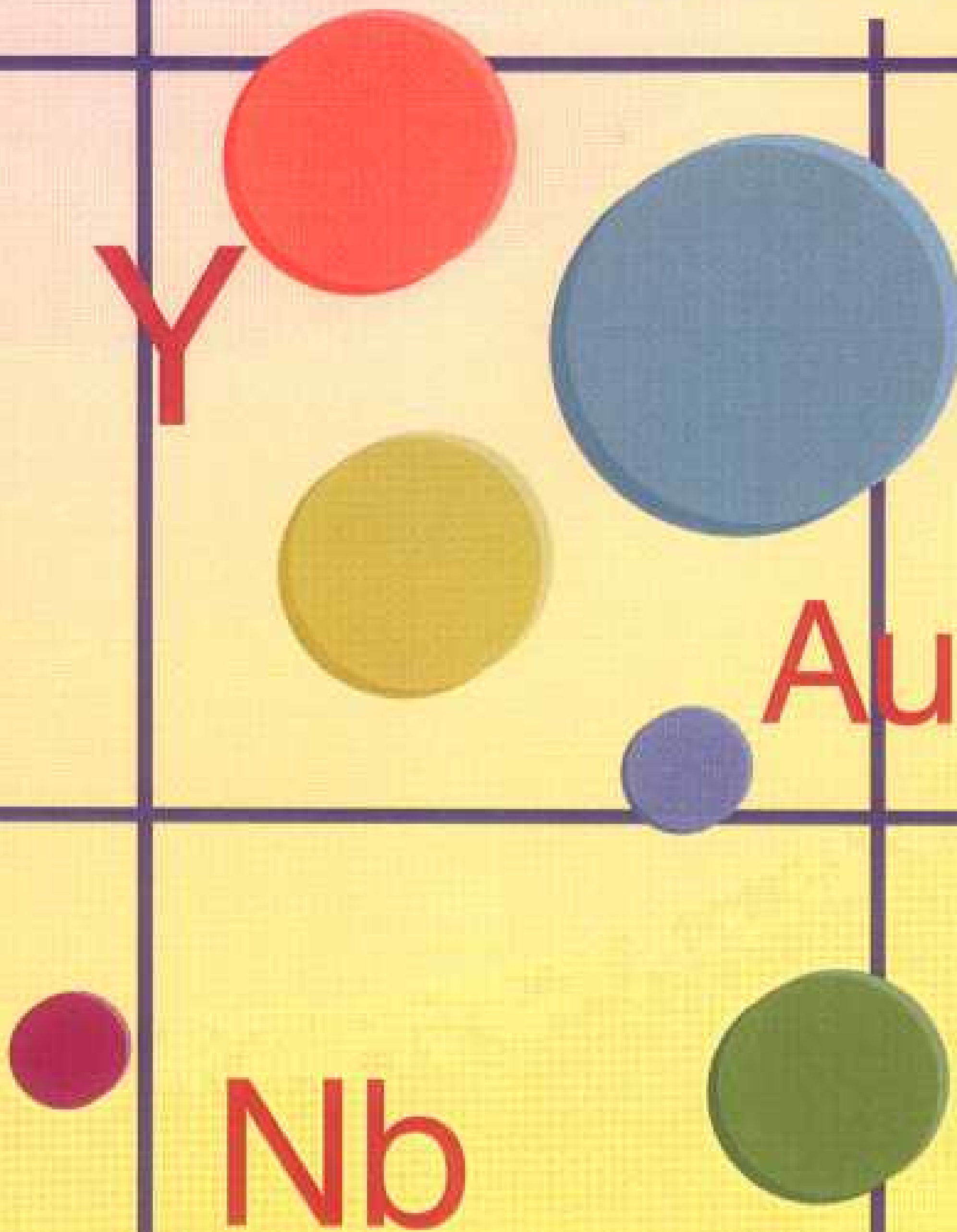
EXPLANATORY NOTES

GOVERNMENT OF WESTERN AUSTRALIA

GEOCHEMICAL MAPPING OF THE COLLIER 1:250 000 SHEET

by J. Coker and J. A. Faulkner

1:250 000 REGOLITH GEOCHEMICAL SERIES



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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Abstract

Regional regolith geochemical mapping on COLLIER at 1:250 000 scale was carried out by sampling regolith at 1008 sites, with a nominal sampling density of one sample per 16 square kilometres. Each sample was analysed for 48 chemical components, as well as pH and conductivity. The distribution of 47 components (excluding SiO_2) and conductivity are shown as spot-concentration maps, whereas acidity–alkalinity and standard scores are shown as contour maps.

