BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

Record 1980/39

STREAM-SEDIMENT GEOCHEMISTRY OF THE SEIGAL AND HEDLEYS CREEK 1:100 000 SHEET AREAS, NORTHERN AUSTRALIA

by

A.G. Rossiter & P.A. Scott

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ABSTRACT

A regional stream-sediment survey of the Seigal and Hedleys Creek 1:100 000 Sheet areas was undertaken during 1975 to delineate broad areas where subsequent detailed exploration should be concentrated and to establish a sound geochemical framework on which to base any future work.

In the Seigal Sheet area a total of 1534 minus-180 µm samples were collected at a density of about 1 per 2 km^2, and analysed for arsenic,barium, beryllium, bismuth, cerium, chromium, cobalt, copper, fluorine, iron, lead, lithium, manganese, molybdenum, nickel, niobium, rubidium, sulphur, thorium, tin, titanium, tungsten, uranium, yttrium, and zinc. In the Hedleys Creek Sheet area 974 samples were collected at a density of 1 per 3 km^2, and analysed for all the above elements except barium, fluorine, sulphur, and titanium.

The results of the survey are presented as a series of 11 computer-drafted maps which are available from BMR. The maps incorporate the following combinations of elements: uranium, cerium, thorium (2 maps); uranium, copper, tin (2); uranium, arsenic, bismuth (2); nickel, copper, zinc (2); lead, arsenic, zinc (2); tungsten, beryllium, niobium (1).

It appears that the area's greatest economic potential lies in the possibility of uranium deposits. These appear to include epigenetic mineralisation associated with Nicholson Granite Complex rocks (there is evidence that large low-grade deposits may be present), deposits of unknown type related to a mafic dyke which extends for the full width of the Seigal Sheet area, and secondary mineralisation within the Westmoreland Conglomerate. Copper, tin, tungsten, and beryllium deposits associated with the Cliffdale Volcanics and the Nicholson Granite Complex are also a possibility. Lead, zinc, and, to a lesser degree, copper are enriched within the Lawn Hill Platform sequence, while minor concentrations of the last occur in the McArthur Basin sequence.

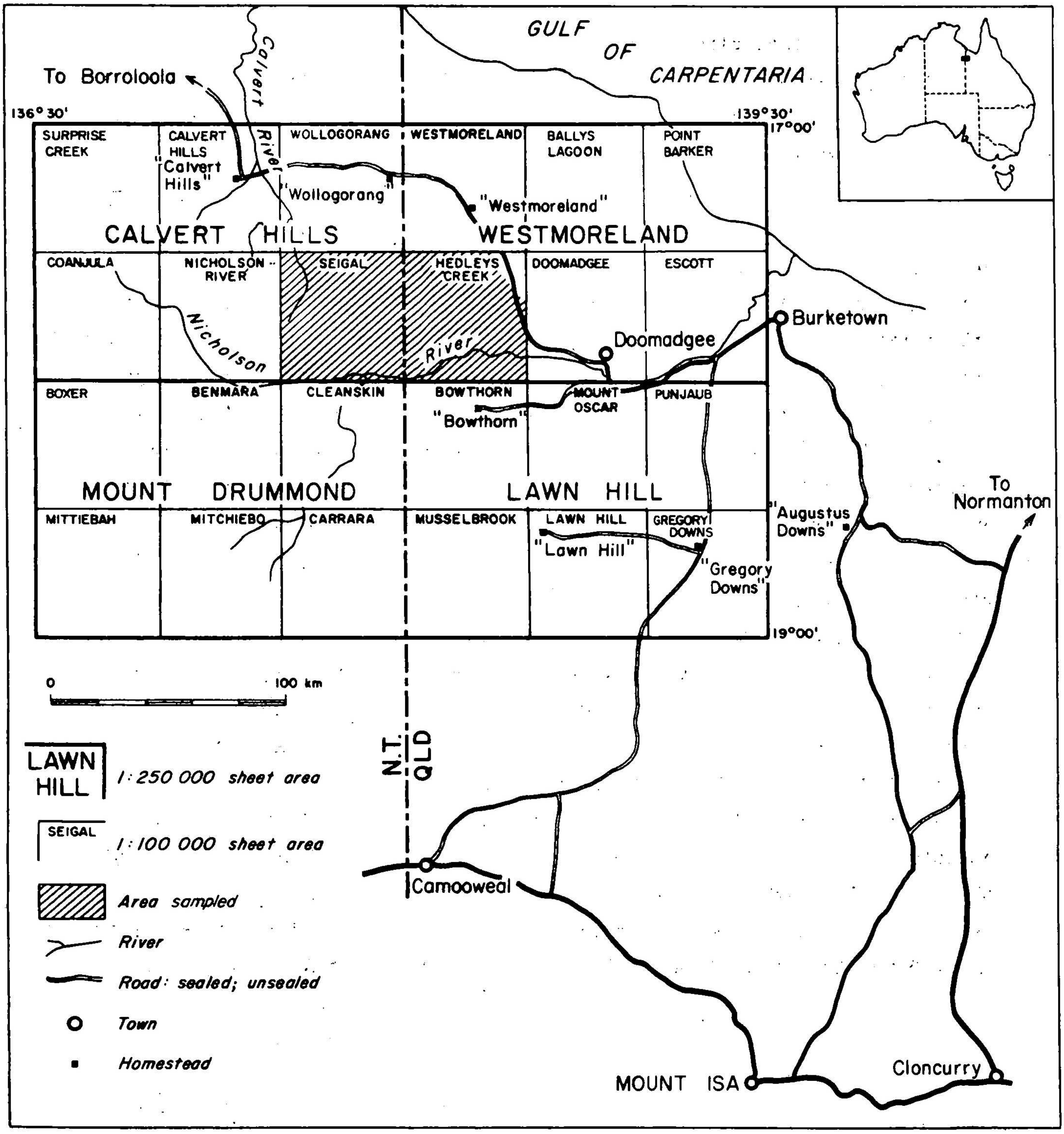

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Fig. 1: Location and access map

INTRODUCTION

Area of investigation

The Seigal and Hedleys Creek 1:100 000 Sheets cover a combined area of about 6000 km^2 bounded by latitudes $17^o30'$ and 18^oS and longitudes $137^o30'$ and $138^o30'E$ (Fig. 1). The Queensland - Northern Territory border forms the boundary between the two.

The Seigal Sheet area consists entirely of Crown Land, while the Hedleys Creek Sheet area incorporates parts of the Bowthorn, Lawn Hill, and Westmoreland pastoral leases. Both Sheet areas are virtually uninhabited; Doomadgee Mission, with a population of about 600, is the nearest settlement.

The main access to the area is by a rough track from Doomadgee Mission, which in turn is linked to Mount Isa by good, mainly dirt, roads (Fig. 1).

Object of investigation

In 1972 the Bureau of Mineral Resources (BMR) and the Geological Survey of Queensland (GSQ) began work in the Seigal/Hedleys Creek area as part of a continuing program of investigation, at 1:100 000 scale, of regions of economic potential in northern Australia. Geological, geophysical, and geochemical data are being collected so that a better understanding of the distribution, controls, and surface expression of the mineral deposits of the various regions will facilitate future mineral exploration.

Geological mapping of the Seigal and Hedleys Creek 1:100 000 Sheet areas was undertaken during 1972-73, and airborne magnetic and radiometric surveys made of the latter during 1973 (Tucker, in prep.). Orientation geochemical studies in 1972-73 (Rossiter, 1976) were a forerunner to the regional stream-sediment survey of the two Sheet areas during 1975. The stream-sediment coverage was designed to detect most major near-surface mineralisation and to delineate broad areas where future detailed exploration should be concentrated.

Climate and vegetation

The study area has a semi-arid to subhumid tropical climate. The annual average rainfall is about 600 mm; rain is almost entirely confined to the period November to April. Temperatures are moderate to high all year, with an average daily maximum of about 32°C.

The area is coverd by a savannah woodland dominated by small eucalyptus such as Snappy gum (Eucalyptus brevifolia). Large trees are found only adjacent to watercourses, and include paperbarks (Melaleuca spp.) and ghost gums (Eucalyptus papuana). Ground cover consists of spinifex (Triodia spp.) and various grasses. Virtually no land has been cleared or cultivated.

Relief and drainage

The elevation of the area ranges from about 60 m to some 300 m above sea level. The physiography is controlled largely by the differential rates of erosion of the various rock types. The most prominent feature is the China Wall, which consists of a series of strike ridges of resistant Precambrian conglomerate and sandstone. The 'wall' extends from the headwaters of the Nicholson River for over 100 km in an east-northeasterly direction to near Westmoreland homestead. It varies from 3 to 10 km in width and in most parts is bounded to the south by a steep escarpment about 130 m high. Flat-lying sandstone remnants of both Precambrian and Mesozoic age also form positive features. The topography is more subdued in areas underlain by Precambrian volcanic units, although rugged hills occur locally. Precambrian granites and pelitic and calcareous sedimentary/metamorphic rocks generally form lowlands. Towards the east the Cainozoic-Recent plains slope gently to the sea.

The study area lies mainly within the watershed of the Nicholson River. Drainage is well developed on all rock types. It is generally dendritic, although sometimes pronounced trends parallel the regional east-northeast strike of the country rocks. In the higher areas streams are youthful, and gorges and waterfalls are common; on the lowlands drainage is more mature. In the eastern part of Hedleys Creek Sheet area many streams divide into a number of distributaries as they leave the uplands - the drainage channels become progressively less distinct out onto the alluvial plain, and some disappear altogether.

Previous geochemical investigations

Mining companies have used geochemical sampling only sparingly in the Seigal/Hedleys Creek area. The most comprehensive stream-sediment and soil surveys for which details are available were carried out by Carpentaria Exploration Company and Westmoreland Minerals in the southwestern part of the Hedleys Creek Sheet area - base metals were the target. A few companies, including Queensland Mines and Mineral Deposits, have used geochemical techniques in the search for uranium, but none reports encouraging results.

GEOLOGY

The geological features of the Seigal/Hedleys Creek area have been discussed by Firman (1959), Carter (1959), Carter & others (1961), and Roberts & others (1963). The results of more recent geological mapping are described by Sweet & Slater (1975), Mitchell (1976), and Gardner (1978).

The Precambrian rocks of the area form part of the Australian Shield. Four major tectonic units are represented - the Murphy Tectonic Ridge, the McArthur Basin, the Lawn Hill Platform, and the South Nicholson Basin (Fig. 2).

The Murphy Tectonic Ridge is a narrow east-northeast-trending belt of Early and Middle Proterozoic igneous and metamorphic rocks. The oldest outcrops are schist and gneiss of the Murphy Metamorphics (Fig. 3). Unconformably overlying these are the Cliffdale Volcanics, which consist of rhyolitic to dacitic ignimbrites, lavas, and tuffs. The earlier workers in the area distinguished the Nicholson Granite, which they considered older than the Cliffdale Volcanics, from the Norris Granite, which intrudes the volcanics. Recent work has indicated, however, that the two granites are very similar chemically and that their age difference is rather small. Consequently, Gardner (1978) has abandoned the term Norris Granite and described all the granitic rocks of the area as phases of the Nicholson Granite Complex.

The Murphy Tectonic Ridge is flanked to the north by the McArthur Basin, which contains rocks of the Middle Proterozoic Tawallah Group. The sequence begins with the Westmoreland Conglomerate resting unconformably on the older rocks. The conglomerates and sandstones pass up into mafic volcanics (Seigal Volcanics), which are in turn overlain by a number of predominantly sedimentary formations (McDermott Formation, Sly Creek Sandstone, Aquarium Formation, and Settlement Creek Volcanics).

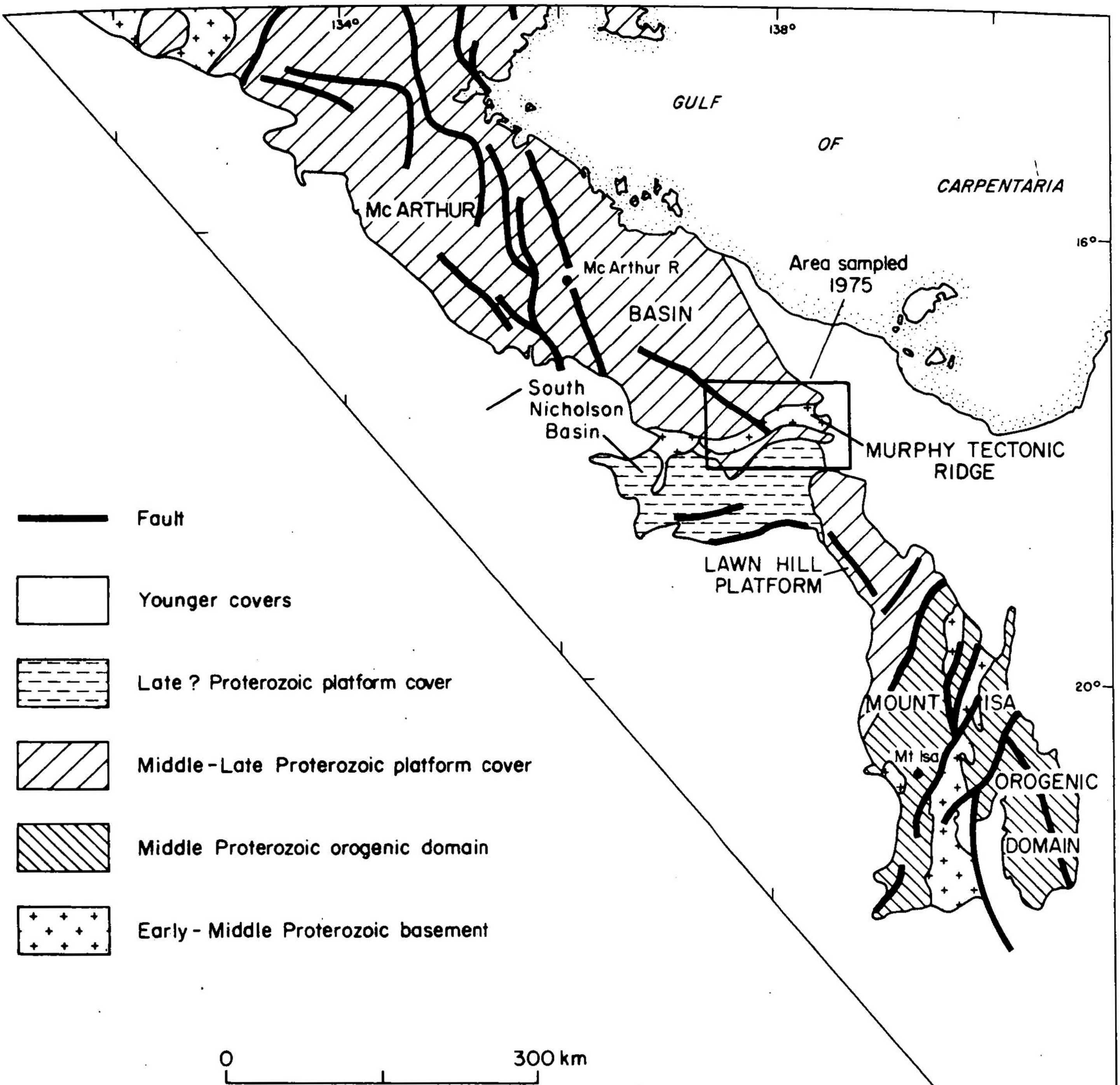

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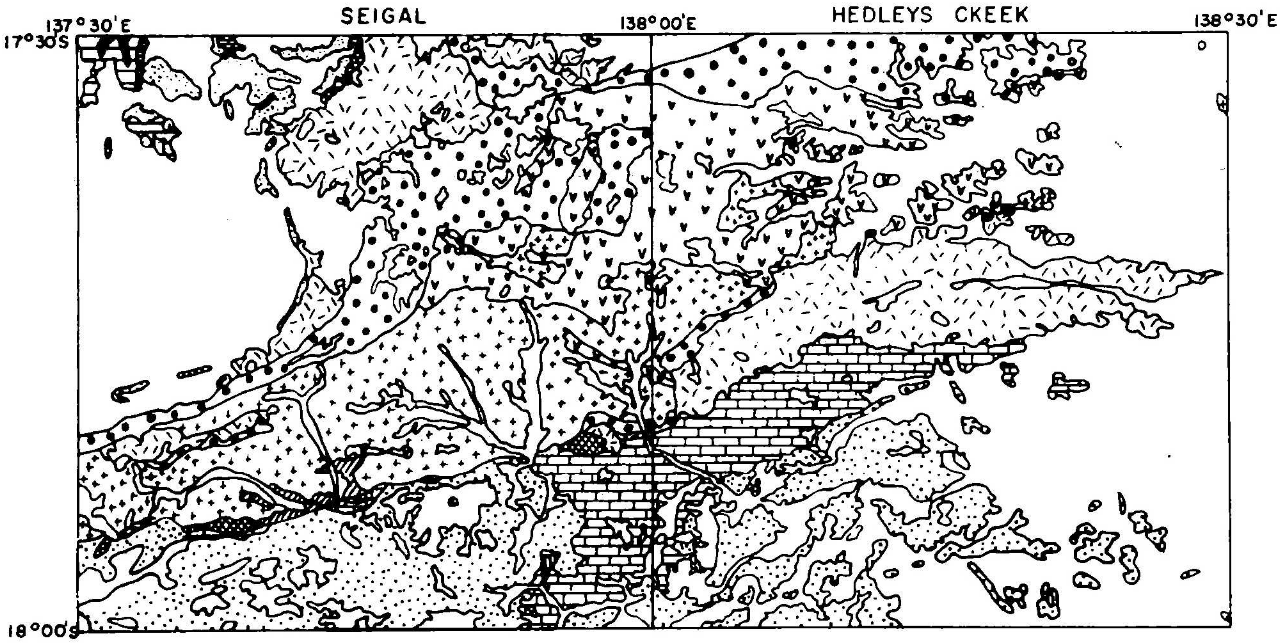
Fig. 2 Regional Tectonic Setting



PALAEOZOIC – RECENT

- *Sandstone, conglomerate alluvium, colluvium*

LATE ? PROTEROZOIC

South Nicholson Group

- Constance Sandstone — *Sandstone, siltstone, conglomerate*

MIDDLE PROTEROZOIC

Fickling Group
- *Dolomite, dolomitic sandstones and siltstones*
- Fish River Formation — *Sandstone, siltstone, conglomerate*

Tawallah Group
- Settlement Creek Volcanics — *Basalt, siltstone, tuff*
- Aquarium Formation — *Sandstone, siltstone*
- Sly Creek Sandstone — *Sandstone*
- McDermott Formation — *Dolomite, dolomitic sandstones and siltstones*
- Seigal/Peters Creek Volcanics — *Basalt, rhyolite, tuff, sandstone, siltstone*
- Westmoreland Conglomerate, Wire Creek Sandstone — *Conglomerate, sandstone*

- Nicholson Granite Complex — *Granite, adamellite*
- Cliffdale Volcanics — *Ignimbritic rhyolite, dacite, tuff*

EARLY PROTEROZOIC

- Murphy Metamorphics — *Gneiss, schist*

0 5 10 15 20 km

Geology by Roberts and others 1957 — 1961 and Sweet and others 1972 — 1973

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Fig. 3 Geology of the Seigal and Hedleys Creek 1:100 000 Sheet areas

To the south of the Murphy Tectonic Ridge on the Lawn Hill Platform the sequence is similar, although the volcanic component tends to be more conspicuous relative to the sedimentary one and salic Volcanics are more common. Sweet & Slater (1975) have made correlations between the Wire Creek Sandstone and the Westmoreland Conglomerate, and between the lower part of the Peters Creek Volcanics and the Seigal Volcanics. The Peters Creek Volcanics are overlain unconformably by sandstone of the Fish River Formation, the basal unit of the Fickling Group. The remainder of the Fickling Group comprises the Walford Dolomite, the Mount Les Siltstone, and the Doomadgee Formation.

