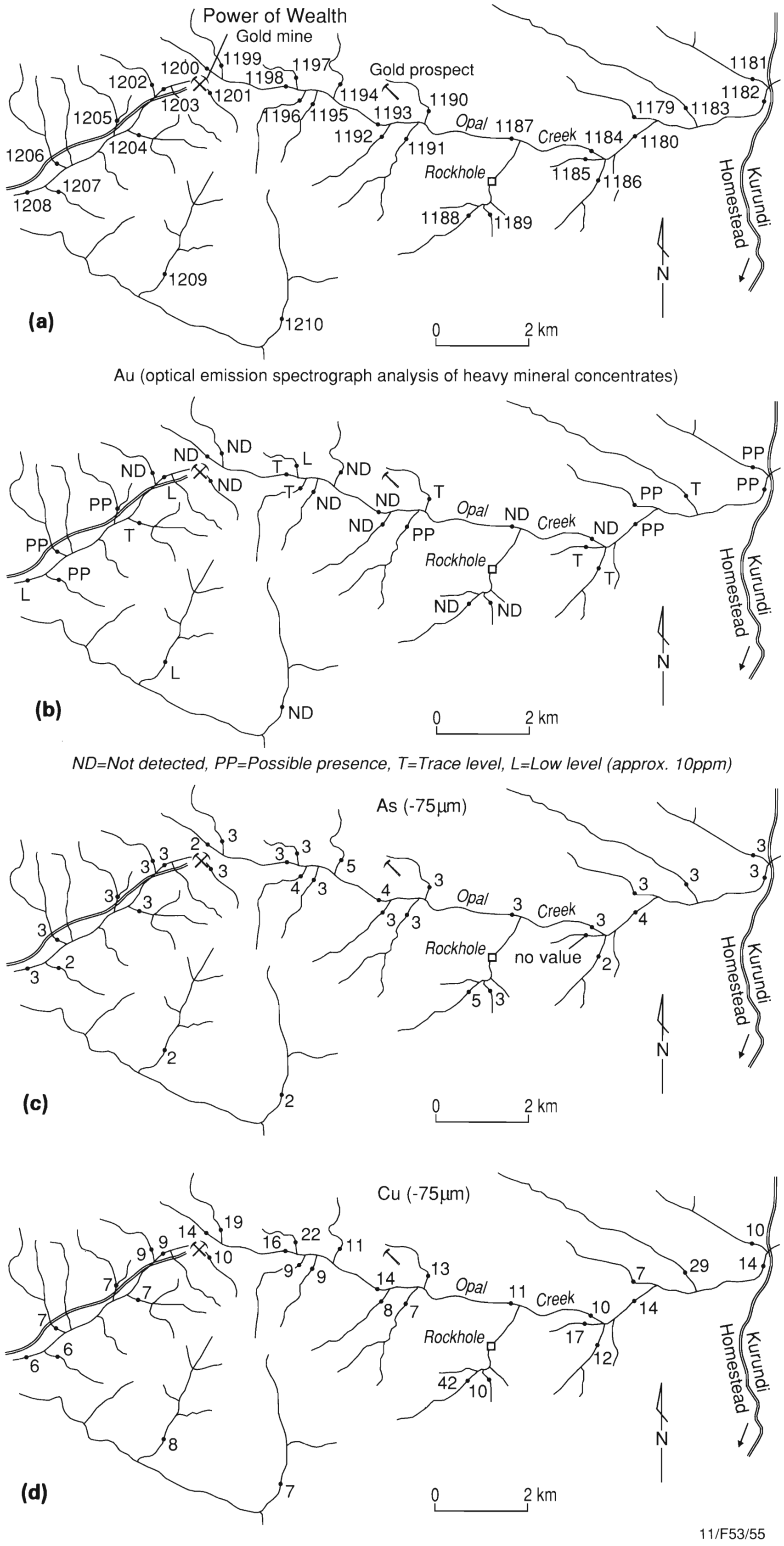

Figure 10. (a) Location of mines and sample sites in the Power of Wealth Mine area. (b-d) Values for Au, As and Cu, respectively.

