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A HEAVY-MINERAL SURVEY OF THE FORSAYTH AREA NORTHEAST QUEENSLAND

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A heavy-mineral survey of the Forsayth 1:100 000 Sheet area, northeast Queensland, is described. The suitability of the technique for detecting gold, tin, and probably uranium mineralisation in the region has been established. The heavy-mineral method is also useful in the interpretation of sieved-sample surveys, and can provide valuable input to geological and metamorphic mapping programs.

Introduction

In 1972, the Bureau of Mineral Resources and Geological Survey of Queensland began a detailed investigation of the geology and mineralisation of the Georgetown region in northeast Queensland. Orientation geochemical studies in 1972–3 (Rossiter, 1975) were forerunners to a regional stream-sediment survey of the Forsayth 1:100 000 Sheet area, combining both sieved-fraction and heavy-mineral samples, in 1974. The regional stream-sediment coverage was designed to delineate broad areas where detailed exploration should be concentrated and to establish a sound framework on which to base future work. The results of the sieved-fraction sampling were discussed by Rossiter & Scott (1978).

The Georgetown region has a semi-arid to monsoonal climate. The mean annual rainfall is about 800 mm and the average daily maximum temperature is about 33°C. Most of the region is covered by savannah woodland dominated by small eucalypts : large trees are generally found only along watercourses. As a consequence of the seasonal rainfall, most streams are dry during the winter: active dissection of the upland areas occurs during the wet season, however, and recently worked sediment is abundant in nearly all stream beds. Permanent waterholes occur almost exclusively on only the largest rivers.

The Newcastle Range is the most prominent topographic feature, and consists mainly of resistant Palaeozoic felsic volcanic rocks. It is flanked to the east and west by moderately hilly country occupied by Precambrian granitic and metamorphic rocks.

The results of the first systematic geological investigation of the Forsayth 1:100 000 Sheet area were published by White (1962, 1965). More recently, detailed mapping has been carried out by Bain & others (1976), and the following notes are based on their work. The regional geology has been described by Withnall & others (1980).

The oldest rocks in the area are the ?Middle Proterozoic Einasleigh Metamorphics and Robertson River Formation (Fig. 1), which may be correlatives. Both comprise multiply deformed, regionally metamorphosed sandstone-siltstone-shale sequences: the former underwent upper amphibolite (and minor granulite) grade metamorphism with greenschist overprinting in places; metamorphism of the latter ranged from greenschist to upper amphibolite facies. During and shortly after deposition of the Robertson River Formation numerous small mafic intrusions (and probably some flows) were emplaced: the amphibolite in the Einasleigh Metamorphics may be related.

The metamorphic rocks are intruded by three major granitic bodies (the Forsayth, Copperfield, and Robin Hood Batholiths) and many smaller plutons. The Forsayth and Copperfield Batholiths are ?Middle Proterozoic and both contain a number of phases. The Robin Hood Batholith may be considerably younger (?Silurian–Devonian) and is remarkably uniform.

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Continental felsic volcanics of the Carboniferous Newcastle Range Volcanics and the Permian Agate Creek Volcanics overlie the Precambrian rocks of the region. Plugs and dykes of rhyolite and microgranite, presumably related to the volcanics, are widespread. Jurassic and Cretaceous marine and non-marine sediments cap many hills in the region.

Mineral deposits are numerous in the Forsayth Sheet area (Withnall, 1976; Bain & Withnall, 1980), although there is no mining on a significant scale at present. The gold deposits of the Forsayth Goldfield occur mainly as small fissure reefs within the Forsayth Batholith. Copper-lead-zinc mineralisation within the Einasleigh Metamorphics in the northeast corner of the area is confined to a single stratigraphic level (Bain & Withnall, 1980) and is probably syngenetic in origin. Small stratigraphically controlled lead-silver deposits occur close to the top of the Robertson River Formation southwest of Forsayth.

Although tin production has been negligible, large stream-sediment tin anomalies are associated with the Newcastle Range Volcanics and overlying sediments (Rossiter & Scott, 1978), and the region holds some promise for the discovery of economic tin deposits. The presence of Maureen-type uranium-molybdenum-fluorine mineralisation (O'Rourke, 1975; Bain, 1977) associated with the Palaeozoic igneous sequences (and their basal sediments) cannot be discounted entirely. Gold deposits in the Oakville and Percyville districts in the south of the area are spatially related to similar rocks, and there may be a genetic relationship as well (Bain & Withnall, 1980).

Sample collection and processing

Field procedures

The bulk of the sampling was carried out during July, 1974, using a Hughes 500 helicopter with a three-man crew (pilot, geochemist-navigator, and field hand). For ease of navigation the sampling loops were designed where possible to follow a major stream, and landings were made at points where tributaries entered. At each locality (Fig. 2) the aircraft remained on the ground for 2–5 minutes, while one or two 5–10-kg samples were taken. Active sediment from near the centre of the stream channel was collected where this was possible: each sample was a composite of three or four scoops a few metres apart. Four loops of about twenty sample sites each could be completed in a day, using about 4 hours flying time. In all, 1121 samples were collected, giving an overall sample density of about one per 2.5 km^2.

The helicopter was able to maintain vertical performance carrying its crew of three, about 150 kg of samples, and sufficient fuel for the return to base camp: however, it was found better to complete loops in difficult terrain in the cool of the morning, when the aircraft performed best. Normally, little difficulty was experienced in landing close to the predetermined sample sites, and it was necessary to move a site closer to a clearing in fewer than 5 per cent of cases. Only rarely was a ground traverse to a sample point needed to maintain adequate sampling coverage.