Geological, geomorphological, and botanical information are summarized, and open-file company data dealing with surface geochemistry and mineral production are tabulated. The generalized regolith map, showing the distribution and composition of regolith, was compiled using Landsat and geophysical imagery, aerial photography, and regolith characteristics recorded at each sample site. COLLIER is characterized by roughly equal areas of erosional, colluvial, and alluvial regolith units, with a further 10% of regolith being either relict or eolian.

The chemistry of regolith on COLLIER is mainly controlled by bedrock composition, with dolerite, in particular, providing a distinctive regolith and regolith chemistry. Statistical treatment of assay data has distinguished different source units beneath sandplain, and indicated more than one population of dolerite.

Additive-index maps highlight areas of anomalous chemistry, such as the Ilgarari mining locality (As and Bi) and the Beyondie Bluff area (Mo and Sb). Sample-site data have been integrated with chemistry and bedrock geology to determine the derivation of ferruginous clasts.

Combining regional regolith chemistry with information on bedrock geology has indicated background levels of components. Areas on COLLIER worthy of further investigation include the Yilgarn Craton (shear-hosted gold), and parts of the Bangemall Basin (stratiform and fracture-related base-metal mineralization in areas of dolerite intrusion).

KEYWORDS: Collier, geochemistry, regolith, mineralization.

Introduction

The COLLIER* regolith geochemical mapping Explanatory Notes are part of a systematic 1:250 000-scale mapping program, conducted by the Geological Survey of Western Australia (GSWA), to collect and synthesize information about the distribution and composition of regolith, in order to assist the mineral exploration industry and other landuse agencies. The regional regolith geochemical mapping program originally focused on the northern part of the Yilgarn Craton. More recent work has concentrated on the less extensively explored areas between the Pilbara and Yilgarn Cratons (Fig. 1; Morris et al., 1998), the Northampton Block, and part of the Albany–Fraser Orogen.

The term 'regolith' is used in the sense of Merrill (1897) to include surficial rock and consolidated or unconsolidated material derived from the weathering and erosion of bedrock. Regolith can form in situ or be transported. Depositional processes include gravitational, fluvial, or eolian action, and chemical precipitation. Large areas of Western Australia are covered by regolith, which restricts direct examination of the bedrock and the contained mineralization. An understanding of the distribution of regolith is, therefore, a valuable and necessary exploration tool (Smith et al., 1989). The main aim of the GSWA regolith geochemistry program is to determine the distribution of regolith types and provide information on the composition of regolith in the form of a geochemical database. These data can form the basis for more-detailed geochemical mapping to identify potential mineralization. Regolith chemistry is also very useful in delineating bedrock units.

* Capitalized names refer to standard 1:250 000 map sheets

Location and access

The COLLIER 1:250 000 sheet (SG 50-04) is bounded by latitudes 24°00' and 25°00'S and longitudes 118°30' and 120°00'E (Fig. 1). The few residents are mainly involved in the mineral exploration and pastoral industries.

The Collier Range National Park covers the central part of the map sheet, and pastoral stations partly or wholly on COLLIER include Weelarrana, Bulloo Downs, Kumarina, Marymia, Mount Vernon, Mingah Springs, Mulgul, Milgun, Woodlands, and Tangadee (Plate 1 and Fig. 2).

The Great Northern Highway crosses the eastern half of the map sheet, and a road linking Meekatharra and Onslow via the Ashburton Valley runs along the western boundary of COLLIER. Station tracks allow access to most of the map sheet, although some of the more rugged country is difficult to reach using ground-based vehicles. During wet weather, most roads become impassable due to flooding. Most stations have airstrips suitable for light planes.

Climate

The climate on COLLIER is arid, with average rainfall of about 200 mm per year and average potential evaporation of 2500 mm per year with no assured growing season. The low precipitation is irregular and associated with thunderstorm and cyclonic events in late summer to early winter. January is the hottest month with a temperature range of 25 to 38°C, and July is the coolest month with a temperature range of 7 to 23°C.

Vegetation

COLLIER lies in the Eremaean Botanical Province of Diels (1906). Beard (1985) subdivided Western Australia into phytogeographic regions based on botanical provinces, regions, and districts or subdistricts, and COLLIER covers part of the Ashburton and Keartland Districts (Beard, 1975).