In the south of the study area the rocks of the South Nicholson Basin unconformably overlie those of the Lawn Hill Platform. The South Nicholson Group consists mainly of sandstone and siltstone of possible Late Proterozoic age - the most important unit is the Constance Sandstone.

MINERAL DEPOSITS

The known mineral deposits of the Seigal/Hedleys Creek area may be conveniently discussed in terms of the following five metallogenic zones (Fig. 4):

Zone IA : Uranium and copper deposits within Seigal Volcanics in the northeastern part of the Seigal Sheet area.

Zone IB : Uranium deposits within Westmoreland Conglomerate in the northwestern part of the Hedleys Creek Sheet area. These are usually associated with mafic dykes intruding the 'conglomerate'.

Zone IIA : Uranium, copper, and tin deposits occurring in association with Cliffdale Volcanics and Nicholson Granite Complex rocks in the Pandanus Creek district of the Seigal Sheet area.

Zone IIB : Copper and tin deposits of similar type to those of Zone IIA situated about 30 km east of Pandanus Creek in the Hedleys Creek Sheet area.

Zone III : Lead-zinc deposits within dolomitic rocks of the Fickling Group in the southwestern corner of the Hedleys Creek Sheet area.

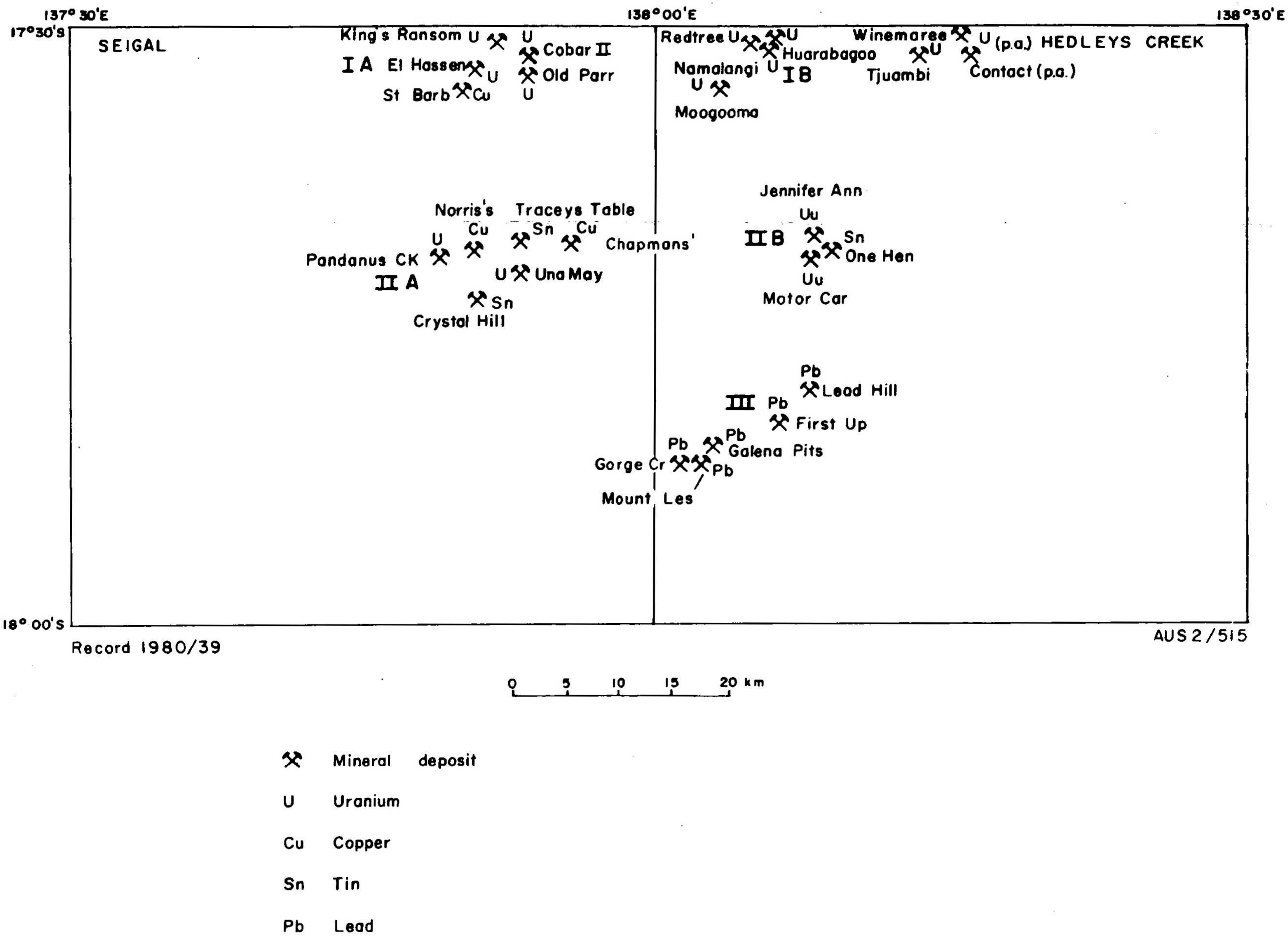

Fig. 4 Mineral deposits of the Seigal and Hedleys Creek 1:100,000 Sheet areas

Zone IA

The Cobar II, Old Parr, King's Ransom, and El Hussen deposits occur in shears and faults cutting basalt of the Seigal Volcanics. The mineralisation often lies close to the contact of the volcanics with the underlying Westmoreland Conglomerate. Sweet & Slater (1975) suggest that the uranium may originally have been deposited at this contact and has since been mobilised and enriched by minor deformations. The ore minerals comprise uraninite, carnotite, saleeite, and sklodowskite (McAndrew & Edwards, 1957; McAndrew, 1958). Northern Australian Uranium Corporation tested the prospects by costeaning, drilling, and tunnelling, but tonnages proved to be small. Cobar II, the only deposit to be worked, produced 73 tonnes of hand-picked ore averaging 10.52 percent U_3O_8 (Stewart, 1965).

Several copper prospects occur in Seigal Volcanics about 8 km southwest of the Cobar II mine (Newton & McGrath, 1958). Malachite and azurite are associated with faults and dykes cutting the volcanics (Sweet & Slater, 1975). The prospects have been tested by short drives and costeans, but do not appear to contain significant quantities of ore.

Zone IB

Several uranium prospects occur within Westmoreland Conglomerate in the northwestern corner of the Hedleys Creek Sheet area. The largest of these is the Westmoreland (Namalangi-Huarabagoo-Redtree) deposit, which has been extensively tested by Queensland Mines and Mount Isa Mines. Here the mineralisation is associated with an altered mafic dyke intruding the 'conglomerate' along a northeast-trending fracture (Hills & Thakur, 1975). The dyke contains some mineralisation but the main reserves occur as thin tabular bodies in the 'conglomerate' on either side of the dyke. The nearly horizontal attitude of the orebodies and their shape suggests that the uranium may have been precipitated at an old watertable level. The ore minerals include uraninite, brannerite, carnotite, and metatorbernite. Queensland Mines have announced probable reserves of 4745 tonnes of U_3O_8 in ore with an average grade of 0.17 percent, and possible reserves of 5650 tonnes of U_3O_8 in material averaging 0.25 percent (Queensland Mines Quarterly Report of the Sydney Stock

Exchange, March 31st, 1979). About half of the latter occurs at the newly-discovered Janugunna prospect, which lies to the north of Hedleys Creek Sheet area. No reserve estimate for Mount Isa Mines' Redtree leases has been announced.

The uranium mineralisation at the Tjuambi prospect is also associated with a northeast-trending mafic dyke, and the Moogooma prospect lies within a kilometre of a similar structure (J. Clavarino, personal communication). No details are known of mineralisation on Queensland Mines' Contact and Winemaree leases.

Zone IIA

A group of deposits containing uranium, copper, and tin in varying amounts occurs in the Pandanus Creek district of the Seigal Sheet area. These include the Pandanus Creek uranium deposit, Norris's copper deposit, and the Crystal Hill tin deposit.

The Pandanus Creek uranium deposit has been discussed by Morgan (1965). The mineralisation occurs in a greisenised zone within dacite of the Cliffdale Volcanics. The ore fluids were probably related to rocks of the Nicholson Granite Complex, which crop out about 1 km to the north and have been intersected in holes drilled into the deposit. The main mineralised zone is about 50 m long and 10 m wide, and the ore appears to have been localised by a series of near-vertical east-west shears. The ore minerals are predominantly silicates such as sklodowskite, boltwoodite, and beta-uranophane, apparently alteration products of uraninite, with some saleeite, autunite, and torbernite. Copper carbonates and gold also occur in the main ore zone, while cassiterite and wolframite are abundant to the north of it. The deposit was extensively tested by Broken Hill Proprietary during 1958-59, but no reserve estimates have ever been announced. Between 1960 and 1962, South Alligator Uranium mined 311 tonnes of ore containing 8.37 percent U_3O_8, and left a spoil dump which contains about 3000 tonnes of material averaging over 1 percent U_3O_8 (Morgan, 1965).

Norris's copper deposit occupies a small northwest-trending quartz vein branching from the main Calvert Fault. The country rock is granite of the Nicholson Granite Complex. Malachite is abundant in the upper levels of the deposit, while the primary zone consists of massive chalcopyrite, which is brecciated and altered along fractures. Minor uranium mineralisation occurs in the area as well, but tin appears to be absent. The lode is about 1 m wide and crops out discontinuously over a strike length of about 300 m. The deposit has been mined intermittently since 1954 on a small scale. The records of the Queensland Mines Department show that during 1968, when mining was most active, 310 tonnes of ore containing 19 percent copper were trucked to Mount Isa. Production registered with the Northern Territory Mines Department between 1972 and 1977 amounted to 143 tonnes of 14.4 percent ore.

The Crystal Hill tin deposit occurs in a micaceous pegmatoidal vein within granite of the Nicholson Granite Complex (Gardiner, 1978). The mineralisation consists of cassiterite, wolframite, cuprite, fluorite, and topaz. Uranium is also enriched in the area (Rossiter, 1976), but the mineralogy of this element is unknown. Small amounts of both lode and alluvial tin have been won, but, although Broken Hill Proprietary tested the deposit, no reserve figures are available. During 1975, small amounts of alluvial tin were being worked at Crystal Hill.

At an early stage of the present survey a large copper-uranium-tin anomaly was located in granitic rocks about 4 km southeast of Norris's copper mine. BMR has since carried out more detailed work in the area (Una May prospect) and extensive low-grade mineralisation, similar in many ways to the Pandanus Creek uranium deposit, is indicated (Rossiter, 1977).

At numerous other localities in the Pandanus Creek area traces of copper, uranium, tin, and tungsten occur in quartz veins and greisens, either within Nicholson Granite Complex rocks or close to the contact of these rocks with the Cliffdale Volcanics. The named prospects are shown in Figure 4. They are discussed in more detail by Roberts & others (1963), Mitchell (1976), and Gardner (1978).

Zone IIB

A cluster of deposits very similar to those discussed in the preceding section occurs about 30 km east of Pandanus Creek (Fig. 4). This second group is associated with a 6 km^2 zone of altered Nicholson Granite Complex rocks. A swarm of north-northwest-trending quartz veins intrudes the alteration zone, and Cliffdale Volcanics crop out nearby. Copper and tin prospects are known in this area. The largest of these is called Jennifer Ann and consists of malachite and azurite veins and coatings associated with quartz in a zone over 30 m long and 2 m wide (Gardner, 1978). Limonite and hematite form a patchy gossan and surface staining. Similar mineralisation occurs at the Motor Car prospect. At One Hen a series of 1 m wide quartz veins containing cassiterite cuts coarse-grained greisenised granite.

Zone III

In the southwestern corner of the Hedleys Creek Sheet area, syngenetic lead-zinc mineralisation occurs within silicified dolomitic rocks of the Fickling Group, usually towards the top of the Walford Dolomite. A comprehensive exploration program by Carpentaria Exploration Company located at least 20 occurrences (Taylor, 1970). The most significant of these are the Lead Hill, Mount Les, Gorge Creek, Galena Pits, and First Up prospects. The primary mineralisation consists of galena, sphalerite, pyrite, and minor chalcopyrite, while cerussite, pyromorphite, and some malachite occur in the oxidised parts of the deposits. The largest prospect is Mount Les where reserves are estimated at 1.5 million tonnes of 0.1 percent lead (Taylor, 1970).

SAMPLING AND ANALYTICAL METHODS

Sampling techniques

The only feasible way of sampling the Seigal and Hedleys Creek 1:100 000 Sheet areas, with the available resources, was to use a helicopter operating from a centrally-situated base camp in each Sheet area, and the program was planned accordingly.

Initially, sample points were plotted on 1:50 000 topographic maps. As the Seigal Sheet area was considered to have outstanding economic potential, the sample density used (1 sample/2km^2) was greater than normal for BMR surveys of this type. Particular attention was paid to the high-level phases of the Nicholson Granite Complex, and to the contact between the Westmoreland Conglomerate and the Seigal Volcanics, as most of the known mineralisation in the area was associated with one or other of these environments. The sample density over the eastern half of the Hedleys Creek Sheet was relatively low, as much of the area is covered by alluvium, drainage is poorly developed, and sampling was restricted to streams containing active sediment. An overall density of 1 sample/3 km^2 resulted for this Sheet area.