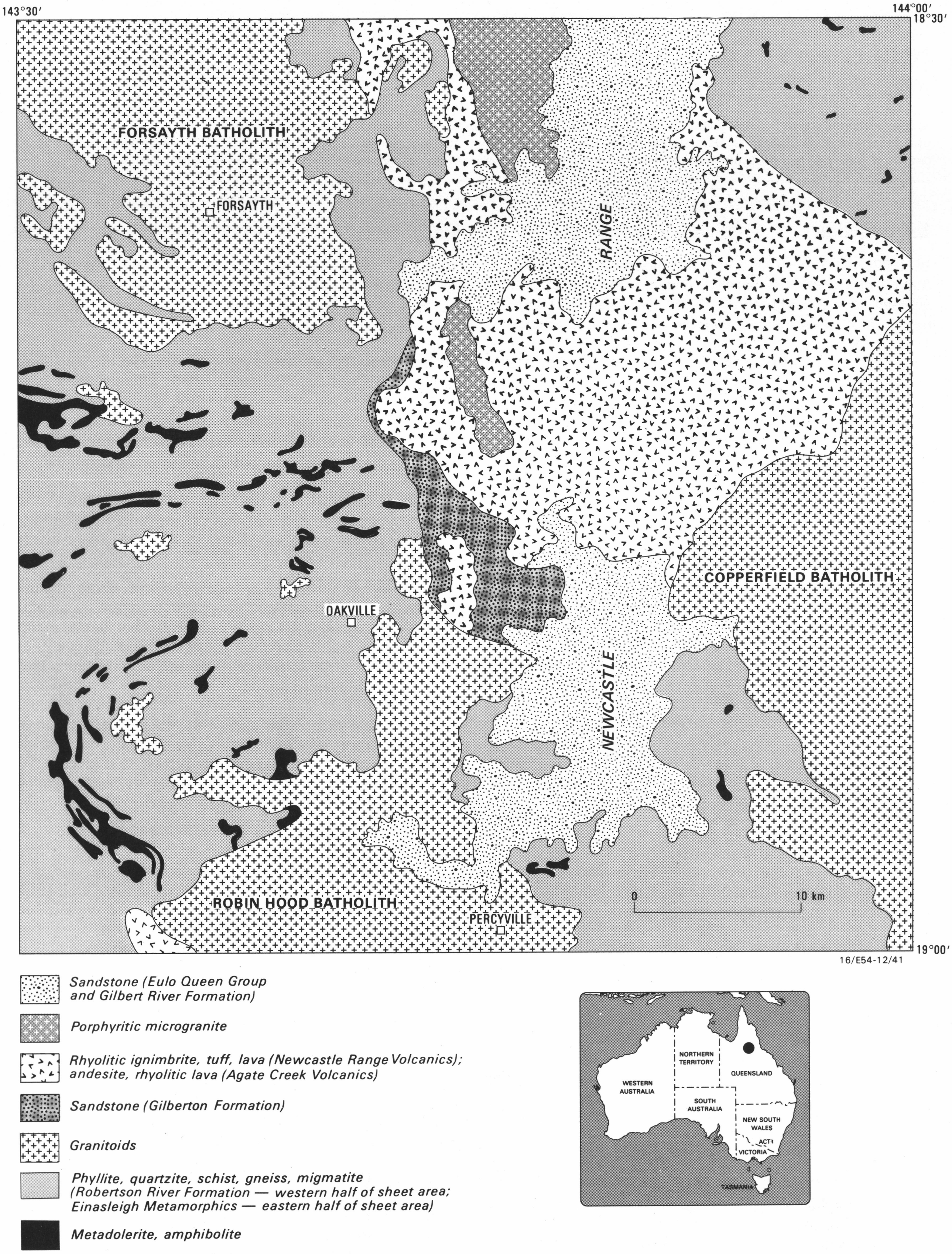


Figure 1. Main rock types.
Simplified from Rossiter & Scott (1978) and modified to take account of Withnall & others (1980).

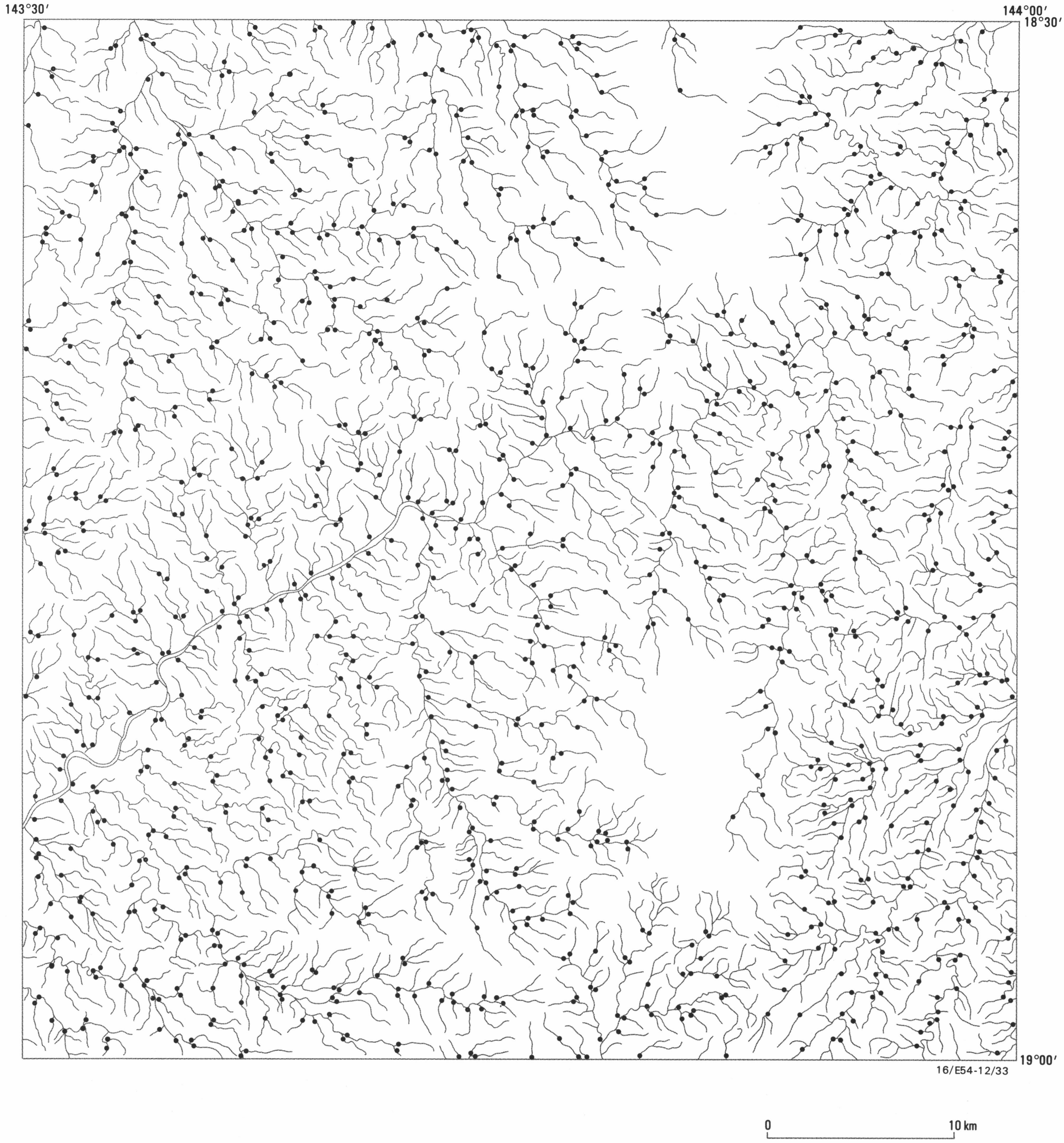


Figure 2. Sample localities.