The southern and eastern parts of COLLIER are part of the Gascoyne Range subdistrict of the Ashburton District. These rugged areas with poor soil cover are dominated by mulga shrubland, with snakewood and other mixed wattle shrubland or teatree in the less rugged areas. The northern, central, and western parts of COLLIER are part of the Kumarina Hills subdistrict of the Ashburton District, which consists of low woodland of *Acacia aneura* on the plains and scrub on low ranges, with *Eucalyptus microtheca* along the major drainage lines.

Part of the Keartland District covers the eastern boundary of COLLIER and is characterized by a sparse vegetation cover. The tops of hills have a grass steppe cover and scattered grevilleas, with mulga stands on the stony slopes. The intervening sandplains are covered in hummock grasslands with well-developed spinifex cover and, in places, single eucalypts, particularly on the dunes.

Geomorphology and soils

A major drainage divide passing through the eastern part of COLLIER separates regions of external and internal drainage (Plate 1). The two catchments of the external drainage are the Ashburton River to the north and Gascoyne River to the south, both of which drain into the Indian Ocean. On COLLIER the Ashburton River forms relatively narrow and incised channels, whereas the Gascoyne River consists of poorly defined channels in broad sheet-flood areas, with the Collier Range and Calyie Syncline forming the watershed (Plate 1). The internal drainage system consists of ephemeral and poorly defined watercourses draining into saline lakes.

Payne et al. (1988) and Wilcox and McKinnon (1972) divided COLLIER into three physiographic provinces (Bangemall, Eastern Tributary, and Eastern Plains), each of which can be further divided into land systems or rangeland types. A land system is defined as an area with a recurring pattern of landform, soil, and vegetation that can be readily identified on aerial photographs and on the ground. Many land systems are common to all three physiographic provinces. The landform definition includes type, dimension, slope, relief, surface features, and the relationship to other land systems (Payne et al., 1988).

The Bangemall Province covers the northern, western, and central parts of COLLIER. The province consists mostly of rugged hill and ridge country, with differential weathering of the bedrock influencing the type and extent of dissection. More-resistant rocks form massive parallel strike ridges or ranges. Soils formed in situ on stripped upland surfaces are very shallow, stony, and have uniform profiles. Soils in drainage floors have duplex profiles or are uniform, cracking and non-cracking alkaline clays (Bettenay et al., 1967).

The Eastern Tributary Province is confined to the southern edge of COLLIER and consists of low hills that rise a few hundred metres above the plains. Skeletal and shallow rocky soils with uniform profiles dominate the hills and rock outcrops. Shallow hardpan soils develop on the lower plains with clayey and duplex types on the alluvial plains.

The Eastern Plains Province extends along the eastern edge of COLLIER and consists of broad plains with shallow hardpan soils, stony plains, eolian sand dunes, and low rocky hills. Skeletal soils and shallow loamy soils with a uniform profile are located on outcrops, with dark-red or reddish-brown coarse-grained acidic sands on the plains.

In summary, the major landforms of the land systems on COLLIER are:

- ridges, hills, and low hills of sedimentary and igneous rocks;
- dissected plains underlain by hardpan, with moderate relief;
- stony uplands of areas of colluvium and subcrop, with moderate relief;

- plateaus, mesas, and buttes of calcrete, with moderate relief;
- broad areas of sandplain, sheetwash, and hardpan plains, with low relief.

Topographic and remote-sensing datasets

The topographic information used in compilation of the accompanying maps was obtained from the Western Australian Department of Land Administration (DOLA) and the Australian Land Information Group (AUSLIG). Landsat Thematic Mapper (TM) scenes were obtained from the Remote Sensing Services of DOLA. Airborne radiometric and magnetic images were generated using data from the Australian Geological Survey Organisation (AGSO; at 1500 m line spacing) and World Geoscience Corporation multiclient data (GSWA, 1996a,b; at 100 m line spacing). Other remote-sensing datasets used in the interpretation of Collier include 1:40 000-scale black-and-white aerial photographs (1972) obtained from DOLA.

Geology

Brakel et al. (1982) described the history of geological investigation on Collier prior to 1960, and also produced the first 1:250 000-scale geological map and comprehensive discussion of the geology. Their work forms the geological basis of these Explanatory Notes, except for the adopted stratigraphy (Table 1), which is after Cooper et al. (1998) and Morris et al. (1998).