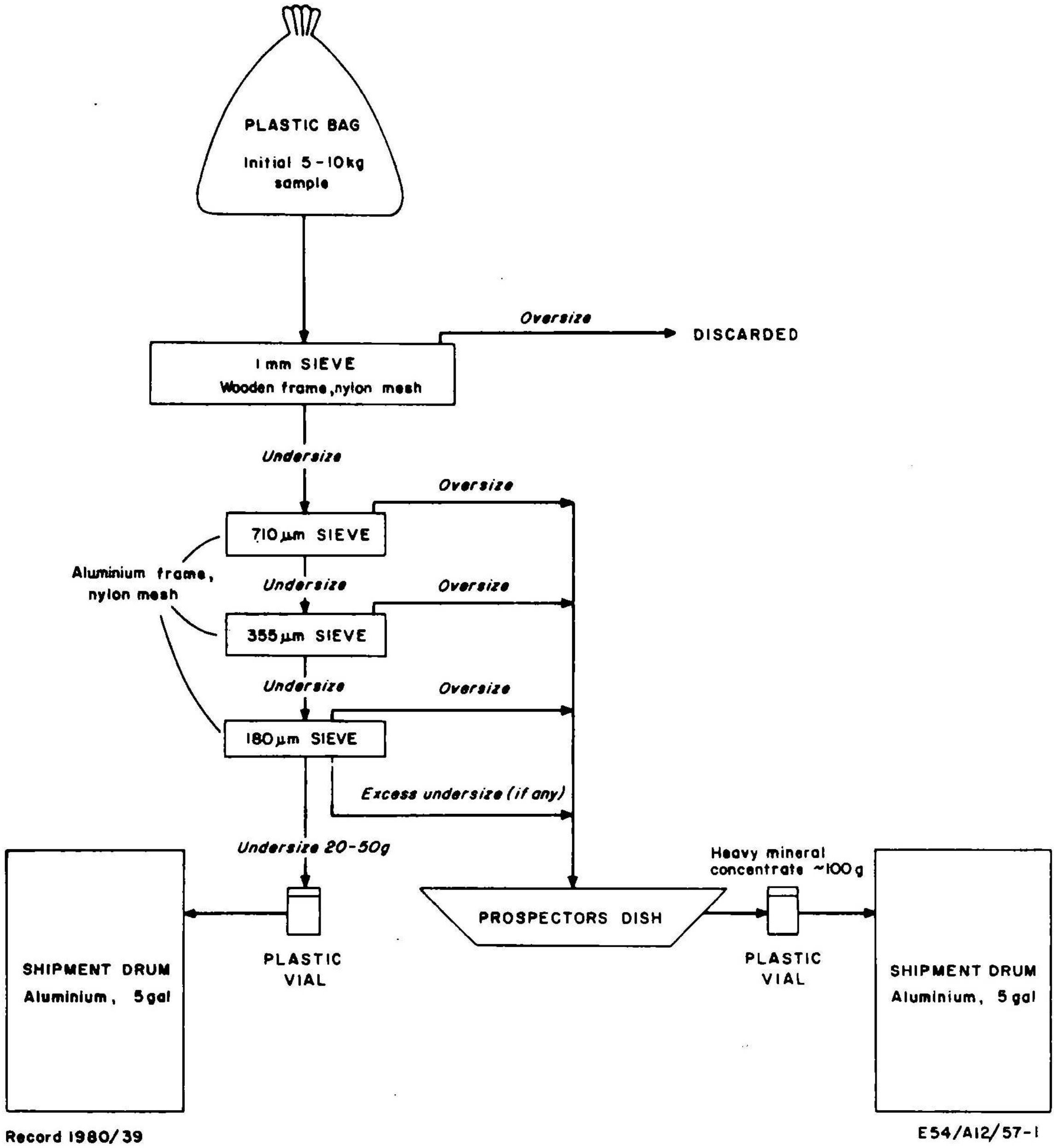

Fig.5 Sample preparation flowchart

Helicopter loops, each linking about 20 sample localities, were then designed. Where possible, loops remote from the selected camp-sites on Fish River and Hedleys Creek were planned with a lesser number of samples, to compensate for the extra weight of fuel that would need to be carried. For ease of navigation the intended path of the aircraft generally followed a major stream with landing sites at points where tributaries entered. Cross-country flights from one catchment area to another were avoided where possible. Once the helicopter loops had been finalised, the sample points were numbered sequentially.

The sample sites and numbers, and the helicopter flight lines were then transferred to overlays on 1:25 000-scale colour aerial photographs. For convenience, points belonging to different loops were plotted on different photos as far as was possible. Numbering of field data sheets and plastic sample bags completed the pre-field phase of the program.

The sampling was carried out during June-August 1975 with a Hughes 500 helicopter carrying a 3-man crew (pilot, geochemist/navigator, and field hand). At each locality the aircraft remained on the ground for 2-5 min while 1 or 2 samples, each weighing 5-10 kg, were taken. Eighty samples (4 loops) could be collected in a day, using a total of about 4 hr flying time and 4 hr idling time.

The helicopter invariably maintained vertical performance carrying 3 men, about 150 kg of samples and sufficient fuel for the return to camp, but it was found advantageous to complete loops in difficult terrain in the cool of the morning when aircraft capability was best. Normally there was little difficulty experienced in landing close to the predetermined sample site and fewer than 5 percent of points had to be moved closer to a clearing. Adequate geochemical coverage was maintained without resort to ground traverse.

At the base camp each sample was sieved and panned as detailed in Figure 5. The final products from each were 20-50 g of material sieved to minus- 180 μm (85 mesh BSS) - the optimum grainsize indicated by the 1972-3 orientation survey - and a heavy-mineral concentrate weighing about 100 g. The methodology and results of the heavy-mineral studies will be reported at a later date.

<u>Analytical techniques</u>

The sieved stream-sediment samples collected in the Seigal 1:100 000 Sheet area were analysed for beryllium, chromium, cobalt, copper, iron, lithium, manganese, nickel, and zinc by atomic absorption spectrophotometry and for arsenic, barium, bismuth, cerium, fluorine, lead, molybdenum, niobium, rubidium, sulphur, thorium, tin, titanium, tungsten, uranium, and yttrium by X-ray fluorescence spectrometry. As the results for barium, fluorine sulphur, and titanium showed very little of interest, these elements were omitted from the list when the Hedleys Creek samples were analysed.

Atomic absorption

A 1g portion of each minus-180 μm sample was mixed with 6 ml of perchloric acid (1:1 concentrated acid and water) and 10 ml of hydrofluoric acid (40% HF) in a platinum basin and heated on a waterbath until fuming. The basin was then transferred to a hot-plate and further heated until a 'dry' cake formed. 5 ml of hydrochloric acid (1:1) was added and the cake dissolved by gentle heating. After cooling the contents of the basin were transferred to a 25 ml volumetric flask and made up to volume.

The samples were analysed using a Varian AA6 spectrophotometer interfaced with a Hewlett-Packard 2100A minicomputer and a teletype. The instrumental conditions employed and the detection limits obtained are shown in Table 1.

Non-atomic absorption corrections were made for low concentrations of cobalt, nickel, and zinc, using a hydrogen-continuum lamp at the analytical wavelength. Construction of calibration curves from instrument responses to standard solutions and all subsequent calculations were performed by the computer.

X-ray fluorescence

All samples were ground for 10 min. in a Kurt-Retsch RMO grinder with an agate mortar and pestle. A 12 g portion of each was then pressed into a pellet using Mowiol as a binding agent.

The samples were analysed using a Philips PW1450 X-ray spectrometer fitted with a 60-position automatic sample changer. The operating conditions employed and the detection limits obtained are shown in Table 2.

The method outlined by Norrish & Chappell (1967) was used for converting count-rates to element concentrations. In the main, artificially prepared standards were used, but occasional checks were made against United States Geological Survey rock standards. The spectrometer automatically corrected for counter dead-time. Empirical interfering-element corrections were made for arsenic (corrected for lead interference), barium (cerium, titanium), bismuth (arsenic, lead) cerium (barium), thorium (bismuth, lead), uranium (rubidium), and yttrium (lead, rubidium, thorium). Large interference effects due to zirconium rendered the Seigal molybdenum determinations of dubious value, but the correction procedure was later modified and the molybdenum values for the Hedleys Creek samples are more reliable. Mass absorption coefficient corrections were of two types. For barium and cerium determinations an iron mass absorption coefficient calculated from the atomic absorption values for iron was used. For all other elements Compton tube line mass absorption measurements (corrected for yttrium interference) were used. Non-linear background corrections were made using 'spec' pure silica.

DATA PRESENTATION METHODS

Choice of presentation system

The reasons why the data presentation system currently used for the BMR's regional stream-sediment surveys was adopted have been discussed in detail elsewhere (Rossiter & Scott, 1978) and will only be briefly outlined here.

The data are presented in map form so as to be easily assimilable, and actual analytical values are shown so that users are free to carry out the interpretation procedures of their choice. Each map combines the results for 3 elements in order that comparisons between related elements are facilitated and a cumbersome number of maps is avoided. Each of the 3 variables is assigned a 120^{o} sector of a circular symbol and the portion of the segment coloured is proportional, via a class-interval graduation scheme, to the actual element concentration. A major advantage of this method as against other computer-based approaches, is that symbol positions can be manipulated to obviate overprinting. The number of class intervals is limited to 4 - a larger number would be difficult to absorb visually. The lowermost class is chosen so that, if possible, all background values for a particular element fall within it. The upper limit of the background class is not defined statistically, but is a figure tried and proven by practical experience in the survey area. Values occupying the three upper class intervals are termed slightly, moderately, and strongly anomalous in the following discussion.

Plotting techniques

Field and analytical data for all samples collected during the Seigal and Hedleys Creek 1:100 000 Sheet stream-sediment surveys are stored on the CSIRO CYBER 7000/7600 computer system as INFOL storage/retrieval files. These files take the form shown in Figure 6. The INFOL package allows new data to be added to the files and data already present to be modified or extracted according to various retrieval criteria. (The retrieval criteria can take many forms e.g. uranium content > 10 ppm and/or cerium content < 150 ppm, contamination = 0, catchment formation = wholly Seigal Volcanics etc.) Data extracted may be printed out in a variable format report (Fig. 7) or copied to another file for attaching to a post-processing program.

The first phase of the map production process for each Sheet area was the generation of 2 data files using the INFOL system - one comprising sample numbers in ascending numerical order and the other corresponding analytical data. All sample locations and the intended positions of the geochemical symbols were then digitised using a Gradicon digitising table interfaced with a Hewlett-Packard 2100A minicomputer. The maps used for digitising were National Mapping 1:100 000 topographic sheets printed on stable base film to minimise stretching/shrinkage problems.

The second phase utilised programs from the BMR Airborne Geophysics Reductions Group library (ARGUS). The sample numbers data file and the sample locations digitised file were merged to form a card image 'fixes' file, comprising sample numbers with their respective latitudes and longitudes. The analytical data file and the symbol locations digitised file were merged to create a random access data file of sample number, corresponding analytical data, and symbol latitudes and longitudes. The final phase consisted of using these 2 files and ARGUS programs to generate a map-plotting file. Figure 8 is a flow diagram depicting the main computer program systems used at the various stages in map production.

The map-plotting file was transferred to magnetic tape and test plotting runs made using a Calcomp 936 Drum Plotter. Sample point, symbol outline, analytical values, and coloured sectors for each group of 3 elements were combined on the one plot during testing. When all editing to eliminate problems such as symbol overlap was completed, a Calcomp 745 Flatbed Plotter was used for the final map drafting. Features of each map to be printed in different colours were scribed on 4 separate masks. The first of these comprised sample point, symbol outline, and analytical values - arrows linking the sample points

21

NAME | | | DATE | SHEET OF

INPUT FORMAT –

```
* 1 * Registered Number * 2 * Samp.Type * Mesh Size (µM) * * 3 * 1:1ØØ ØØØ Sheet Name * Air Photo Reference *
* 4 * Flow * Stream Width (m) * Order * Texture * Posn * * 5 * Relief * Banks * Veg. * Min. * Cont. * * 6 * Lithology * Formation *
* 7 * Cu * Zn * Pb * S * Ag * * 8 * Sn * W * Mo * Bi * Nb * Li * Be * Rb *
* 9 * U * As * F * Th * Ce * Y * Ba * * 1Ø * Mn * Co * Ni * Cr * Fe * . Ti * *
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CODES USED –

Sample Type

S C – sieved channel sample

B C – bulk channel sample

S B – sieved bank sample

H M – heavy mineral sample

Stream Flow

F – flowing

D – dry or with unconnected waterholes

Stream Bed Materials

B O U L – mainly boulders

G R A V – mainly gravel

S A N D – mainly sand

S I L T – mainly silt

Sample Position in Stream

S M – centre of straight section of stream

S E – edge of straight section of stream

B M – centre of stream on bend

B I – inside of bend in stream

B O – outside of land in stream

Relief of Surrounding Area

H – high (mountainous)

M – moderate (hilly)

L – low

Bank Type

A – alluvial

C – one or both banks colluvial

Vegetation

F – forest

G – natural grassland

C – cleared,cultivated

Signs of Mineralisation

Ø – no evidence

S – copper staining

G – gossan

Contamination

Ø – no evidence

U – urban or domestic

R – road

X – railway

A – agricultural

M – mining

Catchment Lithology

W – wholly

M – mainly

P – partly +

D O R T - diorite

G R D R - granodiorite

G R N T - granite

A D M L - adamellite

D L R T - dolerite

G R S N - greisen

B S L T - basalt

A N D S - andesite

R Y L T - rhyolite

Catchment Rock Formation

W – wholly

M – mainly

M U M M - Murphy Metamorphics

C D V C - Cliffdale Volcanics

N C G C - Nicholson Granite Complex

W M C G - Westmoreland Conglomerate

W C S S - Wire Creek Sandstone

S G V C - Seigal Volcanics

M D F M - McDermott Formation

S C S S S - Sly Creek Sandstone

A Q F M - Aquarium Formation

S C V C - Settlement Creek Volcanics

EXAMPLE –

```
* 1 * 7 5 7 6 Ø 2 3 6 * 2 * S C * 1 8 Ø * * 3 * S E I G A L * S L / 9 / 3 5 8 1 *
* 4 * F * 2 Ø * 1 * S I L T * S M * * 5 * M * A * F * Ø * Ø * * 6 * W B S L T * W S G V C *
* 7 * 6 3 * 8 3 * 1 Ø * 5 Ø 8 * - Ø * * 8 * 3 * Ø * 5 * Ø * 1 3 * 2 5 * 1 * 8 8 *
* 9 * 2 * 2 * Ø * 8 * 5 7 * 3 2 * 5 8 9 * * 1 0 * 1 1 4 0 * 2 Ø * 2 4 * 4 8 * 3 3 Ø Ø Ø * 1 0 2 Ø Ø * *
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Ø = not detected

– Ø = not determined

\+ Used when rock types of exceptional geochemistry (metadolerite, amphibolite or sandstone) are present

Record 1980/39

Fig. 6. INFOL input

E54/A12/58-1

REG'D NO:	7576ØØ13	7576ØØ14	7576ØØ17	7576ØØ21	7576ØØ23	7576ØØ24
SAMP.TYPE:	SC	SC	SC	SC	SC	SC
MESH SIZE:	18Ø	18Ø	18Ø	18Ø	18Ø	18Ø
SHEET:	SEIGAL	SEIGAL	SEIGAL	SEIGAL	SEIGAL	SEIGAL
AIR PHOTO:	SL/ 6/3125	SL/ 6/3125	SL/ 6/3125	SL/ 6/3127	SL/ 6/3127	SL/ 6/3127
LATITUDE:	17 42.862	17 43.086	17 42.61Ø	17 42.864	17 42.674	17 42.313
LONGITUDE:	137 52.847	137 52.469	137 52.367	137 51.651	137 51.583	137 53.284
FLOW:	D	D	D	D	D	D
WIDTH:	5	3	4	2	3	8
ORDER:	2	1	3	1	2	2
TEXTURE:	BOOL	BOUL	SAND	SAND	BOUL	BOUL
POSITION:	SM	SM	SM	SM	SM	BM
RELIEF:	M	M	M	M	M	M
BANK TYPE:	A	A	A	A	A	A
VEGETATION:	F	F	F	F	F	F
MINERAL'N:	Ø	Ø	Ø	Ø	Ø	Ø
CONTAM'N:	Ø	Ø	M	Ø	F	Ø
LITHOLOGY:	BANDS	MOUNT	PCLPT	MGRNT	PCLRT	BANDS
FORMATION:	MCDVC	MNLGC	MCDVC	MNLGC	MNLGC	MNLGC
CU:	26	28	28	21	28	43
ZN:	4Ø	56	33	22	35	31
PB:	21	22	36	43	33	33
S:	247	446	416	359	249	438
AG:	1	1	Ø	1	1	1
SN:	28	6	46	22	164	35
W:	1Ø	3	4	4	6	7
MO:	-Ø	-Ø	-Ø	-Ø	-Ø	-Ø
BI:	3	Ø	2	Ø	2	6
NB:	33	19	24	32	44	40
LI:	29	15	14	11	14	23
BE:	5	3	4	3	4	7
RB:	371	171	236	227	236	427
U:	1Ø	5	7	7	16	16
AS:	3	2	2	1	3	4
F:	Ø	Ø	Ø	Ø	Ø	Ø
TH:	49	16	37	45	67	49
CE:	145	93	184	126	128	116
Y:	135	27	43	53	65	47
BA:	77Ø	477	693	643	784	655
MN:	363	35Ø	36Ø	235	445	22Ø
CO:	8	11	9	11	11	8
NI:	7	24	18	7	8	4
CR:	57	113	36	25	43	28
FE:	29ØØØ	21ØØØ	22ØØØ	188ØØ	24ØØØ	15ØØØ
TI:	112ØØ	57ØØ	66ØØ	77ØØ	119ØØ	29ØØ

Figure 7 INFOL report

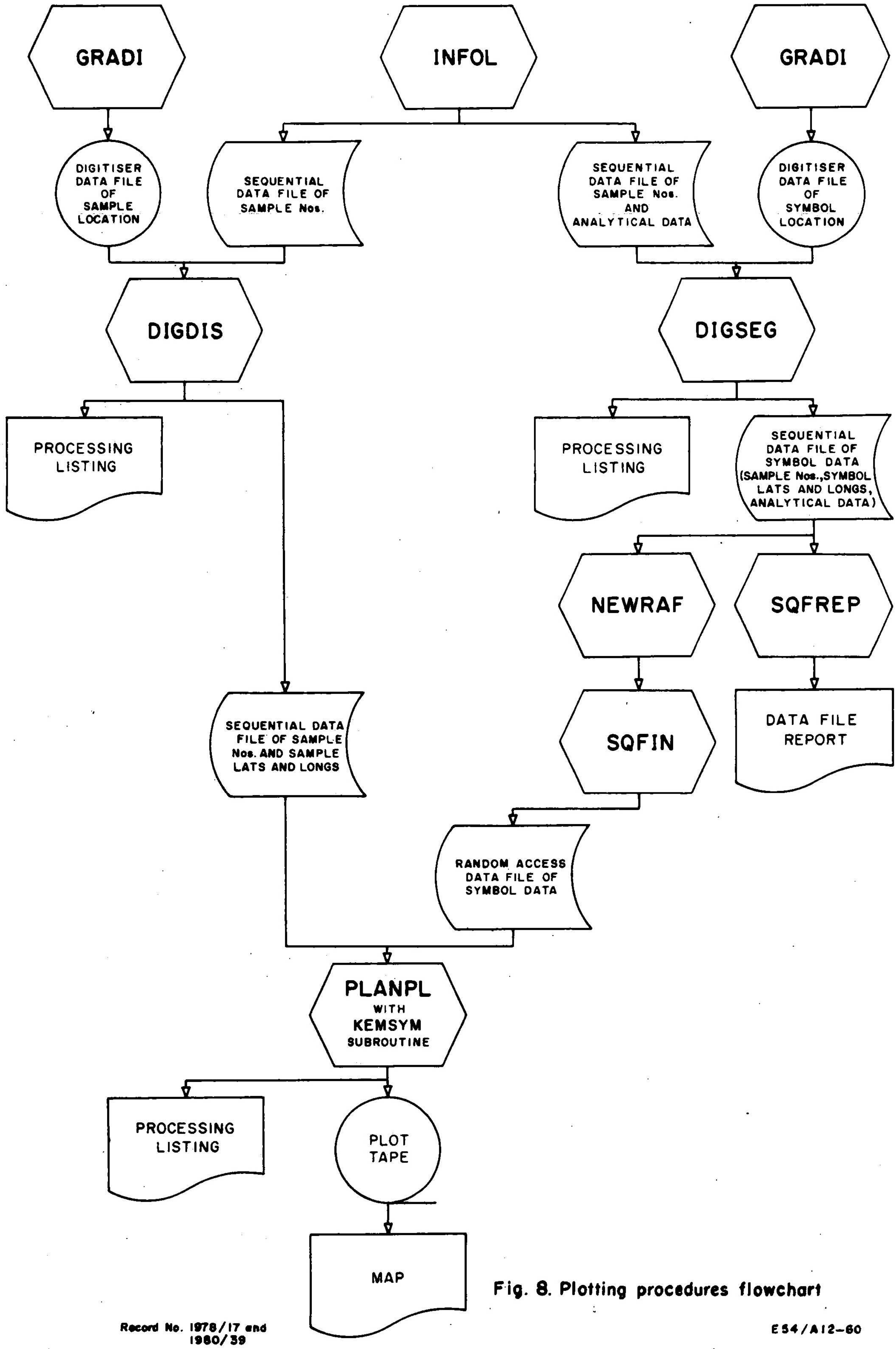

Fig. 8. Plotting procedures flowchart

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with the relevant symbols were added to this mask manually. The coloured sectors for one of each of the 3 elements were scribed onto the other 3 masks. The fifth mask used in printing each map was the relevant National Mapping 1:100 000 topographic base to which the positions and names of all the mines and prospects in the Sheet area had been added manually. Drafting of the map legends was also automated.