At the base camp, each sample was passed through a series of non-contaminating sieves and panned in a prospector's dish* (Fig. 3A). The camp was beside a permanent waterhole and abundant water was available for panning. The heavy minerals were transferred from the pan to a Petri dish and dried in the sun. They were then packed in plastic vials for shipment to the laboratory.

Laboratory procedures

From the field, the samples were sent to the Australian Mineral Development Laboratories for static tetrabromoethane separation. Most of the quartz and feldspar were removed by this procedure, although some fragments, which had presumably stuck to denser grains, persisted in the concentrates. Muscovite and biotite have specific gravities similar to that of tetrabromoethane (2.96), but, owing to their flaky habit, these minerals seldom sank in the heavy liquid.

All subsequent processing of the samples was carried out in the Bureau of Mineral Resources laboratories (Fig. 3B). Firstly, a hand magnet was used to remove magnetite, which was common in most concentrates. The heavy minerals were then checked for anomalous radioactivity on a gamma-ray spectrometer to see if monazite was present. Next, the samples were passed through a Franz isodynamic separator set at a side slope of 10° and a forward slope of 20°. An initial pass at 0.2 or

*A Wilfley table was used successfully in later surveys.

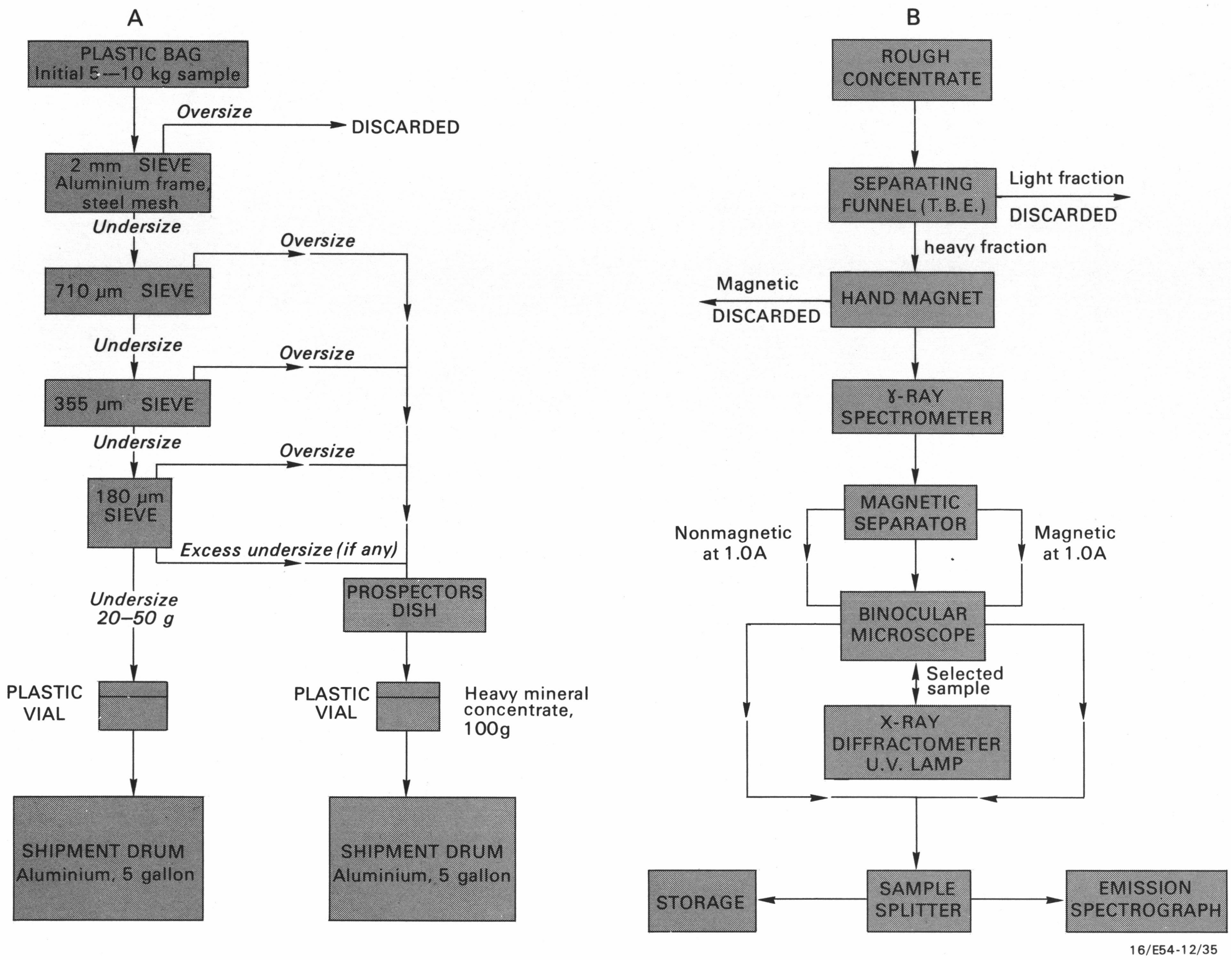


Figure 3. Flow charts of sample treatment in the field (A) and laboratory (B).

0.4 A (the lower current was used if there was any tendency for magnetic minerals to clog the separator) removed ilmenite and garnet, and a further pass at 1.0 A extracted minerals such as epidote, monazite, hornblende, and tourmaline.

The magnetic and non-magnetic fractions were then examined under a binocular microscope fitted with a zoom lens. Generally, the non-magnetic fraction, which contained most of the minerals of economic interest, was small enough for checking to be completed in 15–30 minutes. Any grains that could not be readily recognised were removed with a needle and identified by X-ray diffraction. Selected samples were examined under short (<300 nm) and long-wavelength (300–400 nm) ultraviolet light to check for the presence of fluorite, scheelite, etc. The fractions were then recombined and passed through a sample splitter: one split was crushed and analysed by emission spectrograph for antimony, barium, bismuth, cobalt, chromium, copper, gold, lanthanum, lead, molybdenum, niobium, silver, strontium, tin, tungsten, yttrium, and zinc; the other was stored for later reference.