Five major tectonic terrains are recognized on Collier: the Archaean Yilgarn Craton, the Palaeoproterozoic Bresnahan Basin and Gascoyne Complex, the Mesoproterozoic Bangemall Basin, and Neoproterozoic Savory Sub-basin of the Officer Basin. In these notes, rocks of the Bangemall Basin are subdivided on stratigraphic grounds into the Collier, lower Edmund, and upper Edmund Subgroups. The units assigned to these tectonic terrains are shown on the simplified geological map (Plate 1 and Fig. 3) and assigned to the individual regolith chemical analysis in the accompanying datafile COLLCHEM.CSV.

The Archaean Yilgarn Craton on Collier comprises metamorphosed granitic and sedimentary rocks (Brakel et al., 1982), with small areas of greenstone noted by Cooper et al. (1998). The greenstones are not shown at the scale of the published maps (Brakel et al., 1982). The Bresnahan Group consists of conglomerate and coarse-grained sandstone with minor siltstone and mudstone. In the Bangemall Group, the lower Edmund Subgroup has largely dolomite at the base, with increasing amounts of argillaceous rocks towards the top of the succession. The upper Edmund Subgroup mainly consists of shale with thinly bedded dolomite and subordinate amounts of argillaceous rocks, and is separated from the lower Edmund Subgroup by the Discovery Chert. The Collier Subgroup is dominated by arenaceous rocks with subordinate argillaceous units. The Savory Group is represented by the coarse-grained sandstone of the Glass Springs Formation. There are also mafic intrusions on Collier, consisting of fine- to medium-grained sills and dykes. Detailed discussion of these lithologies are in Brakel et al. (1982) and Muhling and Brakel (1985).

Table 1. Stratigraphy on Collier

This study (Plate 1; Figure 2)	*Constituent units*	*Description*
Dolerite intrusions	Sills and dykes	Fine- to medium-grained mafic igneous rocks
Savory Group	Glass Springs Formation	Medium- to coarse-grained sandstone with minor conglomerate and siltstone
Bangemall Group		
Collier Subgroup	Ilgarari Formation	Greenish shale and mudstone, minor sandstone interbeds
	Calyie Sandstone	Quartz arenite, minor feldspathic arenite, and conglomerate
	Backdoor Formation	Green and dark-grey shale
	Wonyulgunna Sandstone	Coarse- to medium-grained sandstone with local conglomerate
Upper Edmund Subgroup	Ullawarra Formation	Shale, fine-grained sandstone, dolomite, and chert
	Devil Creek Formation	Thinly interbedded dolomite and shale, minor siltstone, and sandstone
Discovery Chert	Discovery Chert	Black massive chert
Lower Edmund Subgroup	Jillawarra Formation	Grey, black, and locally greenish shale and mudstone
	Kiangi Creek Formation	Well-sorted quartz-cemented arenaceous rocks
	Cheyne Springs Formation	Dolomites with subordinate mudstone, siltstone, and sandstone
	Irregully Formation	Dolomite, shale, and sandstone with minor conglomerate, breccia, and chert
Bresnahan Group	Bresnahan Formation	Conglomerate, pebbly sandstone, sandstone, siltstone, and mudstone
Gascoyne Complex		Biotite–muscovite monzogranite with poorly developed foliation
Yilgarn Craton		Metamorphosed sedimentary and granitic rocks

SOURCE: Cooper et al. (1998)

Recorded mineralization

COLLIER is within the Peak Hill Mineral Field where there have been intermittent periods of mining for copper, lead, and manganese. Current exploration in the area focuses on base metals and gold.

Appendix 1 is a collation of data from published and unpublished sources as reported to the Department of Minerals and Energy's Royalties Branch, and includes details of mineral production for 30 individual mineral prospects on COLLIER, prior to March 1998. The coordinates identify the centre of the tenements listed, as determined from survey diagrams, mining registers, tenement application files, public plans, and TENGRAPH (the Department of Minerals and Energy's electronic tenement-graphics system). Where a WAMIN (GSWA's Western Australian Mineral Occurrence database) deposit number is listed against the tenement, locational information is provided from Cooper et al. (1998).

Gold

There is a small occurrence of gold in a borehole intersection associated with greenstone south of Beyondie Bluff, 40 km southeast of Kumarina Roadhouse (AMG 795840, 7235640*; Cooper et al., 1998).