DISCUSSION OF RESULTS

All geochemical values of economic significance encountered during the Seigal and Hedleys Creek 1:100 000 stream-sediment surveys can be conveniently presented for discussion as a series of 12 maps incorporating the following combinations of elements.

Maps S1 and HC1 : Uranium, cerium, thorium

Maps S2 and HC2 : Uranium, copper, tin

Maps S3 and HC3 : Uranium, arsenic, bismuth

Maps S4 and HC4 : Nickel, copper, zinc

Maps S5 and HC5 : Lead, arsenic, zinc

Maps S6 and HC6 : Tungsten, beryllium, niobium

These maps are available from BMR, price $1.50 each.

The data for chromium, cobalt, fluorine, iron, lithium, manganese, molybdenum, rubidium, titanium, and yttrium were considered for presentation in map form, but were rejected for reasons given in the following sections. High barium and sulphur values were very rare and showed no relation whatsoever to mineralisation; the inclusion of these elements in the maps was not seriously contemplated therefore. Summary statistics for all the elements determined during the survey are shown in Tables 3 and 4.

Maps S1, HC1, S2, HC2, S3, and HC3 are designed primarily to assist in the search for uranium deposits, while the purpose of Maps S4, HC4, S5, and HC5 is to highlight zones favourable for the presence of copper and lead-zinc mineralisation. The Seigal/Hedleys Creek area also has potential for tin tungsten, and beryllium deposits and this possibility is covered by Maps S2, HC2, S6, and HC6.

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Uranium

Maps S1 and HC1 (Uranium, cerium, thorium)

High uranium values encountered during a stream-sediment survey do not necessarily indicate the presence of economically significant mineralisation. Detrital concentrations of uraniferous minerals such as monazite ((Ce, La, Y, Th) PO_4^{-}) are responsible for the majority of uranium anomalies in the Georgetown region of north Queensland (Rossiter & Scott. 1978) and this has proved to be the case in the Seigal/Hedleys Creek area as well. In particular the rocks of the Nicholson Granite Complex are very rich in such minerals. To distinguish high uranium levels caused by monazite from those which might indicate mineralisation, the abundances of other elements need to be considered. Samples enriched in uranium, but low in cerium and thorium, are less likely to contain monazite and therefore tend to be the most interesting from an economic viewpoint. Consequently the results for these 3 elements are combined in Maps S1 and HC1. Yttrium and tungsten were also considered as indicators of monazite-bearing rocks, but these elements proved to be less reliable than cerium and thorium, as they are more often enriched near mineralisation (e.g. Una May prospect).

The Seigal 1:100 000 Sheet area survey disclosed 32 anomalous uranium values not accompanied by high cerium and/or thorium (labelled S1-1 to S1-32 in Figure 9). Of these 10 (S1-1 to S1-10) are related to know mineralisation; details are given in Table 5. Three slightly anomalous values (S1-11 to S1-13) deserve following up, as they occur in streams draining outcrops of the prospective Westmoreland Conglomerate. The first two are enriched in tungsten as well. All remaining slightly anomalous samples are associated with Nicholson Granite Complex rocks and probably only reflect higher background uranium levels in these, although 4 (S1-14 to S1-17) may be significant in that they appear to be related to a dolerite dyke which is possibly a continuation of the structure on which the Westmoreland uranium deposit is situated (Fig. 10).

Sampling of the Hedleys Creek 1:100 000 Sheet area revealed 11 samples enriched in uranium, but not cerium and/or thorium (numbered HC1-1 to HC1-11 in Figure 11). As detailed in Table 5, 5 of these are definitely associated with known uranium deposits, while 4 could be related to mineralisation on the Winemaree (HC1-2) and Contact (HC1-7 to HC1-9) leases; but no information concerning these areas is available. Slightly anomalous uranium (HC1-10) occurs in one stream draining the previously mentioned zone of altered Nicholson

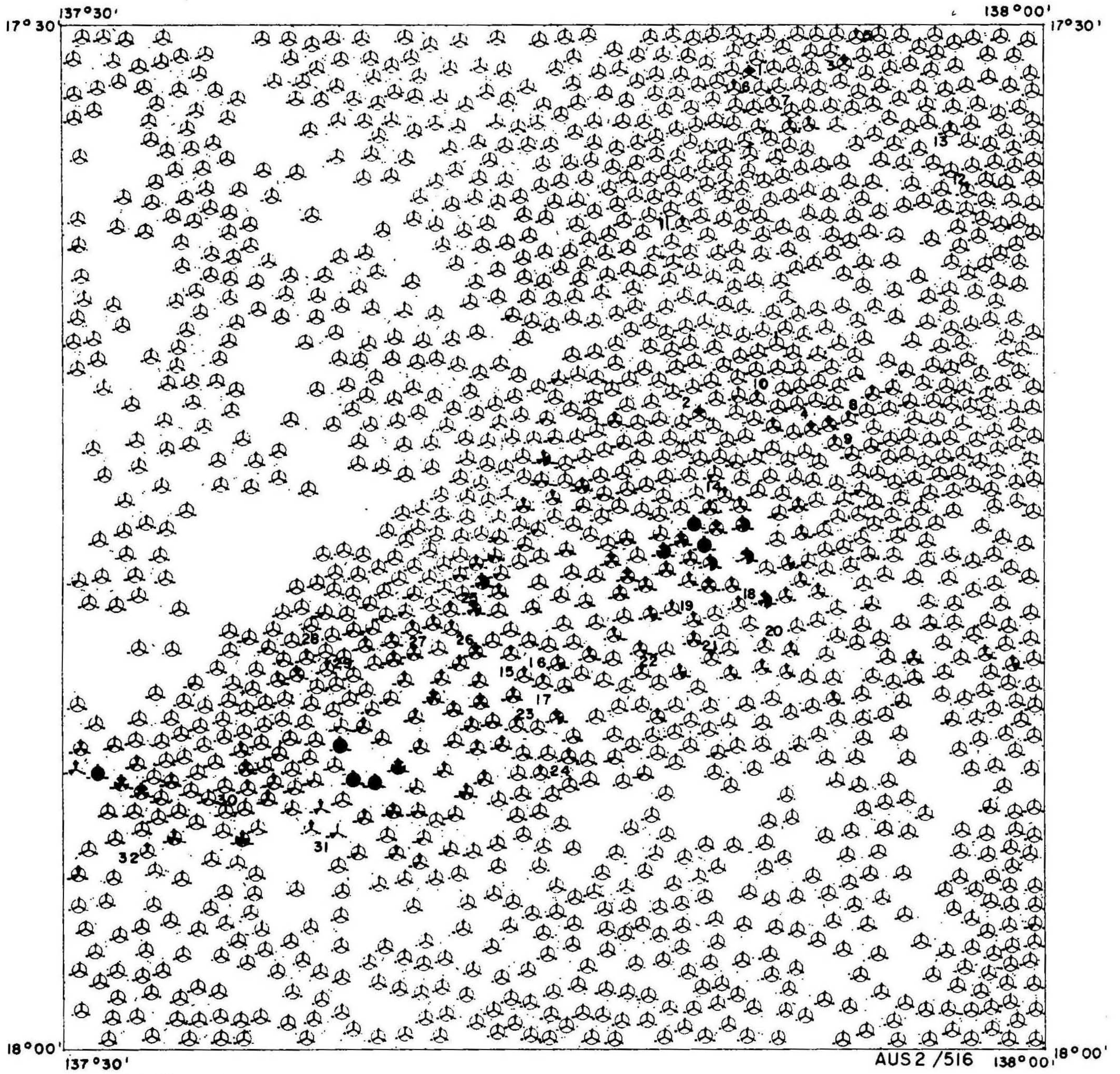

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Fig.9 Key to Map S1. Anomaly numbers are referred in the text as S1-1, S1-2 etc.

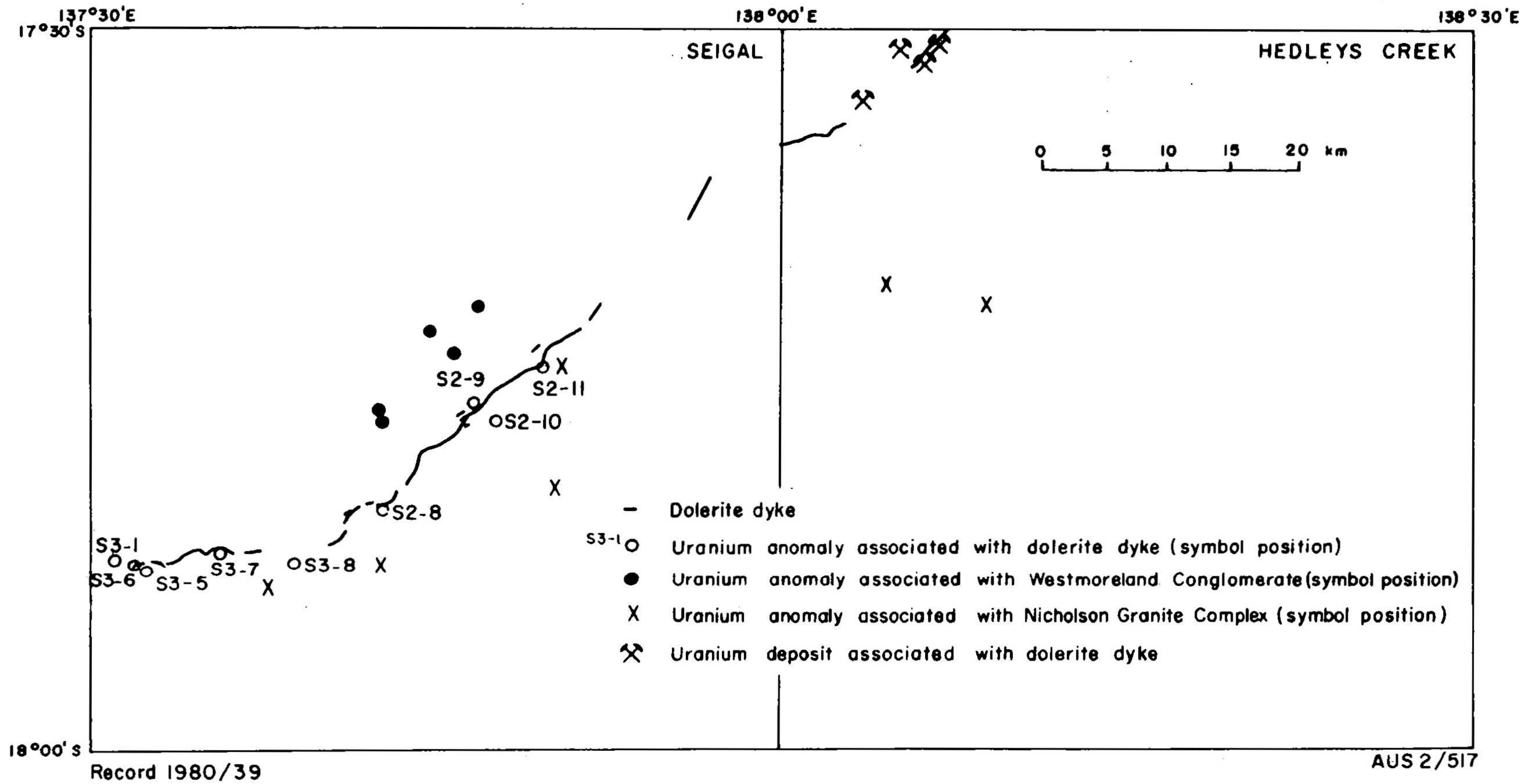
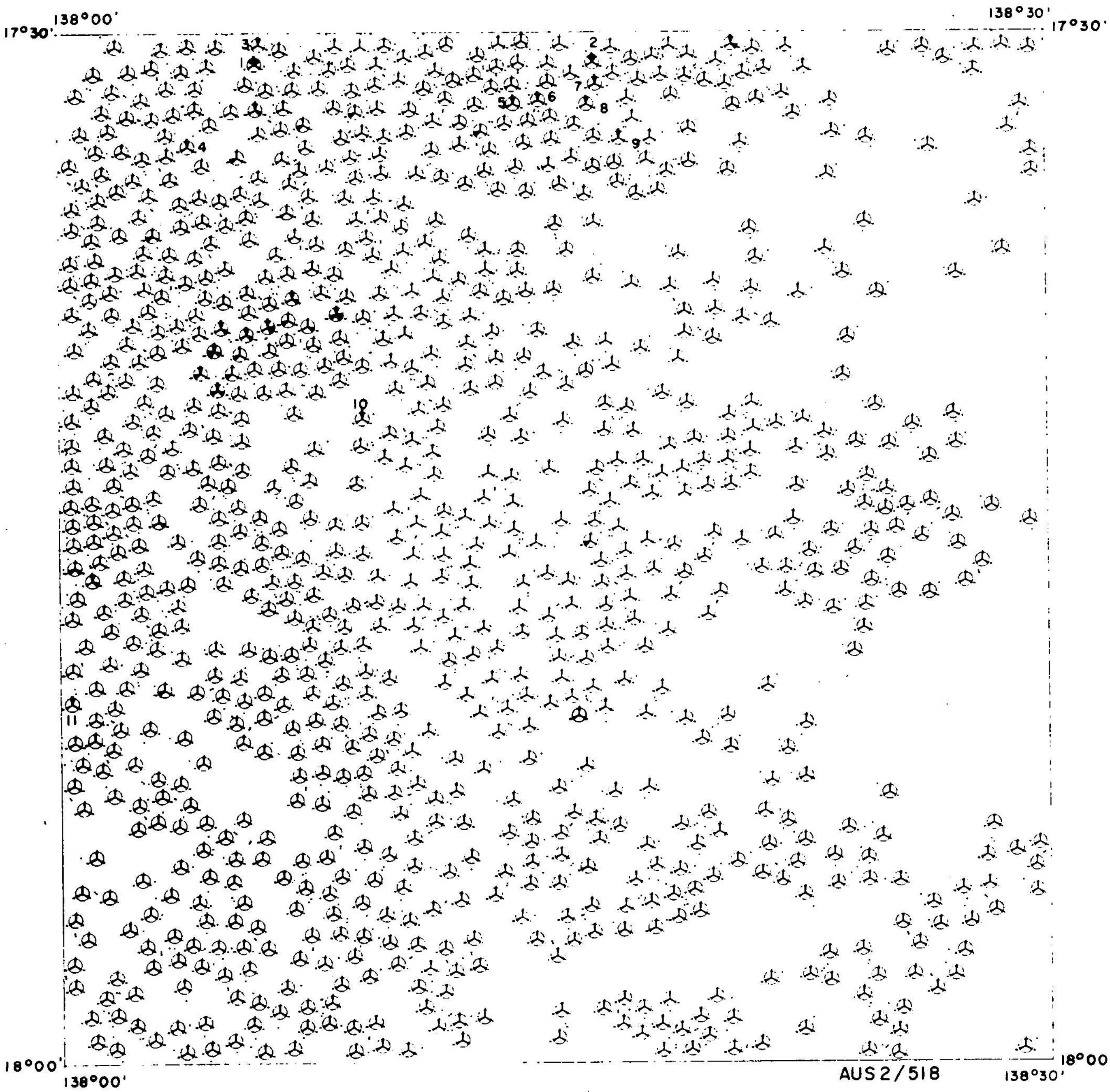


Fig. 10 : Apparent association of uranium anomalies with a dolerite dyke in the Seigal and Hedleys Creek 1:100 000 Sheet areas. Only uranium enrichments associated with high copper, tin, arsenic or bismuth (and therefore almost certainly related to mineralisation) are shown. Anomalies associated with known mineralisation have been excluded.