Discussion of results

Of the minerals identified in the Forsayth concentrates only nine (about one-third) can be considered to be of any economic consequence. Gold, fluorite, cassiterite, and anglesite appear to be the only direct indicators of mineralisation present. Monazite and epidote can be classified as having indirect economic significance, as checking heavy-mineral samples for these species would prove useful in the interpretation of data obtained from future sieved-sample surveys in the region. Andalusite, staurolite, and sillimanite might be useful exploration indicators if the presence of mineralisation (or the possibility of its detection) was somehow related to the metamorphic grade of the host rocks.

Minerals of direct economic significance

Gold. Gold occurs as rounded, irregular grains in the concentrates: a brassy colour often suggests the presence of some copper in solid solution. Malleability is the best test for a suspect grain. Not surprisingly, about 40 per cent of the samples containing gold came from the Forsayth Goldfield area (Fig. 4), but auriferous concentrates were obtained from many other parts of the region as well.

To smooth the data, the Sheet area was divided in twenty-five equal cells and a moving average analysis of the number of gold-bearing samples in each cell was carried out, using a square four-cell window with a 50 per cent lateral overlap. The results are shown in Figure 4: gold concentrations in the northwest and southwest of the study area are strongly highlighted. Cells in which there has been little or no mining activity and which contain three of more gold-bearing samples are indicated in the inset and exploration for previously undetected gold lodes in these areas might be successful. However, the gold so indicated in the north-central and southeast parts of the area may be shedding from Mesozoic sediments after being eroded from the Forsayth and Percyville Goldfields, respectively.

The occurrence of gold in two streams draining only Newcastle Range Volcanics supports the contention of Bain & Withnall

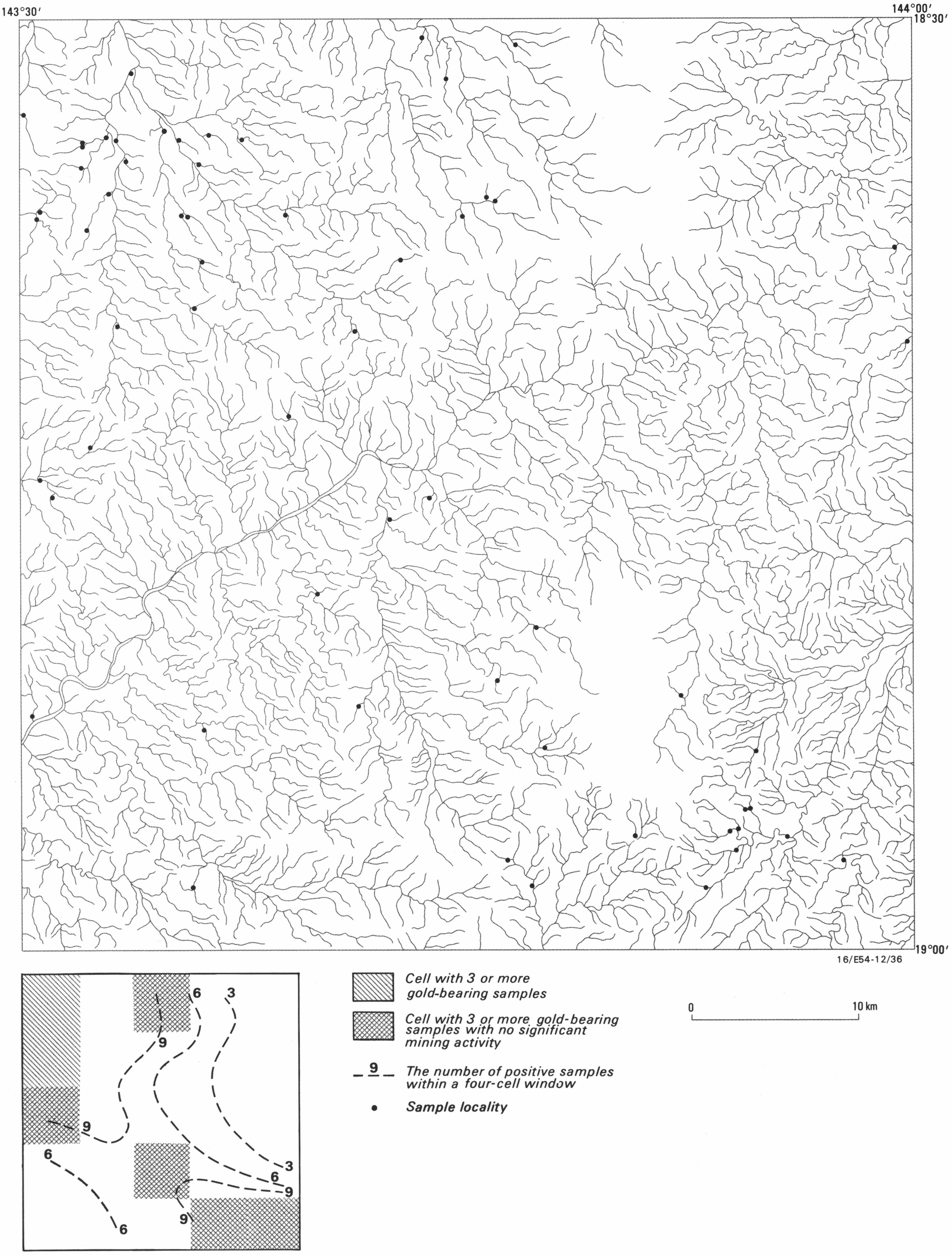


Figure 4. Distribution of gold-bearing heavy-mineral samples.

(1980) that many of the gold deposits of the region are related to Late Palaeozoic volcanic activity. It is also possible, however, that the gold in the two samples came from fossil placers in Mesozoic rocks now removed by erosion.

Fluorite. Fluorite is mentioned here as it has some potential for indicating uranium mineralisation of the Maureen type. It generally occurs in the Forsayth concentrates as equidimensional, colourless–white grains with purple blotches. Green grains are occasionally present in streams draining the Forsayth Batholith. Fluorite can sometimes be distinguished under the ultraviolet lamp by a purplish-blue fluorescence: this effect is more pronounced under long-wavelength radiation.

The distribution of fluorite in the Forsayth concentrates is shown in Figure 5. The main concentration of this mineral is near the northwestern corner of the area and is obviously associated with rocks of the Forsayth Batholith. Cells with more than one fluorite-bearing sample are shown in the inset. Of these, the one in the centre of the area is perhaps the most interesting, as Carboniferous sediments prospective for uranium mineralisation are conspicuous here. Company exploration in this area, however, has not located any mineralisation of economic significance.