Copper

Fault- and fissure-related copper mineralization is distributed in a north-northwesterly trending zone from north of the Ilgarari mining locality, through the Kumarina mining locality, to the Marymia Inlier (Plate 1). The Ilgararie and Kumarina mining localities have produced 896.4 t (813.4 tons) and 638.6 t (579.5 tons) of copper respectively. The copper occurrences in the Bangemall Basin are similar in style and mineralogy (Cooper et al., 1998) and commonly located at faulted shale–dolerite contacts (Marston, 1979). The most common copper minerals are chrysocolla, malachite, azurite, and chalcocite, with minor tenorite, cuprite, chalcanthite, and native copper also reported (Marston, 1979). Shales of the upper part of the Jillawarra Formation of the lower Edmund Subgroup, near the western closure of the Brumby Creek Anticline (Plate 1), contain malachite, either as thin surface coatings on bedding and joint planes or more rarely as nodules (Chuck, 1984).

Lead

Significant lead mineralization is known from the abandoned Keep-it-Dark mine (AMG 758928 7326734) and the Abra deposit (AMG 660383 7273296). The Keep-it-Dark mine and minor surface occurrences of galena north of the Ilgarari mining locality are associated with the same fault system, and dolerite is common in the immediate vicinity (Cooper et al., 1998). The main lead-bearing minerals are galena and cerussite, along with manganese oxides. The recorded production from the Keep-it-Dark mine was 1545.2 t (1402.2 tons) of lead. The Abra deposit and other stratabound deposits and occurrences are located in an easterly trending zone, about 20 km north of Woodlands Homestead (on MOUNT EGERTON to the west). The main sulfides are pyrite, galena, chalcopyrite, and sphalerite. Abra is a blind, shallow-water, polymetallic deposit at the top of the Kiangi Creek Formation of the lower Edmund Subgroup (Vogt, 1995).

Manganese

Manganese encrustation is common on rocks of the Ilgarari Formation (at the top of the Collier Subgroup of the Bangemall Basin) between the Ilgarari mining locality and Butcher Bird mine. At Yanneri Pool (7 km southeast of Yanneri Well), manganese enrichment in subcropping shales of the Calyie Sandstone of the Collier Subgroup and overlying ferricrete has been recorded by Madan (1978).

Geochemical surveys in open-file company reports

To comply with the Mining Act (1978), mineral exploration companies must lodge reports detailing exploration activity. These are listed in GSWA's WAMEX (Western Australian Mineral Exploration) database as either open-file or confidential reports. Details of open-file company reports containing surface or near-surface geochemical data for COLLIER have been summarized as part of a mineral prospectivity program in the Bangemall Basin (Cooper et al., 1998), and are shown in Appendix 3. Reports common to a particular exploration project are grouped together and assigned an identification number (ID no. of Appendix 3), which is shown, along with project boundaries, on Plate 2. Most projects cover a single area, although some projects cover two or more distinct areas. Projects with fewer than 30 reported samples have been omitted. Areas with significant surface geochemistry reported in open-file reports up to 1997 include northwest and west of the Calyie Syncline (Cu, Ni, Pb, and Zn), the Marymia Inlier (Au and Cu), Ilgarari mining locality (Cu, Zn, and Pb), Backdoor Hills (Cu and Zn), Brumby Creek Anticline (Cu and Zn), and north of the Ashburton River (Cu and Zn).

Eighteen projects covering the period from 1965 to 1996 are tabulated in Appendix 3 in order of increasing M number (the project number assigned for the WAMEX database). When reports are released to open file, the M number is replaced by an I (or Item) number, with the highest I number denoting the most recent release. Gaps in reporting result from either the failure of some tenement holders to lodge reports, or the lack of obligation of mineral-claim holders to report all of their exploration results prior to 1978.

* Localities are specified by the Australian Map Grid standard reference system. AMG coordinates of all localities on Plates 1–3 are listed in Appendix 2.

The exploration company projects listed in Appendix 3 are grouped according to the targeted mineralization as follows:

- copper 26%
- base metals 26%
- copper–lead 21%
- copper–zinc 11%
- gold 11%
- manganese 5%

Regolith sampling and mapping on COLLIER

Sampling of regolith on COLLIER was carried out in April 1998 by six, two-person sampling teams, each consisting of a geologist and field assistant. Teams were transported by two helicopters, which were ideally suited to accessing the more difficult parts of the map sheet where ground-based vehicle access would have been either slow or impossible. The classification scheme and sampling methodology are summarized in Appendices 4 and 5 (digital).