Record 1980/39

Fig. 11 Key to Map HC 1. Anomaly numbers are referred to in the text as HC 1-1, HC 1-2 etc.

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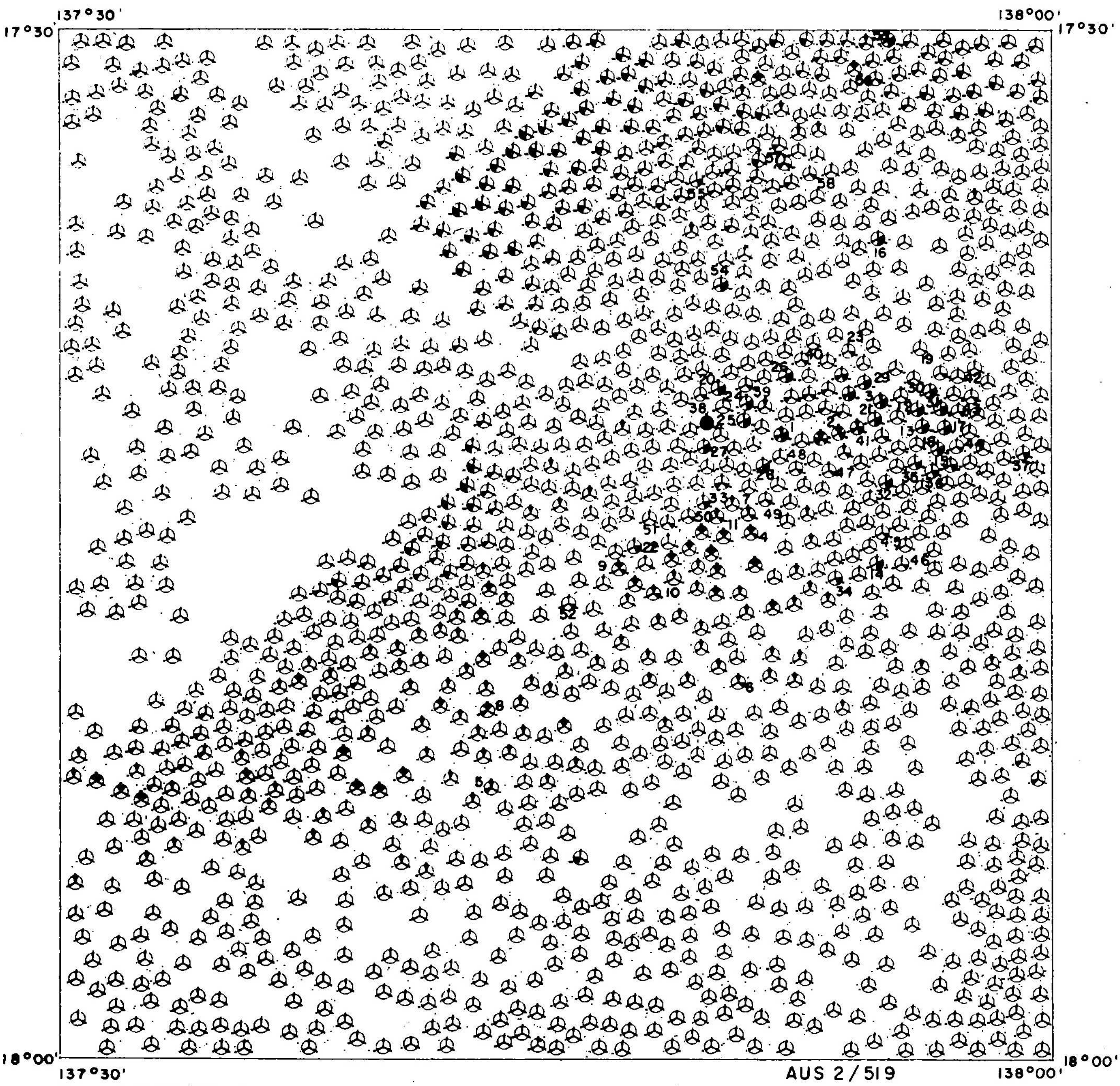

Record 1980/39

Fig. 12 Key to Map S 2. Anomaly numbers are referred to in the text as S 2-1, S2-2 etc.

Granite Complex rocks with which small copper and tin prospects are coincident. Tin and tungsten are high in the same sample. Perhaps mineralisation similar to that at the Una May prospect is indicated. The remaining slightly anomalous value (HC1-11) is associated with granitic rocks and is not thought to be of economic significance.

Maps S2 and HC2 (Uranium, copper, tin)

Previous work (Rossiter, 1976; Rossiter, 1977) has shown that elements such as arsenic, bismuth, copper, fluorine, lithium, molybdenum, rubidium, and tin are enriched in the uranium deposits of the Seigal/Hedleys Creek area. Copper and tin are especially prominent near epigenetic uranium mineralisation (e.g. Pandanus Creek, Una May) and so these elements are displayed together in Maps S2 and HC2. High arsenic levels occur close to syngenetic deposits (e.g. Westmoreland), while bismuth is anomalous near mineralisation of both types. Data for arsenic and bismuth, therefore, are shown in Maps S3 and HC3.

Fluorine, lithium, molybdenum, and rubidium were also evaluated as possible pathfinders for uranium mineralisation. Fluorine is enriched near some deposits, but the X-ray fluorescence technique used to determine this element was too insensitive (theoretical detection limit 650 ppm) for presentation of the results in map form to be justified. Molybdenum is known to be higher than normal at the Una May prospect (Rossiter, 1977), but analytical problems (large interference effects caused by zirconium during X-ray fluorescence analysis) and the fact that this element appears to be enriched in many streams draining mafic volcanic rocks (Table 6) limited its usefulness as a uranium indicator. Lithium values are also anomalously high in sediments derived from the mafic rocks of the area (Table 6). Rubidium is enriched in the highly fractionated phases of the Nicholson Granite Complex, but while these are sometimes associated with uranium mineralisation, this is not always the case.

Some economic significance should be attached to samples containing anomalous uranium in combination with high cerium and/or thorium, and enriched also in one or more of the pathfinder elements arsenic, bismuth, copper, and tin. In the Seigal Sheet area, known mineralisation accounts for 1 sample (labelled S2-1 in Figure 12) with high uranium copper, tin, and thorium, and and 3 (S2-2 to S2-4) anomalous in uranium, tin, and cerium <u>or</u> thorium (Table 5). In addition there are 3 slightly anomalous uranium values (S2-5 to S2-7) remote from known mineralisation which are accompanied by high copper <u>or</u> tin and high cerium <u>or</u> thorium. All 3 are associated with Nicholson Granite Complex rocks; the rocks; the first is anomalous in bismuth, the last in beryllium, bismuth, niobium, and tungsten. A further 4 samples combine uranium enrichments with high copper or tin as well as high cerium and thorium. Two of these (S2-8, S2-9) aremoderately anomalous in uranium and contain high beryllium and bismuth, and high tungsten, respectively; the others (S2-10, S2-11) are slightly anomalous. It is significant that all 4 coincide with the previously mentioned dolerite dyke, which may have exerted an important influence over the formation of uranium mineralisation in the Seigal Sheet area (Figure 10).

The Hedleys Creek Survey disclosed 1 sample (labelled HC2-1 in Figure 13), anomalous in uranium (slightly), tin, cerium, thorium, bismuth, and zinc. This anomaly is associated with rocks of the Cliffdale Volcanics and the Nicholson Granite Complex.

Maps S3 and HC3 (Uranium, arsenic, bismuth)

Stream-sediment coverage of the Seigal Sheet area encountered 3 samples (S3-1 to S3-3 in Figure 14) enriched in uranium, arsenic, bismuth, cerium, and thorium. The first is strongly uraniferous and lies on the line of the dolerite dyke to which attention has already been drawn (Fig. 10), although only Nicholson Granite Complex rocks have actually been mapped in the catchment. Niobium and tungsten also occur in higher than normal amounts here. Anomalies S3-2 and S3-3 are associated with outcrops of Westmoreland Conglomerate. The former is moderately high in uranium and enriched in lead and tungsten; the latter is slightly uraniferous and is also high in tungsten.

One sample from a stream draining Nicholson Granite Complex rocks (S3-4) was found to be anomalous in uranium (slightly), bismuth, and cerium. Five other samples proved to be anomalous in these elements plus thorium. Of these, 3 (S3-5 to S3-7) appear to be related to the dolerite dyke of Figure 10, while a fourth (S3-8) lies on the same line and unmapped dolerite may be present within its area of influence. Samples S3-5 and S3-8 are strongly anomalous in uranium, while the other 2 are moderately so; all are enriched in tungsten, S3-5 is rich in niobium also. The remaining anomaly in this category (S3-9) is associated with Westmoreland Conglomerate; tungsten is again high in this sample. Slightly anomalous uranium values accompanied by high arsenic, cerium, and thorium occur in sediments derived from Westmoreland Conglomerate at 2 localities (S3-10 and S3-11).

Apart from HC2-1 mentioned above, none of the Hedleys Creek samples contained anomalous uranium in combination with arsenic and/or bismuth as well

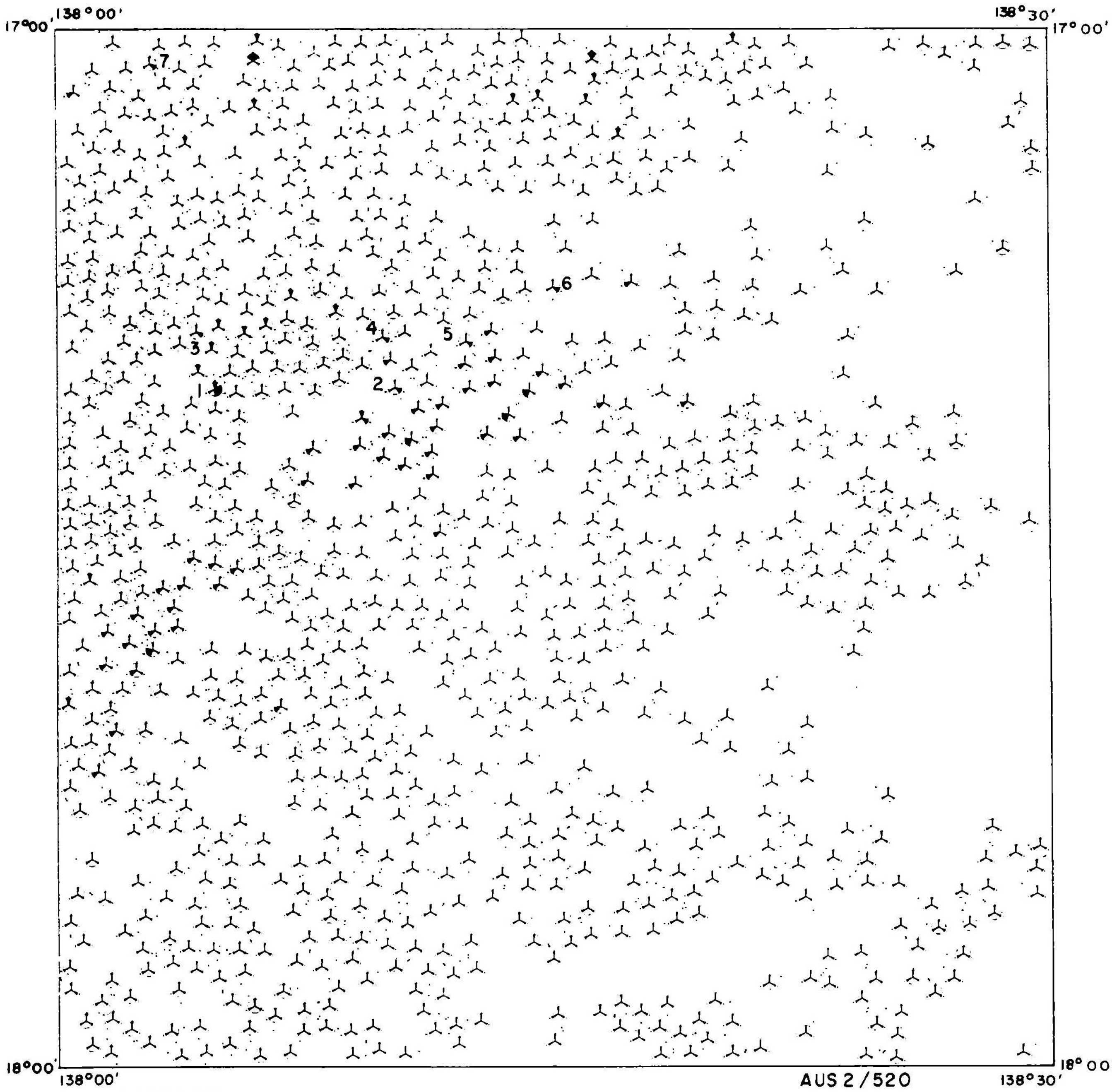

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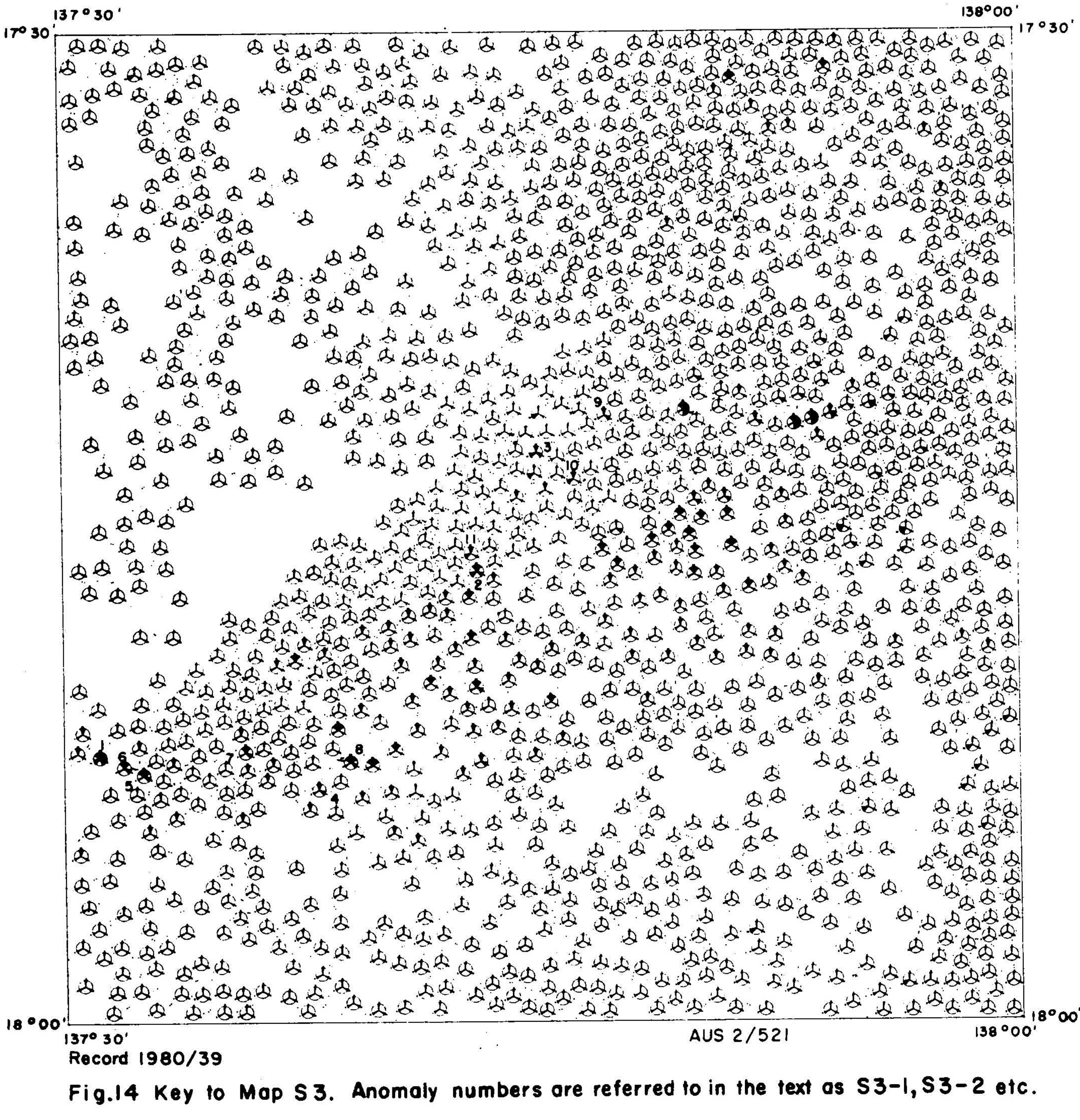
Fig. 13 Key to Map HC 2. Anomaly numbers are referred to in the text as HC 2-1, HC 2-2 etc.



Record 1980/39

Fig.14 Key to Map S3. Anomaly numbers are referred to in the text as S3-1, S3-2 etc.