Cassiterite. The cassiterite in the Forsayth heavy-mineral samples is fine-grained and difficult to identify microscopically. Figure 6 is based on spectrographic analyses of the concentrates. As tin rarely enters the crystal lattices of many heavy minerals — sphene and micas are notable exceptions (Hamaguchi & Kuroda, 1969), but these are not abundant in the Forsayth samples — tin analyses can be taken as fairly reliable indicators of the presence of cassiterite. Where the mineral could be confidently distinguished under the microscope it was present as small, equidimensional brown grains.

Samples that probably contain cassiterite are largely confined to the northeast quarter of the area, where Newcastle Range Volcanics and Mesozoic sediments crop out. It appears that the mineral has originated from both mineralisation in the Newcastle Range Volcanics and locally-derived fossil placers at the base of the Mesozoic sequence. If the cassiterite shedding from the Mesozoic had a distant source, large amounts of this mineral would be expected in all other parts of the area where rocks of this age are represented. However, apart from a slight concentration in the south-central part of the study area, such an effect is not observed. The large tin anomalies outlined by the sieved-sample survey (Rossiter & Scott, 1978) and the present study have not been thoroughly evaluated by exploration companies.

Anglesite. Anglesite has been noted in a few concentrates from the Forsayth Goldfield, but is not readily recognisable under the microscope. Spectrographic lead determinations do not help, as samples rich in monazite contain anomalous lead derived from radiogenic decay. In addition, the anglesite present does not appear to fluoresce under ultraviolet light. It was thought that anglesite might prove a useful indicator of gold mineralisation, but, because of the problems mentioned above, this did not prove to be the case.

Minerals of indirect economic significance

Monazite. Monazite is abundant in the Forsayth heavy-mineral concentrates (Fig. 7). It occurs as smallish, rounded, colourless to yellow and red grains, and is easily detected by gamma-ray measurements. Monazite is particularly common in streams draining the Forsayth Batholith and the Einasleigh Metamorphics. It is noticeably scarce in areas occupied by Newcastle Range Volcanics and low-grade Robertson River Formation rocks.

Monazite can be considered to have some economic significance, as it produces geochemical and radiometric anomalies that are not related to uranium mineralisation. During a stream-sediment survey for uranium, it is necessary to have a technique for discounting anomalies caused by monazite. The examination of heavy-mineral samples and the consideration of analytical data for elements such as cerium and thorium (Rossiter & Scott, 1978) can both be used for this.

Epidote. Epidote is very common in the Forsayth concentrates, but the mineral varies greatly in appearance. Most commonly, it occurs as large yellowish-green grains, often having striated crystal faces. In streams draining mafic igneous rocks within the Robertson River Formation the epidote grains are similar, but light brown. Small, rounded, yellow epidote grains are abundant in areas where Einasleigh Metamorphics crop out: white and pink varieties occur on occasions.

Brown epidote has some economic interest as an indicator of mafic igneous rocks in the Forsayth area. Such rocks produce copper anomalies in sieved samples taken downstream from them and, if these are to be distinguished from copper enrichment related to mineralisation, heavy-mineral work or scrutiny of analytical data for elements such as cobalt, nickel, and chromium is necessary.

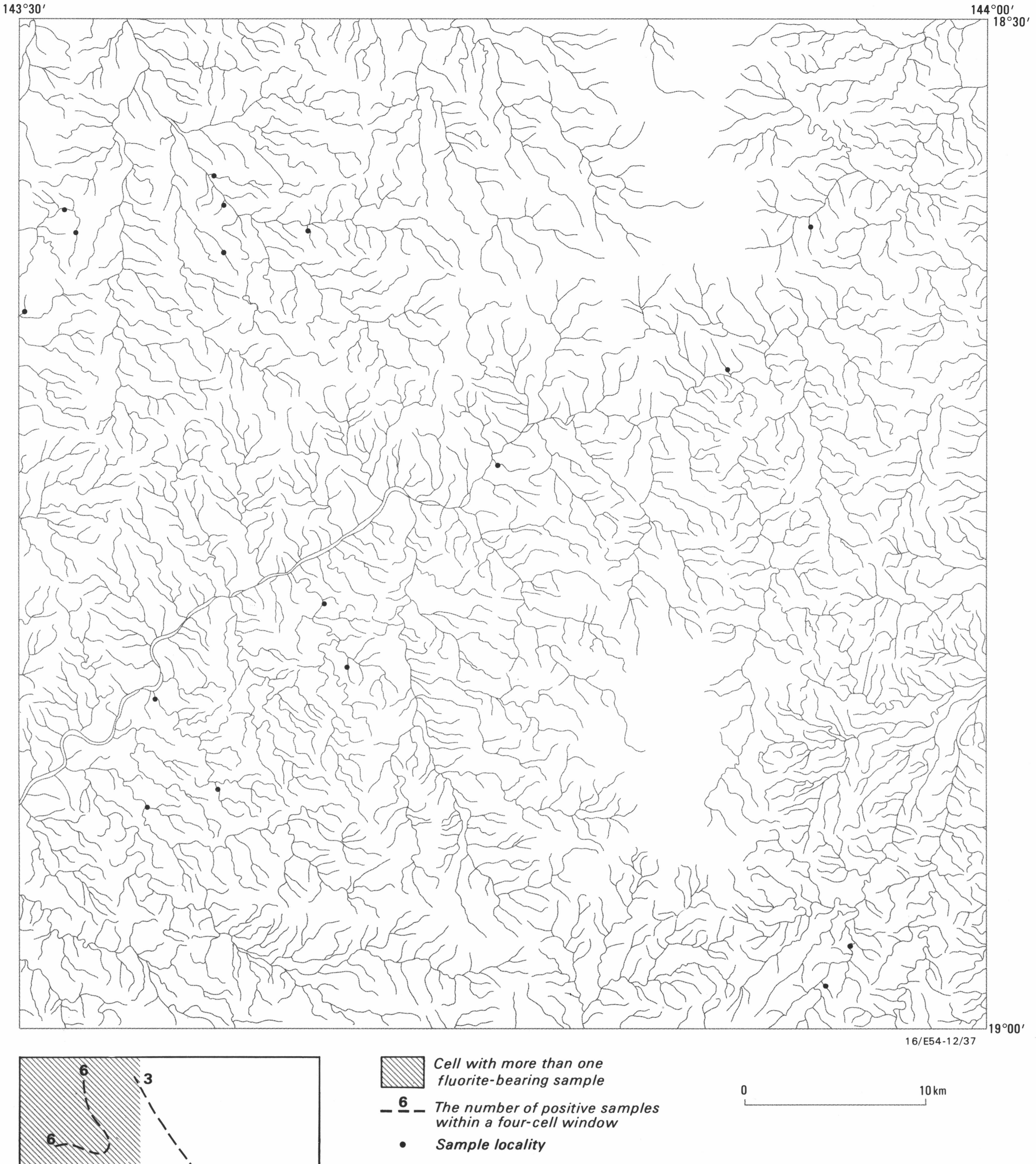
Andalusite, staurolite, sillimanite. Andalusite is present as large, rounded, transparent grains, ranging from colourless to pink: numerous black inclusions are diagnostic. There is also an opaque, light grey-brown variety. Staurolite occurs as largish, equidimensional crystals, varying from orange to red-brown. Conchoidal fracturing can be seen in places, but none of the cruciform twins that characterise staurolite in other areas was observed. Sillimanite is present mainly as large, white to grey, sometimes iron-stained, fibrous masses (fibrolite) with large clear to milky, striated grains occurring in places. Micaceous aggregates in some samples appear to be retrogressed sillimanite.