A regolith-materials map (Plate 3) has been produced for COLLIER using Landsat TM imagery, aerial photography, magnetic and radiometric data, field observations recorded at each sample site, and the 1:250 000 geological mapping of Brakel et al. (1982). The geological data for COLLIER were integrated with satellite imagery (Coker et al., 1998) and re-interpreted. Observations from the sample-recording forms completed by geologists in the field were used to validate the interpretation. The regolith-materials map has also been generalized into relict, erosional, and depositional (colluvial, alluvial, and eolian) environments in Figure 4.

The physiography of COLLIER is controlled by outcrops of the Calyie Sandstone of the Collier Subgroup (e.g. the Collier Range and Calyie Syncline), which divide the map sheet into northwest and southwest regions. Northwestern parts of the map sheet are drained by branches of the Ashburton River, which are deeply incised into areas of erosional and colluvial regolith. The Calyie Sandstone, Discovery Chert, and dolerites tend to form outcrop, whereas the Ilgarari Formation, Backdoor Formation, and dolomites of the Edmund Subgroup outcrop poorly and are covered by consolidated colluvium.

Relict regime (*R*)

The relict-regime regolith occupies about 1% of the area on COLLIER, and seven regolith samples were taken (Table 2). The relict-regime units consist of ferruginous duricrust (*Rf*) and chalcedonic capping (*Rz*) on calcretes, which are commonly located north of the Collier Range. The ferruginous duricrust makes up the majority of the relict-regime regolith, and is mainly located around the northern limb of the Ashburton River, although smaller areas exist throughout COLLIER. Small areas of ferruginous duricrust over the Archaean Yilgarn Craton could represent ferruginized greenstone belts. The ferruginous duricrust in the northern part of COLLIER is commonly near dolerites. Many of the dolerites are ferruginized and form areas of positive relief, very commonly expressed as breakaways, mesas, and knolls of massive and pisolitic deposits that locally overlie leached zones. Dolerite and ferruginized surfaces form a continuum with stripping of the lateritized surface, leaving variably ferruginized bedrock remnants. Stream sediments in these areas commonly contain ferruginous clasts.

Although calcrete is well developed on COLLIER, it is not as extensively silicified as on MOUNT EGERTON to the west. The silicified relict unit is developed on top of the calcrete and only found along the Ashburton River system. Relict quartzofeldspathic material developed on sedimentary rocks (*Rgs*) accounts for less than 1% of the total area and is a relatively stable sandstone mesa formed on low-gradient backslopes of the Collier Range.

Erosional regime (*E*)

Erosional-regime regolith makes up 30% by area of COLLIER, and accounts for 24% of regolith samples (Table 2; Plate 3). About 23% of COLLIER consists of siliciclastic rock outcrop and subcrop (*Egs*), mainly in areas of prominent relief (such as the Collier and Lofty Ranges), where it is developed on the Calyie Sandstone (Collier Subgroup) and Glass Springs Formation (Savory Group). Mafic outcrop and subcrop (*Emp*) make up 3% of the map sheet area and regolith samples, and form areas of positive relief (due to ferruginization) that are more extensively developed in the northern part of the map sheet. Carbonate outcrop (*Eks*) of the upper and lower Edmund Subgroups is of limited extent (2%), mainly in the northwestern corner of COLLIER, and accounts for less than 1% of samples collected. Erosional-regime regolith is developed over quartzofeldspathic volcanic (*Egv*), plutonic (*Egp*), and metamorphic rocks (*Egm*), which together make up less than 1% of COLLIER, near the Marymia Inlier and Coobarra Dome. The felsic volcanic regolith overlies the potassic rhyolite described by Gee et al. (1976). Small, but prominent, outcrops of erosional-regime regolith are present over banded iron-formation (*Efs*) in parts of the Yilgarn Craton and the eroding remnants of a ferruginized surface (*Ef*) near O'Donnell Soak. Due to their restricted distribution, however, no regolith samples were collected over these units. Although the Discovery Chert (*Eqs*) forms a regionally distinctive marker unit, it makes up less than 0.3% of the area of COLLIER, and accounts for only three erosional regolith samples. The Discovery Chert is only in the western part of COLLIER where, due to differential erosion, it forms the rims of synclines and anticlines.