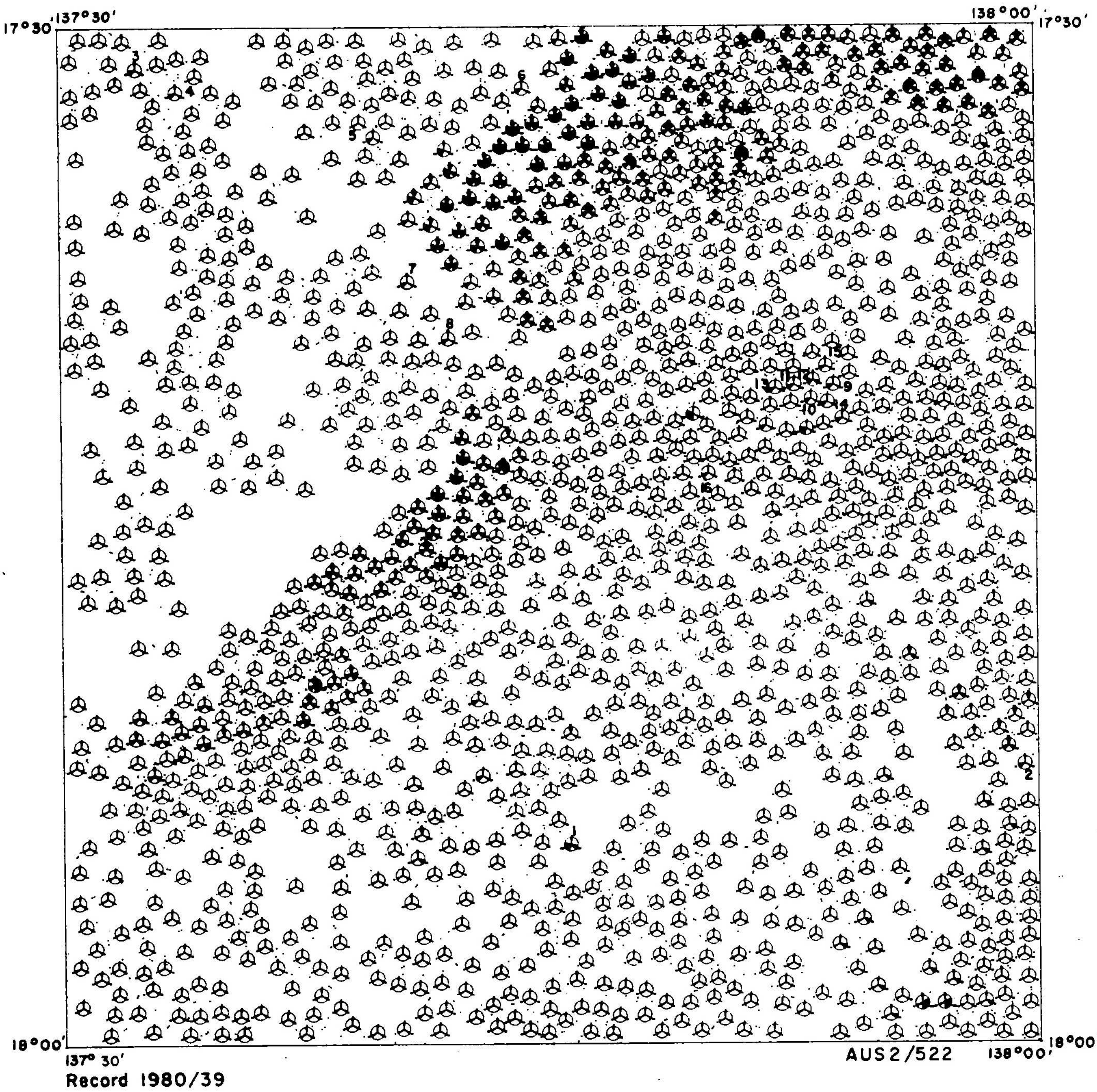
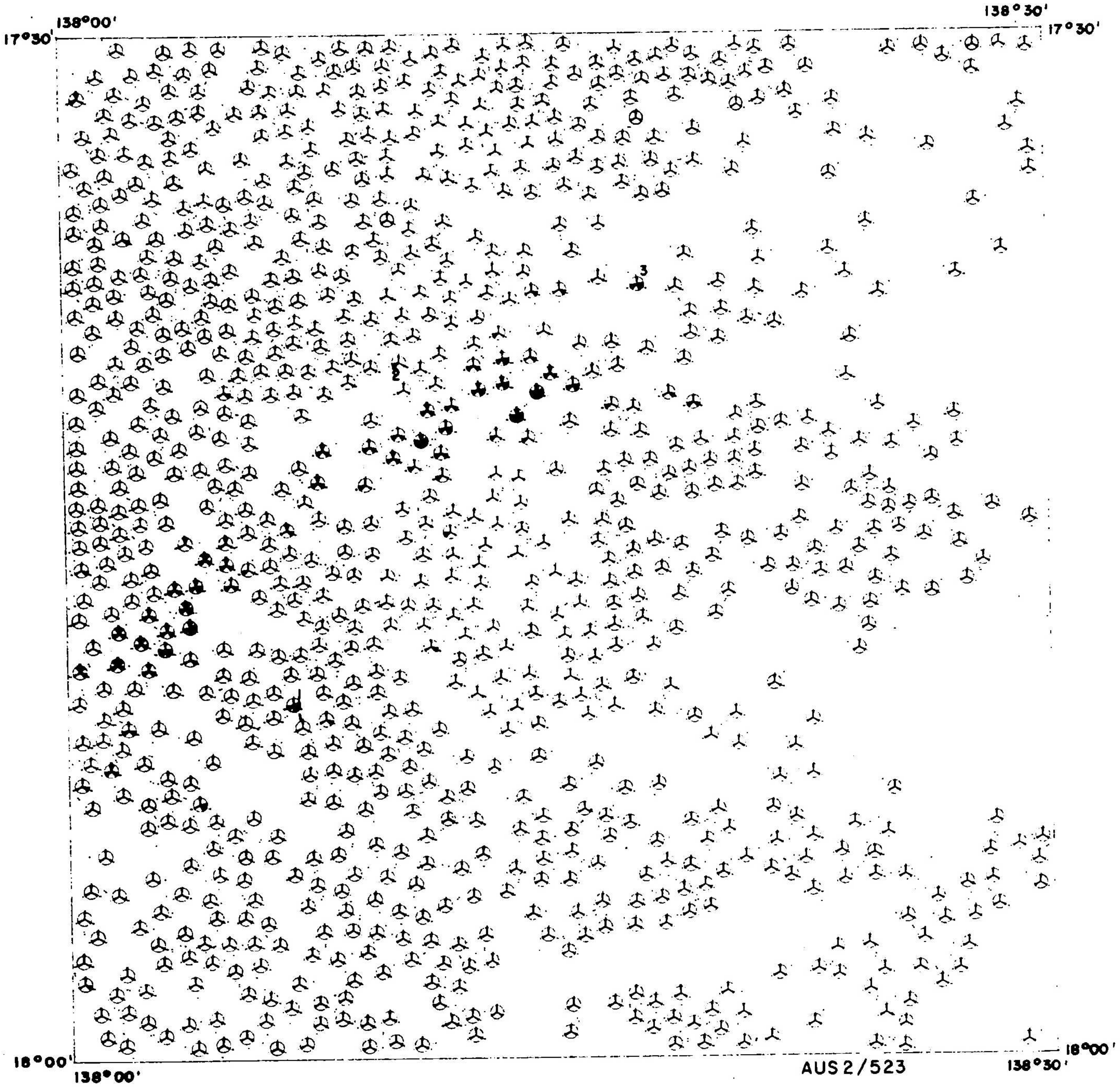


Fig. 15 Key to map S4. Anomaly numbers are referred to in the text as S4-1, S4-2 etc.



Record 1980/39

Fig. 16 Key to Map HC 4. Anomaly numbers are referred to in the text as HC4-1, HC4-2 etc.

as cerium and/or thorium.

Copper

Maps S4 and HC4 (Nickel, copper, zinc)

The Seigal survey disclosed 16 samples (labelled S4-1 to S4-16 in Figure 15) anomalous in copper which are not associated with either uranium anomalies or mapped mafic igneous rocks and whose low nickel* contents suggest that derivation from unmapped rocks of this nature is unlikely. Syngenetic affinities are exhibited by 8 of these. One moderately anomalous value (S4-1) and one slightly anomalous value (S4-2) appear to be related to the Walford Dolomite. The former sample is high in zinc; the latter is high in lead. The Walford Dolomite is seemingly the only unit of the Lawn Hill Platform sequence to show copper enrichment - only lead and zinc anomalies have so far been detected where Mount Les Siltstone and Doomadgee Formation rocks crop out. A further 6 copper anomalies (S4-3 to S4-8) are associated with the McArthur Basin sequence. All are slightly anomalous and all but one occur in streams draining Sly Creek Siltstone. The first two are enriched in arsenic as well.

The remaining 8 copper anomalies appear to be related to epigenetic mineralisation. Seven slightly anomalous values (S4-9 to S4-15) occur in the Una May area. Beryllium is high in sample S4-9, bismuth in S4-9, S4-10, and S4-15, tin in S4-9, S4-11, and S4-15, and zinc in S4-12. Slightly anomalous copper associated with tin is present in one stream draining granite and dolerite (S4-6).

In the Hedleys Creek 1:100 000 Sheet area, only 3 slightly anomalous copper values (labelled HC4-1 to HC4-3 in Figure 16) not accompanied by high uranium and apparently unrelated to mafic igneous rocks have been found. The first occurs in a stream draining the First Up prospect; the host rock to the mineralisation is Walford Dolomite. High arsenic, lead, and zinc are also present. HC4-2 is associated with the previously mentioned alteration zone within the Nicholson Granite Complex. This sample contains high bismuth and tungsten as well. The third anomalous sample (HC4-3) occurs in an area where Cliffdale Volcanics crop out; high zinc is also present.

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* Chromium, cobalt, iron, and manganese were also considered as indicators of mafic igneous rocks but these elements proved less reliable than nickel (Table 7).

Lead-zinc

Maps S5 and HC5 (Lead, arsenic, zinc)

Scrutiny of Maps S4 and S5 reveals a total of 25 lead and/or zinc anomalies in the Seigal 1:100 000 Sheet area (S5-1 to S5-25 in Figure 17) that have not been previously discussed because of an association with uranium or copper enrichments and which do not appear (using the criteria outlined in the previous section) to be related to mafic igneous rocks. Two of these (S5-1 and S5-2) are high in lead, arsenic, and zinc. The former is strongly anomalous in both lead and zinc while the latter is moderately anomalous in lead and slightly enriched in zinc; Doomadgee Formation rocks crop out in both catchments.

Three samples (S5-3 to S5-25) contain anomalous lead and zinc but low arsenic; the first two are associated with Doomadgee Formation rocks, the last with the Mount Les Siltstone. Lead is slightly anomalous in all 3, zinc is strongly anomalous in S5-3 and slightly enriched in the others.

Four samples (S5-6 to S5-9) are enriched in lead alone; the first is strongly anomalous, the others slightly. Anomalies S5-6 and S5-7 occur in areas of Westmoreland Conglomerate while S5-8 and S5-9 are associated with the Walford Dolomite and the Nicholson Granite Complex respectively. The last is anomalous in beryllium as well.

Sixteen samples (S5-10 to S5-25) are anomalous (all slightly) in zinc only. Previous work in the Seigal/Hedleys Creek area (Rossiter, 1976) has shown that care must be taken in the interpretation of high zinc values here, as false anomalies caused by manganese scavenging can occur. Six zinc enrichments not accompanied by high manganese and associated with the prospective Mount Les Siltstone (S5-10 and S5-11) and Doomadgee Formation (S5-12 to S5-15) appear to have economic significance. Anomalies S5-16 and S5-17 combine high manganese and zinc and have perhaps been caused by scavenging but given their proximity to economically quite promising samples they should not be discounted entirely. The 8 remaining anomalous zinc values all occur in streams draining Nicholson Granite Complex rocks or the Cliffdale Volcanics and probably reflect higher background levels in these units rather than mineralisation.

A further sample (S5-26 in Figure 17), is anomalous in both zinc (slightly) and arsenic; it also contains high copper. Although this anomaly is worthy of follow-up it may be that the zinc and copper are related to mafic igneous rocks rather than mineralisation (anomalous nickel is present as well).

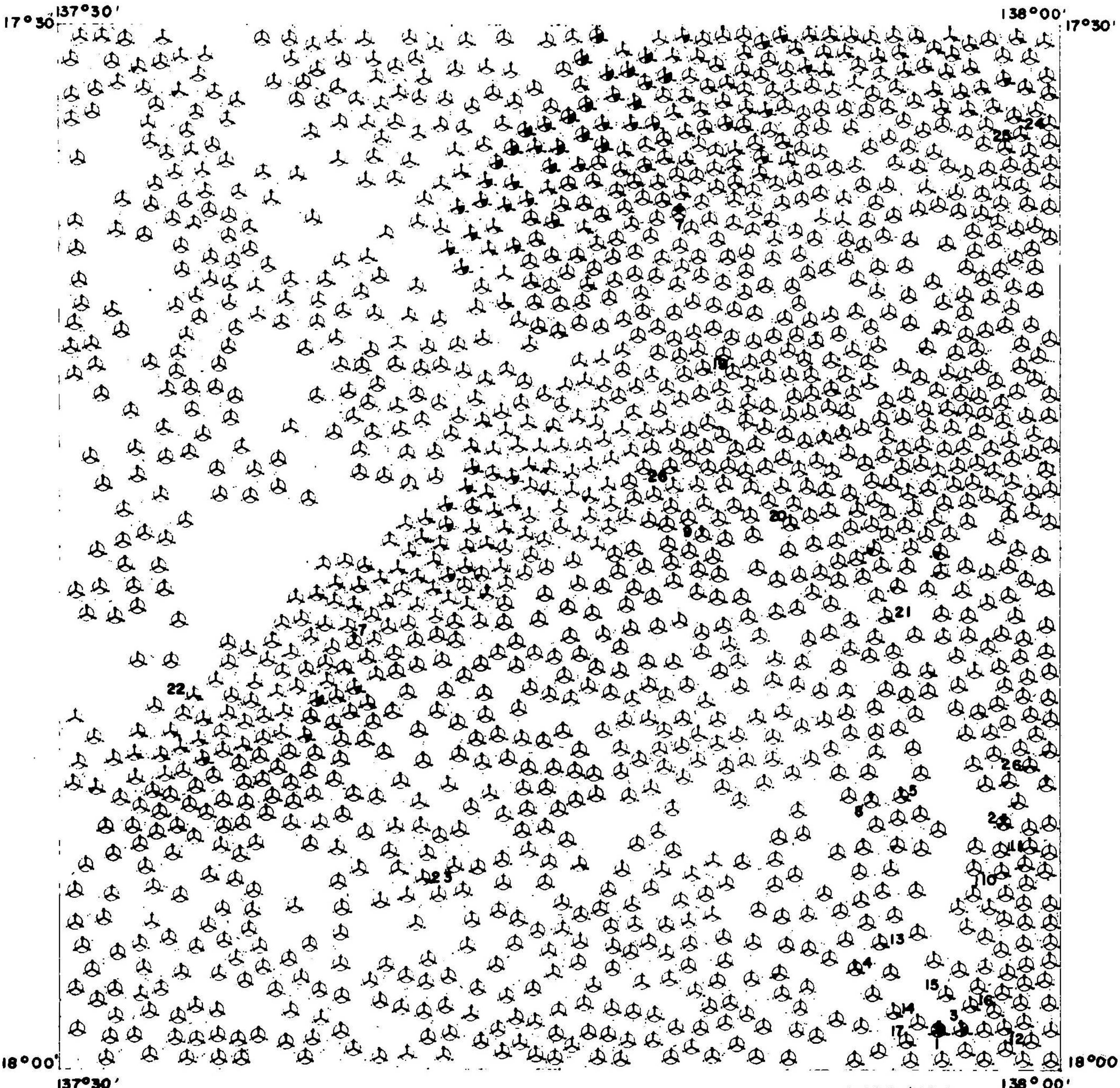

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Fig. 17 Key to map S5. Anomaly numbers are referred to in the text as S5-1, S5-2 etc.