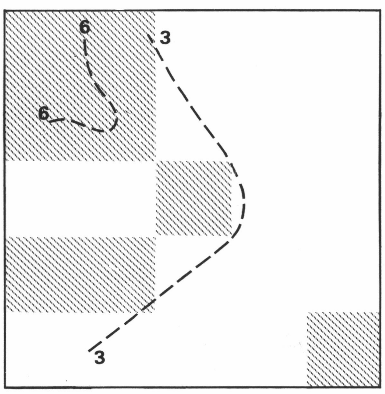
Figure 8 shows the distribution of these minerals within the Forsayth 1:100 000 Sheet area and the metamorphic zones that can be inferred from them. Andalusite and staurolite are confined to streams draining Robertson River Formation rocks, but sillimanite is more general in its distribution. The onset of amphibolite facies conditions is marked by the formation of andalusite and staurolite. At higher pressures, andalusite disappears and staurolite coexists with sillimanite. At still higher pressures staurolite disappears and sillimanite is the only one of these metamorphic indicators preserved in the heavy-mineral assemblages. In a similar application, Stendal (1978) mapped metamorphic facies boundaries in Norway by noting the distribution of hornblende and hypersthene in heavy-mineral samples.

The heavy-mineral technique may have exploration significance in an area where syngenetic mineralisation has reached economic grade (or economic grain size) only when the host rocks were subjected to certain metamorphic conditions. In addition, heavy-mineral reconnaissance in unmapped areas could indicate whether metamorphism has been severe enough to cause the reduction of pyrite to pyrrhotite and enable the usefulness of magnetic surveys to be assessed.

Other minerals

Garnet, hornblende, and iron oxides and hydroxides are, with epidote, the most abundant minerals in the Forsayth concentrates, and seem to be associated with most of the rock units. Almandine is the most common garnet variety: it occurs as largish, rounded, equidimensional, pink to reddish grains, commonly with pitted surfaces. In streams draining the