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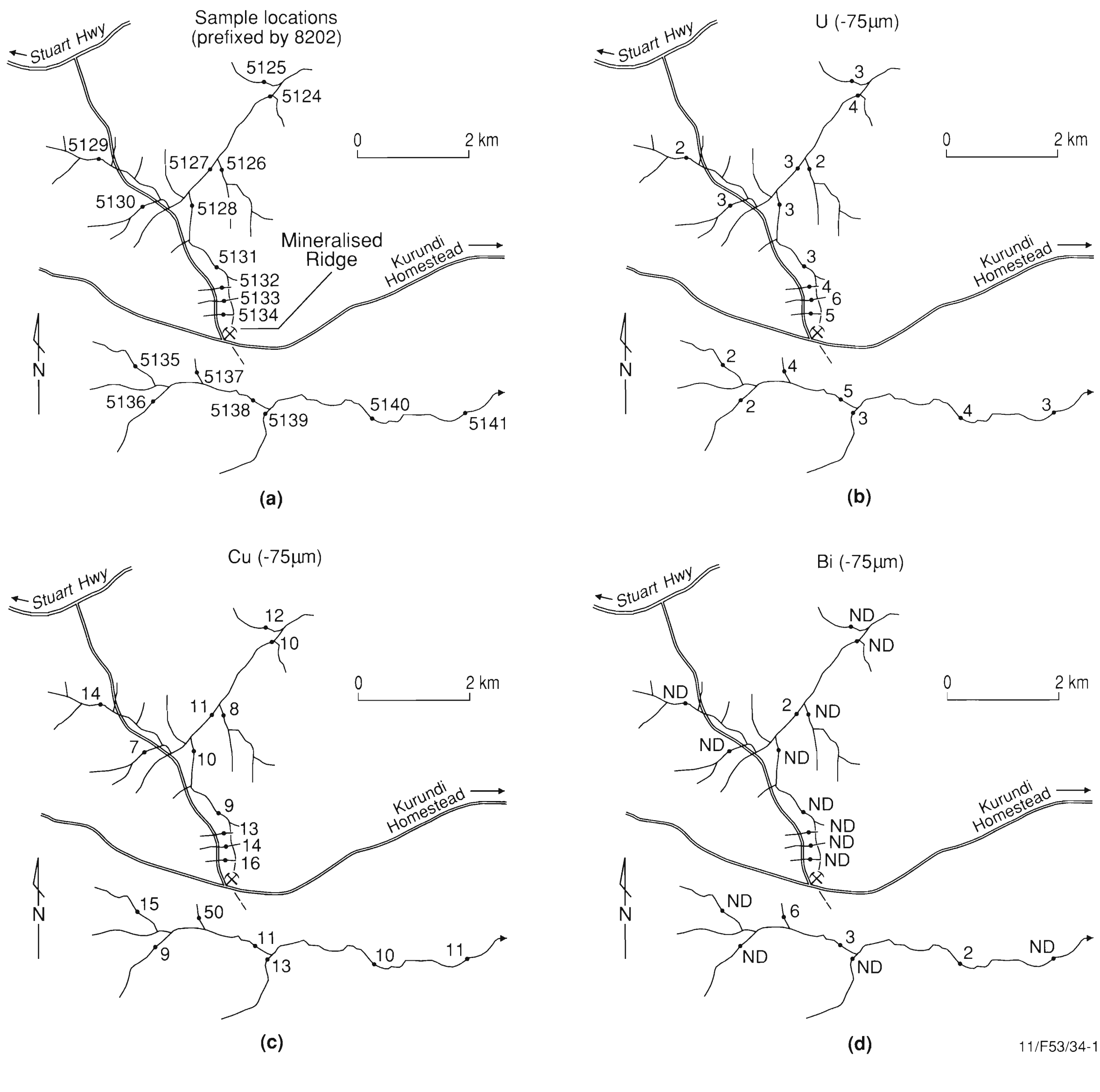

Figure 11. (a) Location of prospect and sample sites in the Munadgee Uranium Prospect area. (b-d) Values for U, Cu and Bi, respectively.