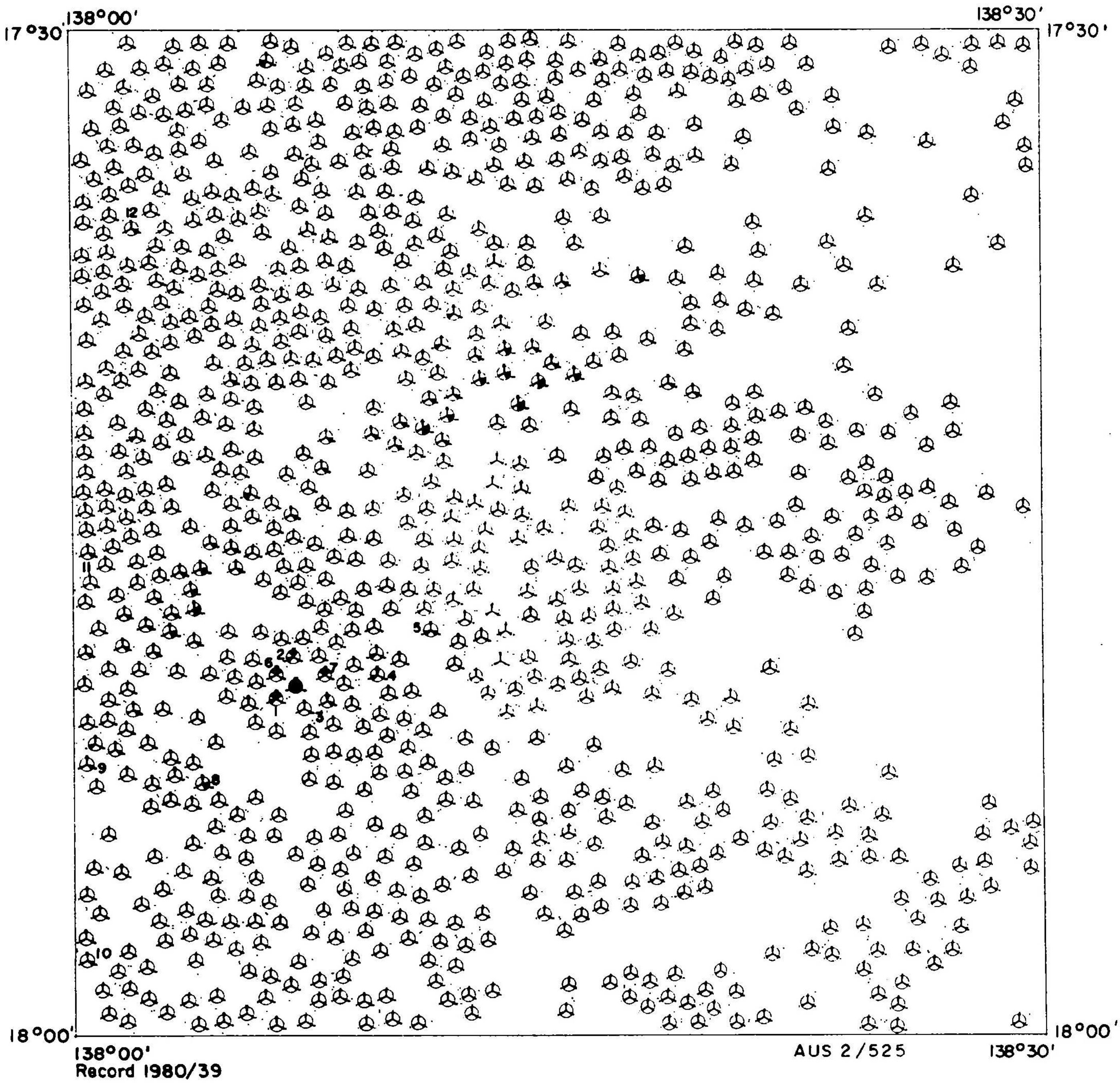


Fig.18 Key to Map HC 5. Anomaly numbers are referred to in the text as HC 5-1, HC 5-2 etc.

The single instance of anomalous lead, arsenic, and zinc being present in the same Hedleys Creek sample has already been pointed out by virtue of its richness in copper (HC4-1). A further 5 samples (HC5-1 to HC5-5 in Figure 18) in the Hedleys Creek Sheet area contain anomalous amounts of 2 of these elements. Strongly anomalous lead associated with high arsenic is present in a stream draining the First Up prospect (HC5-1). One sample (HC5-2) anomalous in lead (moderately) and arsenic and another (HC5-3) slightly enriched in both lead and zinc occur in the same general area. Slightly anomalous lead (HC5-4) and zinc (HC5-5) values both associated with arsenic enrichments are more remote from known mineralisation.

The First Up area also produced two samples (HC5-6 and HC5-7) strongly anomalous in lead with no conspicuous arsenic or zinc accompanying it. Five instances not previously discussed in which zinc alone is enriched should be mentioned, as they are apparently unrelated to mapped mafic igneous rocks and low nickel contents make it unlikely that hitherto undetected rocks of this type are present. One moderately (HC5-8) and 2 slightly anomalous (HC5-9 and HC5-10) samples are derived from Doomadgee Formation rocks and Mount Les Siltstone and deserve consideration. The remaining slightly anomalous values are associated with rocks of the Nicholson Granite Complex (HC5-11) and the Cliffdale Volcanics (HC5-12) and are not thought to be of economic significance.

Tin-tungsten-beryllium

Maps S2 and HC2 (Uranium, copper, tin)

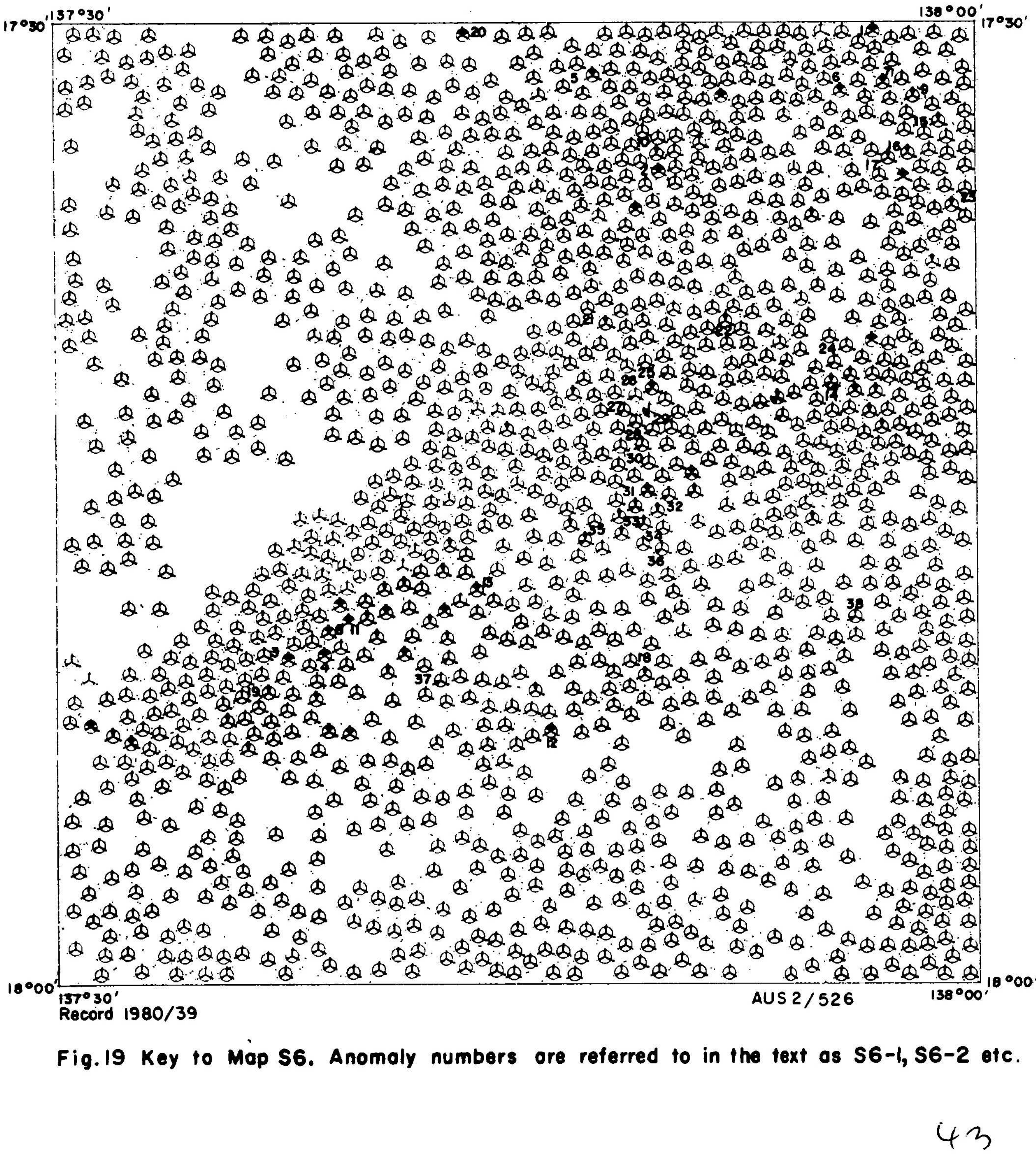
The vast majority of tin anomalies encountered during the Seigal survey and not previously mentioned under the Uranium and Copper headings are associated with the Nicholson Granite Complex or the Cliffdale Volcanics (which are probably underlain at shallow depths by granitic rocks in any case). There are 41 anomalous tin values (labelled S2-12 to S2-52 in Figure 12) associated with these rocks in the Seigal 1:100 000 Sheet area. Other late-stage hydrothermal elements, particularly tungsten and bismuth, are often high in these tin-rich samples. Anomalous tin, tungsten, and bismuth in combination occur in 4 samples (S2-12 to S2-15); tin is strongly enriched in the first 3 of these and moderately high in the last. Four samples (S2-16 to S2-19) contain high tin and tungsten; all are strongly stanniferous except the last which is slightly anomalous in tin. A further 4 tin anomalies (S2-20 to S2-23) are associated with high bismuth. S2-20 and S2-21 are strongly anomalous while S2-22 and S2-23 are moderately and slightly anomalous respectively. The remaining 29 tin anomalies (S2-24 to S2-52) associated with the Nicholson Granite Complex and Cliffdale Volcanics are not enriched in tungsten or bismuth. Of these 9 (S2-24 to S2-32) are strongly stanniferous and 5 (S2-33 to S2-37) are moderately anomalous. Beryllium is enriched in samples S2-12 and S2-27.

Six tin anomalies (S2-53 to S2-58) occur in a different geological environment to the enrichments discussed above. They appear to be more closely associated with Mesozoic sandstone, and to a lesser degree Westmoreland Conglomerate, than any other rock types and may be derived from placer concentrations of cassiterite within the sandstones. An absence of other late-stage elements is typical of this group. Strongly (S2-53 and S2-54), moderately (S2-55), and slightly anomalous (S2-56 to S2-58) values are all represented.

The Hedleys Creek survey disclosed 6 slightly anomalous tin values not already commented on (Fig. 13). One sample (HC2-2) contains high tungsten as well as tin and is associated with the alteration zone within the Nicholson Granite Complex. A further 4 samples enriched only in tin (HC2-3 to HC2-6) occur in areas of Cliffdale Volcanics and Nicholson Granite Complex rocks. The remaining anomalous value (HC2-7) appears to be related to the Westmoreland Conglomerate.

Maps S6 and HC6 (Tungsten, beryllium, niobium)

Many of the tungsten anomalies recorded by the Seigal survey are associated with high cerium and/or thorium and this suggests that the tungsten is present either in monazite or a mineral of similar provenance and specific gravity. There are, however, 23 anomalous values (labelled S6-1 to S6-23 in Figure 19) which do not appear to be caused by monazite or other rock-forming minerals and which have not been mentioned previously. Ten of these are apparently related to the Siegal Volcanics; strongly (S6-1 to S6-4), moderately (S6-5 to S6-8), and slightly (S6-9 and S6-10) anomalous values all occur in this geological environment. Primary tungsten mineralisation associated with the mafic igneous rocks is most unlikely and perhaps this element has been concentrated during the intense metasomatic event which these rocks have undergone. It may be relevant that the mafic members of the Peters Creek Volcanics which appear identical to the Seigal Volcanics are very high in potassium (Sweet & Slater, 1975) and, possibly, molybdenum (Table 6).



Record 1980/39

Fig.19 Key to Map S6. Anomaly numbers are referred to in the text as S6-1, S6-2 etc.

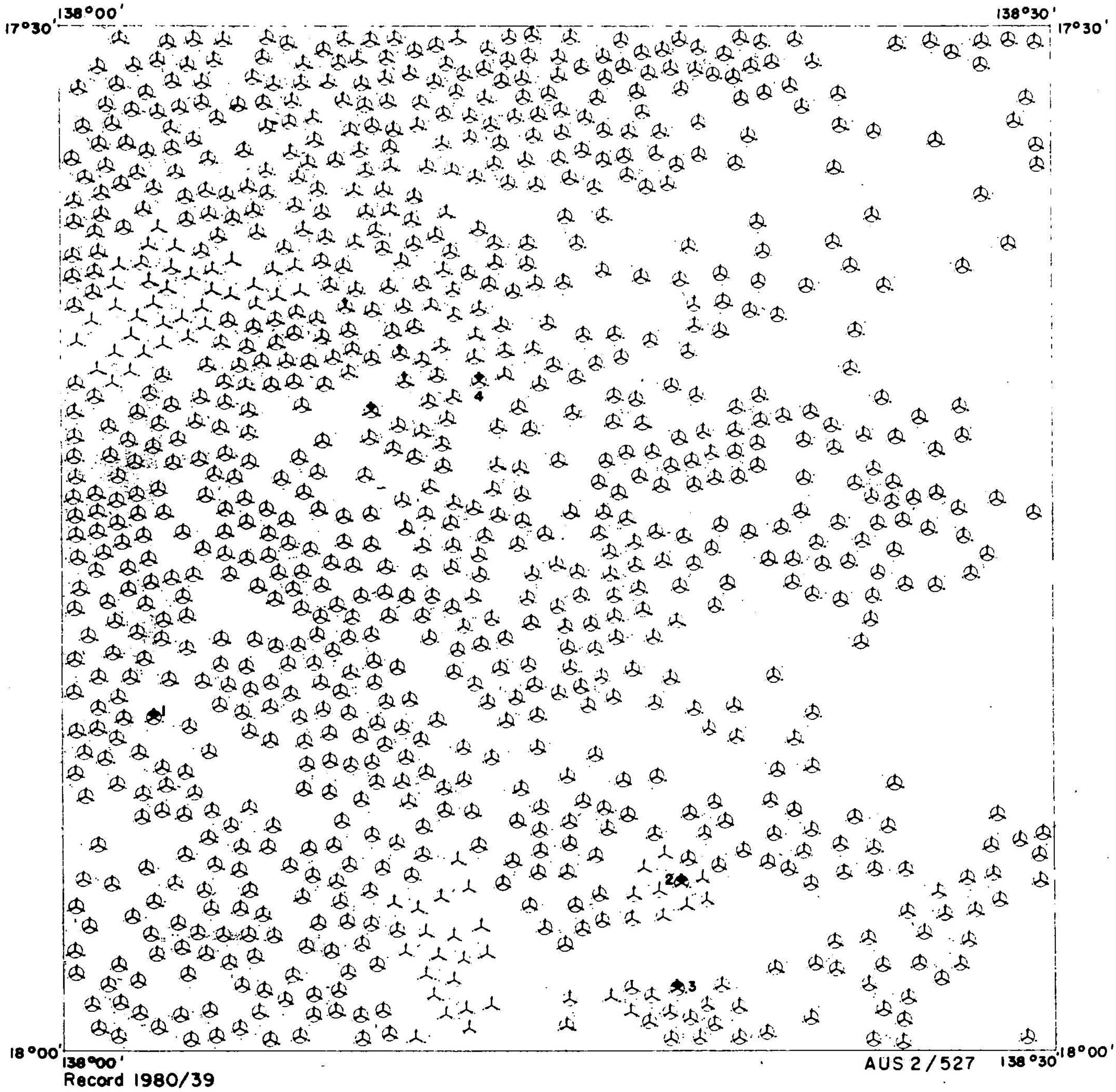


Fig. 20 Key to Map HC 6. Anomaly numbers are referred to in the text as HC 5-1, HC 5-2 etc.

A further 9 of the samples enriched in tungsten, but low in cerium, thorium, tin*, and uranium* were collected from streams draining rocks of the Nicholson Granite Complex and the Cliffdale Volcanics. Again strongly (S6-11 and S6-12), moderately (S6-13), and slightly (S6-14 to S6-19) anomalous values are represented. Beryllium and bismuth are high in sample S6-14. One strong tungsten enrichment (S6-20) appears to be related to the Sly Creek Sandstone and 3 slightly anomalous samples (S6-21 to S6-23) are associated with Westmoreland Conglomerate.

Beryllium anomalies within the Seigal 1:100 000 Sheet area not already mentioned number 15 (labelled S6-24 to S6-38 in Figure 19); all are slightly anomalous. Broad beryllium enrichments occur around the Una May prospect (S6-24), near the Pandanus Creek uranium mine (S6-25 to S6-30), and to the southwest of Crystal Hill (S6-31 to S6-36). S6-31 and S6-33 are anomalous in niobium as well. Anomalies S6-37 and S6-38 occur in streams draining Nicholson Granite Complex rocks.

The Hedleys Creek sampling detected 4 tungsten anomalies (labelled HC6-1 to HC6-4 in Figure 20) not already mentioned which do not appear to be related to detrital monazite concentrations. Strongly anomalous values are apparently associated with Walford Dolomite (HC6-1) and Constance Sandstone (HC6-2 and HC6-3). A moderately anomalous value (HC6-4) was found in a stream draining mainly Peters Creek Volcanics. Beryllium and niobium are low over the entire Sheet area. Map HC6 was not considered sufficiently interesting to justify the expense of publishing a full-scale colour print.

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* Samples enriched in these elements have been discussed in previous sections.

CONCLUSIONS AND RECOMMENDATIONS

Stream-sediment sampling of the Seigal and Hedleys Creek 1:100 000 Sheets suggests that the area's greatest economic potential lies in the possibility of uranium deposits, but copper, lead, zinc, tin, tungsten, and beryllium mineralisation may also be present.

Epigenetic uranium mineralisation associated with Nicholson Granite Complex rocks is indicated at several localities (Fig. 10) and there is evidence to suggest that large low-grade deposits may occur at Una May and Pandanus Creek (Rossiter, 1977), and within the alteration zone in the Hedleys Creek Sheet area. Any future work should take into account that high levels of copper, tin, tungsten, and beryllium accompany uranium mineralisation of this type. The possibility of false uranium anomalies caused by detrital monazite should also be remembered. The determination of bismuth, cerium, and thorium, as well as the elements above, can help distinguish uranium enrichments due to this cause from those more likely to indicate mineralisation.