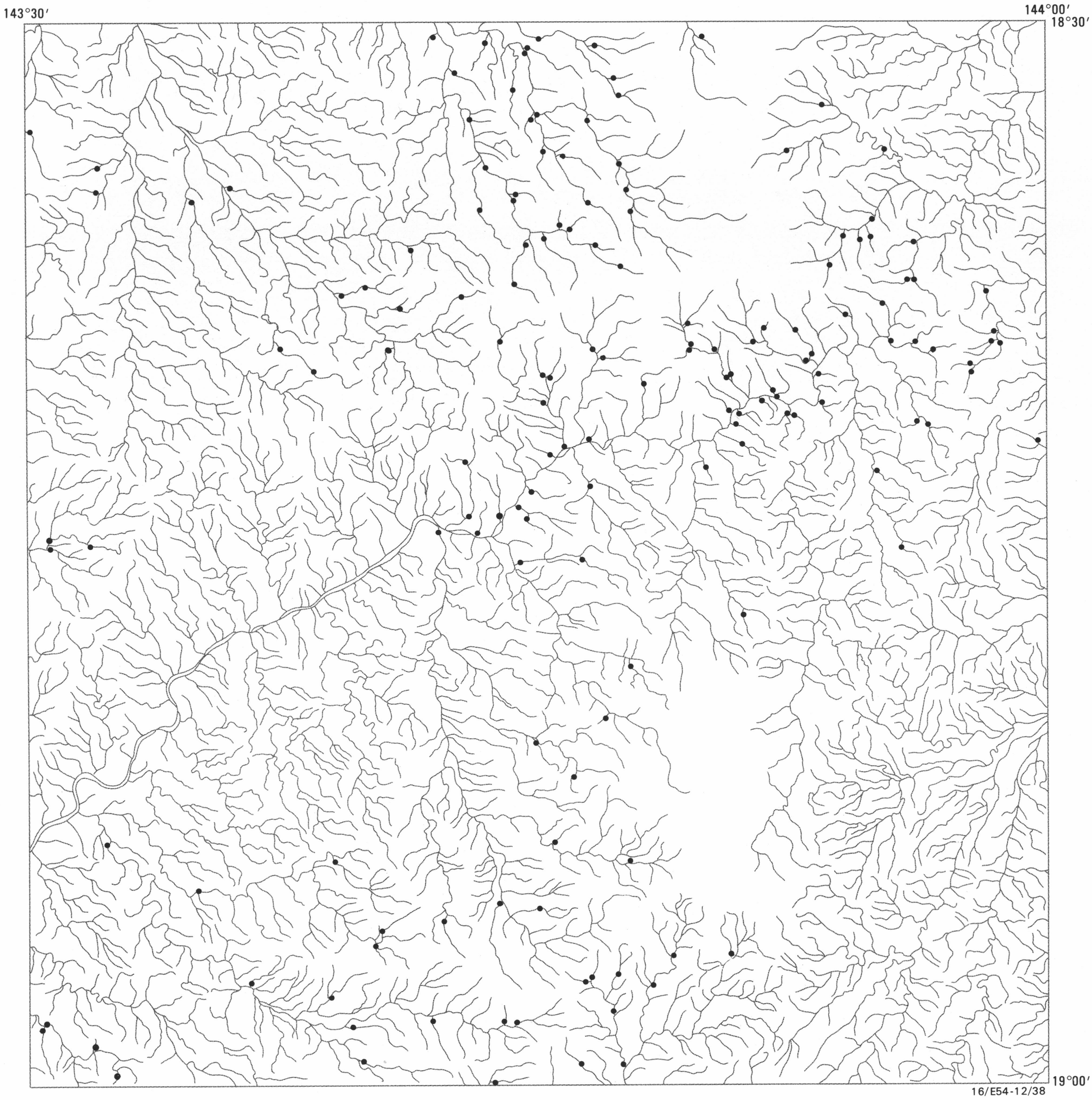


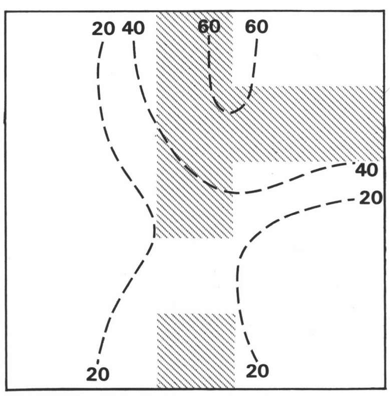
Cell with more than one fluorite-bearing sample

6 The number of positive samples within a four-cell window

• Sample locality

Figure 5. Distribution of fluorite-bearing heavy-mineral samples.





Cell with more than 10 cassiterite-bearing samples

20 The number of positive samples within a four-cell window

• Sample locality

0 10 km

Figure 6. Distribution of cassiterite-bearing heavy-mineral samples.

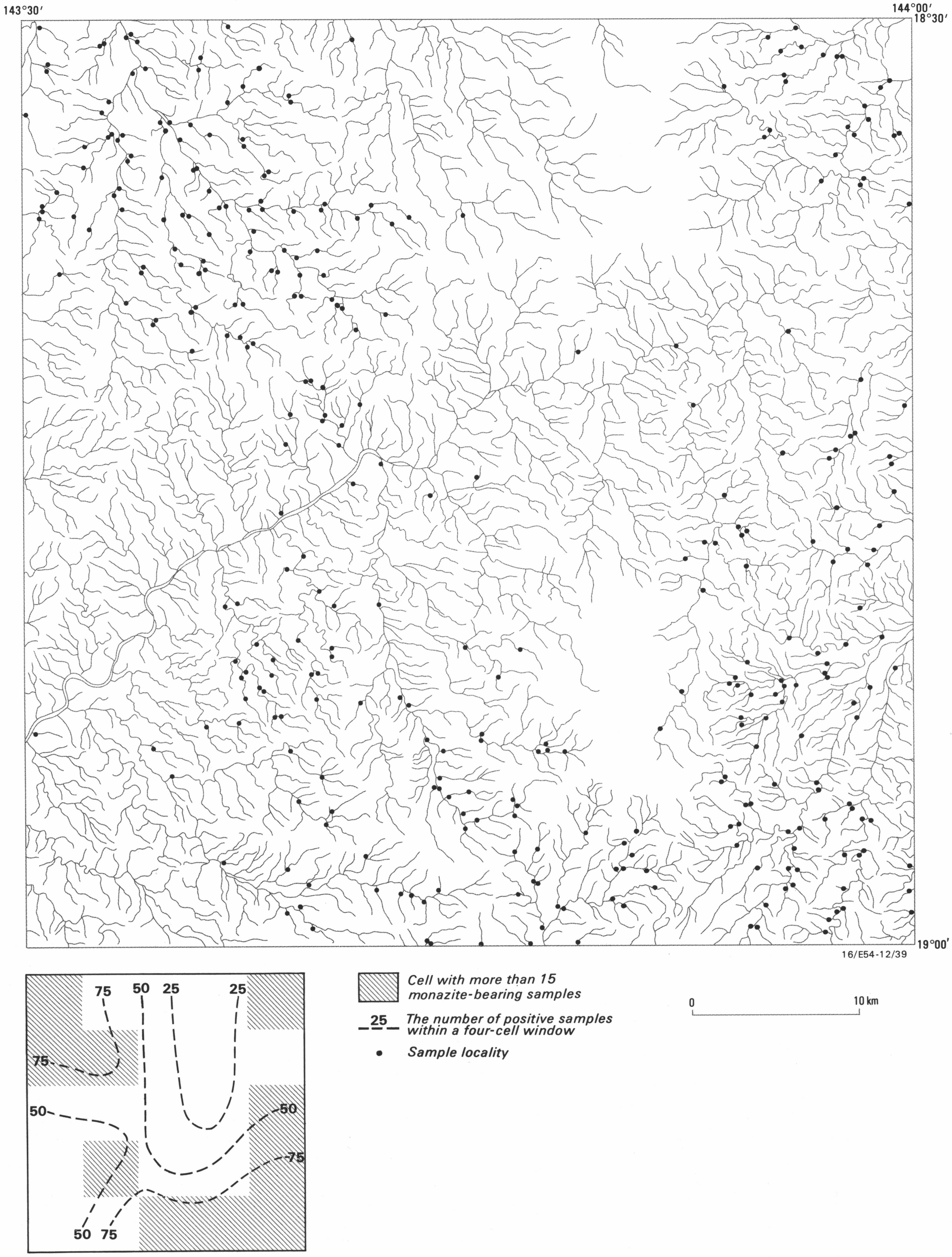


Figure 7. Distribution of monazite-bearing heavy-mineral samples.