A dolerite dyke extending the full width of the Seigal Sheet area, and apparently related to the Westmoreland uranium deposit in the Hedleys Creek Sheet area, is associated with uranium anomalies along much of its length (Fig. 10) and is well worthy of more detailed prospecting. It is difficult to escape the conclusion that the dyke either introduced the uranium or provided a heat source responsible for leaching the uranium from the host rocks and concentrating it. It could be argued that the Westmoreland deposit formed where soluble uranium migrating through the sandstones of the Westmoreland Conglomerate came into contact with ferrous iron in the dyke and was precipitated. However, in the Seigal Sheet area, the dyke intrudes granitic rocks along much of its length and it would appear unlikely that uranium could migrate from a source some distance away through such an impermeable host rock.

A number of uranium anomalies associated with outcrops of Westmoreland Conglomerate were also located by the survey (Fig. 10) and these should be further investigated for mineralisation similar to that at Westmoreland.

There is some possibility of lead-zinc deposits in the Lawn Hill Platform sequence; the Seigal 1:100 000 Sheet area has been less intensively prospected and probably offers the best prospects. Copper assumes more importance where rocks of the Walford Dolomite crop out, and is also anomalous at several localities within the McArthur Basin sequence. It should be remembered that high copper and zinc background values are associated with the mafic igneous rocks of the area. Nickel is useful as an indicator of mafic rocks, and arsenic is a good pathfinder for copper-lead-zinc mineralisation.

Many tin anomalies occur in areas underlain by Cliffdale Volcanics and Nicholson Granite Complex rocks and there is a good chance that economic discoveries of this metal will be made in the Seigal/Hedleys Creek area. Tungsten, likewise, is commonly anomalous in the same rocks, as well as being enriched in areas of mafic igneous rocks. These latter anomalies are as yet unexplained.

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Table 1: Instrumental conditions employed for atomic absorption analysis

Element	Line (nm)	Spectral bandpass (nm)	Lamp current (mA)	Flame type*	Flame stoichiometry	Detection limit (ppm)**
Be	234.9	0.50	8	NO/A	Reducing	1
Co	240.7	0.20	8	A/A	Oxidising	2
Cr	357.9	0.20	5	NO/A	Reducing	4
Cu	324.8	0.50	3	A/A	Oxidising	2
Fe	372.0	0.20	6	A/A	Oxidising	1000
Li	670.8	0.20	5	A/A	Oxidising	1
Mn	279.5	0.20	5	A/A	Oxidising	10
Ni	232.0	0.20	8	A/A	Oxidising	2
Zn	213.9	0.50	6	A/A	Oxidising	1

* A/A - air/acetylene; NO/A = nitrous oxide/acetylene

** Detection limit defined as ppm in solid equivalent to 0.004 A in solution (1 g/25ml)

Table 2: Instrumental conditions employed for X-ray fluorescence analysis. Vacuum was used throughout. The gas used in the flow counter was 10 percent v/v methane in argon.

Element	Line	Peak 2θ	Peak count time(s)	Background 2θ's	Background count time(s)	Tube	Tube voltage (kV)	Tube current (mA)	Primary collimator	Crystal	Counter	Theoretical detection limit (ppm)
As	K-alpha	33.98	40	±0.44	20	Mo	90	30	Fine	LiF 200	Flow + Scint.	0.4
Ba	L-beta	128.99	100	±2.30	40	Au	60	45	Coarse	LiF 220	Flow	2.1
Bi	L-alpha	33.00	40	±0.60	20	Mo	90	30	Fine	LiF 200	Flow + Scint.	0.8
Ce	L-beta	111.78	100	+2.20 -1.60	40	Au	60	45	Coarse	LiF 220	Flow	2.3
F	K-alpha	90.93	100	±1.75	40	Cr	50	40	Coarse	TlAP	Flow	650
Mo	K-alpha	28.85	100	+0.33 -0.18	40	Au	90	30	Fine	LiF 220	Scint.	1.2
Nb	K-alpha	21.37	40	±0.37	20	Au	90	30	Fine	LiF 200	Scint.	0.8
Pb	L-beta	28.25	40	±0.27	20	Mo	90	30	Fine	LiF 200	Scint.	0.9
Rb	K-alpha	26.58	20	±0.30	10	Mo	90	30	Fine	LiF 200	Scint.	0.5
S	K-alpha	75.83	40	±1.20	20	Cr	50	40	Coarse	PE	Flow	5
Sn	K-alpha	19.84	100	±0.45	40	Au	90	30	Fine	LiF 220	Scint.	1.0
Th	L-alpha	27.46	40	±0.20	20	Mo	90	30	Fine	LiF 200	Scint.	0.9
Ti	K-alpha	86.20	40	-1.00	20	Au	50	20	Fine	LiF 200	Flow	3
U	L-alpha	37.30	100	±0.25	40	Mo	90	30	Fine	LiF 220	Scint.	0.6
W	L-alpha	62.49	100	±0.75	40	Mo	90	30	Fine	LiF 220	Flow + Scint.	1.8
Y	K-alpha	33.84	20	±0.43	10	Mo	90	30	Fine	LiF 220	Scint.	0.6

Table 3: Summary statistics for all elements determined during the Seigal stream-sediment survey. All values are in parts per million.

Element	Arithmetic mean	Standard deviation	2 x mean	Mean + 2 standard deviations	Threshold used on maps
Cu	25	31	50	87	50
Zn	27	33	54	93	50
Pb	13	11	26	35	50
S	310	178	620	666	-
Sn*	7	24	14	55	25
W*	3	7	6	17	10
Bi*	1	1	2	3	4
Nb	13	7	26	27	50
Li	15	9	30	33	-
Be	2	1	4	4	5
Rb	102	95	204	292	-
U	5	5	10	15	10
As	4	2	8	8	10
F*	15	130	30	275	-
Th	28	40	56	108	75
Ce	89	72	178	233	150
Y	38	44	76	126	-
Ba	410	267	820	944	-
Mn	299	379	598	1060	-
Co	10	11	20	32	-
Ni	14	19	28	52	30
Cr	48	51	96	150	-
Fe	23000	20000	46000	63000	-
Ti	5030	3920	1060	12870	-

No. of samples = 1534

* Figures for Sn, W, Bi, and F are artificially low as a value of zero was arbitrarily assigned in any instance in which these elements could not be detected.

Table 4: Summary statistics for all elements determined during the Hedleys Creek stream-sediment survey. All values are in parts per million.

Element	Arithmetic mean	Standard deviation	2 x Mean	Mean + 2 standard deviations	Threshold used on maps
Cu	16	15	32	46	50
Zn	21	29	42	79	50
Pb	11	22	22	55	50
Sn*	4	5	8	14	25
W*	2	3	4	8	10
Mo*	1	1	2	3	-
Bi*	0	1	0	2	3
Nb	13	6	26	25	50
Li	11	5	22	21	-
Be	1	1	2	3	5
Rb	80	62	160	204	-
U	4	3	8	10	10
As	4	2	8	8	10
Th	15	14	30	43	75
Ce	65	32	130	129	150
Y	31	15	62	61	-
Mn	242	325	484	892	-
Co	7	7	14	21	-
Ni	7	9	14	25	30
Cr	27	22	54	71	-
Fe	16000	11000	32000	38000	-

No. of samples = 974

* Figures for Sn, W, Bi, and Mo are artificially low as a value of zero was arbitrarily assigned in any instance in which these elements could not be detected.

Table 5: Anomalies associated with known uranium mineralisation in the Seigal and Hedleys Creek Sheet areas.

Anomaly	Source	Strength of anomaly	Associated elements
S1-1	El Hussen	Strong	
S1-2	Pandanus Creek	Strong	Be, Bi, Cu, Sn, W
S1-3	Cobar II-Old Parr	Moderate	
S1-4	Una May	Moderate	Be, Bi, Cu, Nb, Pb, Sn
S1-5	Cobar II-Old Parr	Slight	Cu (prob.basic rocks)
S1-6	El Hussen	Slight	
S1-7	El Hussen	Slight	W
S1-8	Una May	Slight	Be, Bi, Sn
S1-9	Una May	Slight	Be, Bi, Cu, Sn
S1-10	Norris's	Slight	
HC1-1	Westmoreland	Strong	As, Bi
HC1-2	Winemaree?	Moderate	As
HC1-3	Westmoreland	Slight	
HC1-4	Moogooma	Slight	
HC1-5	Tjuambi	Slight	
HC1-6	Tjuambi	Slight	
HC1-7	Contact?	Slight	
HC1-8	Contact?	Slight	
HC1-9	Contact?	Slight	
S2-1	Una May	Slight	Bi, Cu, Sn, Th
S2-2	Una May	Moderate	Be, Bi, Nb, Pb, Sn, Th, W
S2-3	Una May	Slight	Be, Ce, Sn
S2-4	Crystal Hill	Moderate	Be, Ce, Sn, Th, W

Table 6: Arithmetic means for sediments derived from the various rock units of the Seigal and Hedleys Creek 1:100 000 Sheet areas. All values are in parts per million. The means for tungsten, molybdenum, bismuth, and fluorine do little more than indicate which units these elements were detected in. Samples showing obvious signs of contamination were excluded from the calculations.

Rock unit	Murphy Metamorphics	Cliffdale Volcanics (rhyolites)	Cliffdale Volcanics (rhyolites/andesites)	Nicholson Granite Comp. (adamellites)	Nicholson Granite Comp. (granites)	Westmoreland Congl./Wire Ck Sandstone	Siegal/Peters Ck Volcs (basalts)	Peters Creek Volcanics (rhyolites)	Sly Creek Sandstone	Fish River Formation	Walford Dolomite	Mount Les Siltstone	Doomadgee Formation	Constance Sandstone (sandstones)	Constance Sandstone (siltstones)	Mullera Formation	Mesozoic
No. samples	3+	46	33	28	25	87	29	11	3+	6	6	16+	15	41	6	5+	13
Cu	26	17	25	16	26	8	103	15	7	9	43	16	16	8	12	16	11
Zn	23	33	36	24	23	9	112	13	4	9	34	36	35	7	9	16	10
Pb	16	14	19	19	28	8	11	6	3	5	30	40	34	7	8	12	7
S*	265	284	361	241	259	334	436	–	167	–	392	403	293	292	220	331	323
Sn	4	12	22	6	20	3	3	4	0.7	2	0.7	3	2	2	0.8	2	0.9
W	4	3	4	4	7	3	1	2	ND	ND	ND	1	1	0.4	0.5	ND	0.2
Mo**	–	0.5	ND	2	–	0.5	4	1	–	1	ND	0.3	4	ND	ND	–	–
Bi	1	0.1	1	0.7	2	0.4	0.1	ND	ND	ND	0.3	ND	ND	0.1	ND	ND	ND
Nb	13	19	18	13	28	14	14	22	4	8	10	10	10	6	10	9	6
Li	18	13	20	19	21	7	30	11	5	9	13	11	11	7	11	13	10
Be	2	3	3	3	4	1	2	1	ND	1	2	2	2	0.8	1	1	0.8
Rb	168	179	202	187	321	47	88	84	15	26	41	82	85	26	74	57	20
U	7	5	5	8	15	5	2	4	1	3	3	3	3	2	3	2	1
As	3	4	4	5	3	5	2	3	2	3	10	7	8	2	2	4	2
F*	ND	ND	32	ND	100	ND	ND	ND	ND	–	250	ND	ND	ND	ND	ND	ND
Th	44	21	21	60	105	31	9	17	5	7	8	12	12	9	11	10	6
Ce	100	99	98	128	210	99	60	83	27	51	58	67	82	49	57	68	65
Y	41	36	31	60	107	36	31	49	11	21	25	27	31	19	26	24	15
Ba*	636	952	974	704	579	229	579	–	87	–	327	253	354	147	209	200	246
Mn	246	233	283	367	237	57	988	190	30	98	694	442	790	39	119	167	130
Co	11	6	8	10	9	3	33	6	0.7	3	12	6	10	2	5	7	5
Ni	16	4	8	9	7	5	59	7	4	5	14	6	10	4	5	8	5
Cr	58	19	41	35	26	22	146	21	14	20	29	26	32	18	20	28	26
Fe	18000	19000	22000	17000	15000	15000	70000	15000	7000	13000	18000	13000	17000	9000	11000	18000	12000
Ti*	4670	3650	5020	3780	3640	4000	15100	–	1970	–	3030	3660	4450	2330	2480	3140	3450

ND = not detected

* Data available for Seigal only

** Data available for Hedleys Creek only (Zr interfered with XRF analysis of Seigal samples)

\+ So that a reasonable number of values was available for calculation of the means it was necessary for these rock units to include samples from catchments containing minor amounts of other rocks with similar geochemistry.

Table 7: Evaluation of various elements as indicators of unmapped mafic igneous rocks (Seigal 1:100 000 Sheet area only).

Indicator element	Threshold (ppm)	Presence of mafic rocks established by geological mapping but indicator element < threshold (A)	No mafic rocks apparent, copper and zinc not anomalous but indicator element > threshold. (B)	Number of incorrect classifications (A + B)
Co	25	53	17	70
	20	24	37	61
	15	5	78	83
Cr	100	64	29	93
	75	32	90	122
	50	20	230	250
Fe	50000	45	18	63
	40000	21	43	64
	30000	3	105	108
Mn	600	76	78	154
	500	42	118	160
Ni	40	64	10	74
	35	41	18	59
	30	26	27	53
	25	16	47	63

Table 8: Spearman rank correlation coefficients for the Seigal (1534 samples) and Hedleys Creek (974 samples) stream-sediment data. The mid-rank method was used in the case of ties. As tungsten, molybdenum, bismuth, and fluorine were not detected in many samples meaningless coefficients resulted for these elements. Spearman's method was preferred as it makes no assumption of normality for the data population.

	Cu	Zn	Pb	S	Sn	Nb	Li	Be	Rb	U	As	Th	Ce	Y	Ba	Mn	Co	Ni	Cr	Fe	Ti	
Cu		0.86	0.46	0.44	-0.23	0.46	0.84	0.15	0.47	0.17	0.15	0.09	0.30	0.32	0.61	0.75	0.68	0.58	0.75	0.81	0.74	
Zn	0.82		0.52	0.43	-0.23	0.57	0.83	0.21	0.62	0.29	0.21	0.23	0.38	0.43	0.74	0.82	0.67	0.54	0.66	0.77	0.69	
Pb	0.71	0.77		0.13	-0.13	0.54	0.52	0.27	0.70	0.52	0.20	0.50	0.57	0.55	0.66	0.49	0.34	0.17	0.26	0.30	0.24	
S	-	-	-		-0.24	0.14	0.33	-0.01	0.06	-0.03	0.23	-0.06	0.21	0.04	0.25	0.37	0.29	0.25	0.41	0.52	0.42	
Sn	0.09	0.19	0.19	-		-0.10	-0.20	0.29	-0.09	-0.02	-0.14	-0.10	-0.14	-0.13	-0.16	-0.24	-0.14	-0.13	-0.33	-0.29	-0.30	
Nb	0.43	0.49	0.30	-	0.28		0.46	0.25	0.72	0.66	0.38	0.70	0.75	0.80	0.62	0.37	0.27	0.13	0.21	0.36	0.51	S
Li	0.78	0.81	0.71	-	0.17	0.42		0.25	0.60	0.27	0.03	0.21	0.33	0.38	0.73	0.77	0.67	0.56	0.70	0.71	0.60	E
Be	0.23	0.35	0.28	-	0.37	0.23	0.31		0.35	0.34	-0.10	0.21	0.20	0.26	0.35	0.21	0.33	0.20	-0.01	0.04	-0.03	I
Rb	0.71	0.81	0.69	-	0.27	0.66	0.77	0.38		0.72	0.20	0.75	0.69	0.77	0.85	0.55	0.34	0.16	0.20	0.28	0.21	G
U	0.33	0.40	0.35	-	0.34	0.70	0.35	0.34	0.58		0.27	0.83	0.69	0.81	0.53	0.23	0.17	0.05	0.01	0.05	0.06	A
As	0.46	0.57	0.52	-	0.19	0.46	0.42	0.23	0.50	0.53		0.34	0.43	0.31	0.12	0.10	0.00	-0.05	0.10	0.26	0.24	L
Th	0.38	0.46	0.43	-	0.35	0.79	0.45	0.25	0.72	0.83	0.58		0.78	0.81	0.52	0.14	0.02	-0.07	-0.03	0.01	0.05	
Ce	0.49	0.57	0.48	-	0.26	0.74	0.52	0.28	0.66	0.71	0.58	0.80		0.80	0.58	0.28	0.17	0.03	0.12	0.26	0.28	
Y	0.51	0.51	0.40	-	0.28	0.83	0.49	0.27	0.67	0.76	0.50	0.81	0.77		0.59	0.35	0.23	0.06	0.08	0.19	0.25	
Ba	-	-	-	-	-	-	-	-	-	-	-	-	-	-		0.68	0.51	0.34	0.47	0.51	0.43	
Mn	0.72	0.75	0.65	-	0.05	0.28	0.72	0.21	0.61	0.16	0.34	0.22	0.34	0.34	-		0.74	0.55	0.64	0.68	0.54	
Co	0.62	0.61	0.53	-	0.15	0.15	0.62	0.40	0.46	0.13	0.27	0.12	0.26	0.26	-	0.69		0.70	0.60	0.63	0.51	
Ni	0.59	0.50	0.44	-	0.01	0.02	0.49	0.13	0.25	0.01	0.23	-0.02	0.15	0.14	-	0.55	0.55		0.66	0.58	0.51	
Cr	0.61	0.49	0.50	-	-0.02	0.11	0.55	0.04	0.32	0.12	0.36	0.15	0.20	0.19	-	0.51	0.46	0.61		0.83	0.75	
Fe	0.77	0.80	0.60	-	0.14	0.49	0.73	0.28	0.66	0.41	0.59	0.44	0.62	0.54	-	0.65	0.61	0.53	0.61		0.81	
Ti	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		

HEDLEYS CREEK