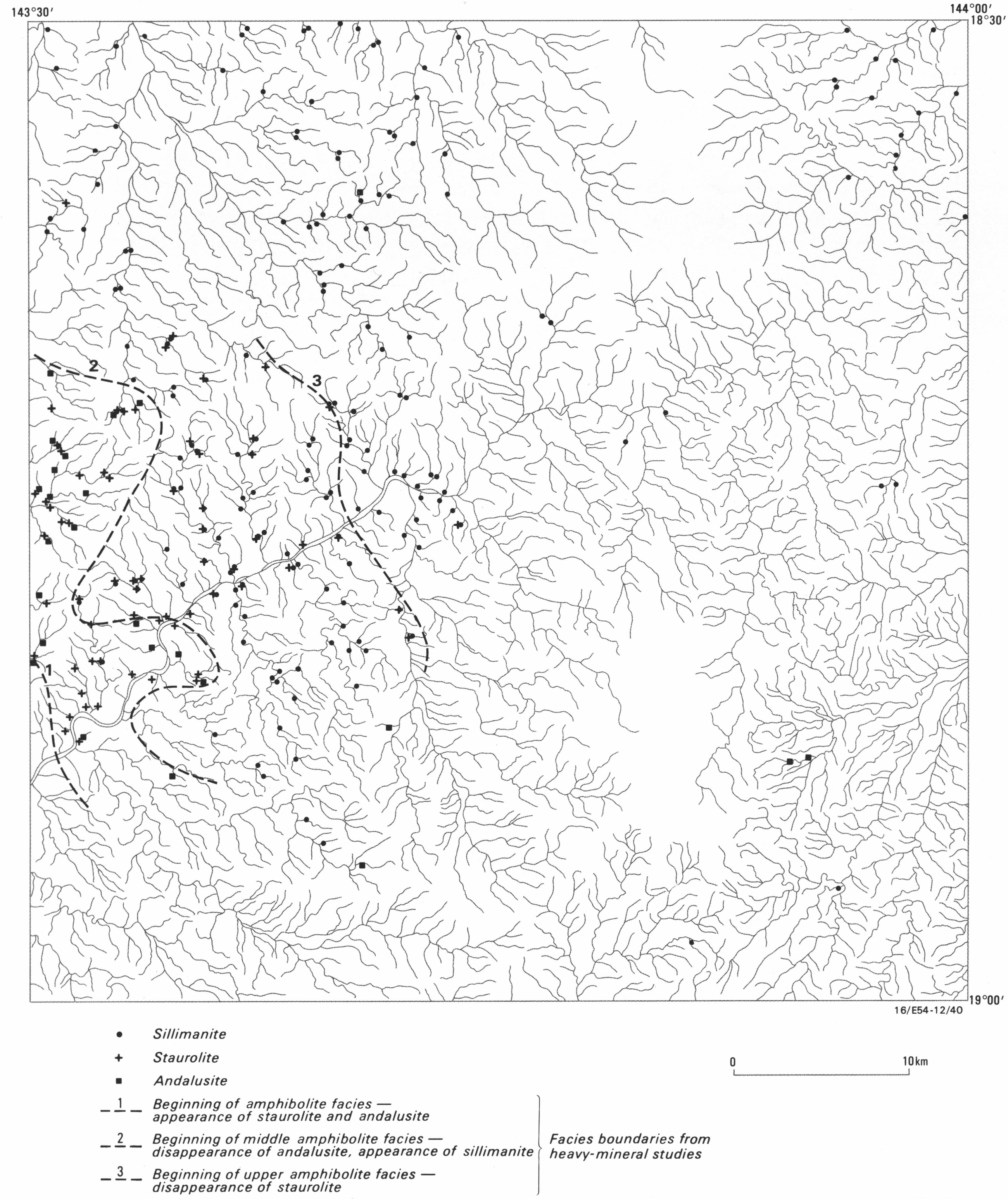


Figure 8. Distribution of heavy-mineral samples containing andalusite, staurolite, and sillimanite, and their inferred metamorphic zones.

Copperfield Batholith, small, euhedral, brown spessartine grains are conspicuous. Hornblende is generally dark green, but brown grains are prominent in some areas. The grains are mostly irregular and ragged: striated faces and fractures filled with light green chlorite are prominent features. Iron minerals are represented in every sample. These minerals were not studied in detail, but all concentrates were checked for anomalous chromium. Ilmenite is the most abundant, but hematite and limonite (sometimes forming cubic pseudomorphs after pyrite) are also present. The spectrographic analyses suggest that chromite occurs only in small amounts.

The common accessory minerals in the concentrates are brown prismatic-rounded tourmaline, bladed-prismatic red to black rutile, colourless, white, yellow, and brown zircon, showing a variety of habits, and colourless to white apatite grains of diverse form. Of less common occurrence are topaz, sphene, anatase, and spinel; kyanite, grossular, xenotime, barite, andradite, and diopside are rarely present.

Conclusions and recommendations

As expected, gold emerged as the most important indicator of mineralisation during the Forsayth heavy-mineral survey. It was found in many streams remote from known mine workings and perhaps there are deposits awaiting discovery within the area. The heavy-mineral survey also proved capable of detecting tin and, probably, uranium concentrations, but produced few data for examples of such mineralisation additional to those provided by the sieved-sample work.

The examination of every concentrate during a program like the Forsayth survey involves an enormous amount of work, and future surveys of this kind could probably be justified only in areas where there is very good reason to suspect potentially economic deposits of gold, platinum-group metals, or diamonds, which would not normally be detected by conventional sieved-sample surveys. It is a fairly simple matter, however, to collect a heavy-mineral separate while carrying out a routine stream-sediment survey, and there is no doubt that examination of the corresponding concentrate can be of great assistance in the interpretation of an ambiguous sieved-sample value. In the Forsayth region such an approach is valuable in the processing of analytical data for copper and uranium. Brown epidote in a heavy-mineral sample can indicate that a copper anomaly in the associated sieved fraction is probably due to mafic igneous rocks. Similarly, monazite can be used to distinguish which uranium anomalies are likely to be associated with mineralisation. In an area of more complex metallogeny the technique could prove even more useful.

This study has established that heavy-mineral work can provide valuable input to geological and metamorphic mapping programs. Indeed, in a particularly inaccessible and densely vegetated area, the technique might prove almost indispensable. The presence in a catchment area of several rock units of the Forsayth 1:100 000 Sheet area is immediately recognisable from the heavy-mineral assemblage. For example, long, doubly terminated, clear zircon prisms with characteristic iron-staining are present in areas occupied by Newcastle Range Volcanics, while apatite prisms with colourless rims and dark cores indicate Forsayth Batholith rocks. Staurolite and andalusite are confined to the Robertson River Formation, spessartine occurs only in Copperfield Batholith rocks, and brown epidote typifies concentrates from streams draining mafic igneous rocks within the Robertson River Formation.

The survey has also shown that checking of heavy-mineral concentrates for andalusite, staurolite, and sillimanite can be used to map metamorphic zones within amphibolite facies terrains. Such work might be applicable to exploration programs in areas where syngenetic mineralisation has reached economic grade (or economic grain size) only when the host rocks were subjected to certain metamorphic conditions. In addition, heavy-mineral reconnaissance in unmapped areas could indicate whether metamorphism has been severe enough to cause the reduction of pyrite to pyrrhotite and enable the usefulness of magnetic surveys to be assessed.

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