Depositional regime (*C, A, W, O, L, S*)

Depositional-regime regolith is divided into colluvial (*C*), diluvial (*W*), alluvial (*A, O*), lacustrine (*L*), and eolian (*S*) units. Depositional-regime regolith is widespread on COLLIER, occupying about 36% of the sheet and accounting for 37% of regolith samples (Table 2, Plate 3).

Colluvial regolith (*C*) is in areas downslope from outcrop or subcrop and typically consists of medium- to

Table 2. Regolith-landform unit area and number of samples for COLLIER

Regolith code	*Area (km²)*	*Percent of total area*	*Number of samples*	*Percent samples of total*
Relict				
Rz	19.0	0.11	1	0.1
Rf	160.9	0.95	6	0.6
Rgs	20.8	0.12	–	–
Total relict	200.7	1.18	7	0.7
Erosional				
Ef	10.2	0.06	–	–
Efs	11.7	0.07	–	–
Egs	3 920.6	23.28	180	17.9
Egm	29.6	0.18	–	–
Egp	121.5	0.72	9	0.9
Egv	0.4	0.01	–	–
Eks	375.7	2.23	21	2.1
Emp	554.5	3.29	29	2.9
Eqs	49.0	0.29	3	0.3
Total erosional	5 073.2	30.13	242	24.1
Depositional — colluvial				
C	2 180.8	12.94	135	13.4
Cf	43.8	0.26	1	0.1
Cfs	3.8	0.02	1	0.1
Cgs	1 691.1	10.04	114	11.3
Cgm	8.6	0.05	1	0.1
Cgp	109.9	0.65	6	0.6
Cks	56.0	0.33	5	0.5
Cmp	59.8	0.36	1	0.1
Cqs	5.4	0.03	1	0.1
Cw	170.6	1.01	10	1.0
Ch	1 676.0	9.95	96	9.4
Total colluvial	6 005.8	35.64	371	36.7
Depositional — alluvial				
A	520.8	3.09	106	10.5
O	562.1	3.34	39	3.9
Ok	926.5	5.50	62	6.2
W	1 924.7	11.42	103	10.2
L	29.5	0.18	2	0.2
Total alluvial	3 963.6	23.52	312	31.0
Depositional — eolian				
S	1 605.5	9.53	76	7.5
Total eluvial	1 605.5	9.53	76	7.5
TOTAL	**16 848.8**	**100.0**	**1008**	**100.0**

NOTE: The colluvial, alluvial, and eolian depositional regimes are considered separate regimes for the purposes of this calculation

coarse-grained material with a sandy clay-rich matrix. Further downslope, this material is finer grained and better sorted. These areas comprise just over 13% of COLLIER, and account for 13% of regolith samples. Their provenance is the sedimentary rocks and dolerites in the northwestern part of the map sheet. Less than 1% of colluvium is derived solely from dolerites (*Cmp*). This is because of the limited outcrop of these rocks, the fact that dolerite is often interleaved with sedimentary rocks, and that there are only small and isolated areas of depositional regime in the northwestern part of the map sheet. Colluvium derived from quartzofeldspathic sedimentary rocks (*Cgs*) makes up just over 10% of the area of COLLIER and 11% of the samples collected. This material forms fans derived from areas of prominent relief around the Collier Range and Calyie Syncline. Only a small amount of colluvium is derived from quartzofeldspathic metamorphic (*Cgm*) or igneous (*Cgp*) rocks, because of their limited outcrop or low relief, or both.

Areas of iron-rich colluvium (*Cf*) are characterized by regolith that contains highly ferruginized clasts of variable composition. This regolith type is of limited areal extent and mostly restricted to the Ashburton River. Iron-rich colluvium is commonly derived from ferruginized relict surfaces. There are also patches of iron-rich colluvium associated with small outcrops of dolerite near the Ilgarari mining locality and Weelarrana Hill. These occurrences, coupled with a strong potassic signature from airborne radiometrics, suggest that there may be a greater proportion of dolerite than shown in published large-scale geological maps (Brakel et al., 1982). Consolidated colluvium (*Cw*) makes up about 1% of COLLIER by area and is typically high in the landform profile, particularly on the Collier and Lofty Ranges. This material represents the near or very near source deposits of a weathered surface. These areas have elevated potassium values in the radiometric data (GSWA, 1996a), which may also indicate more-extensive areas of dolerite than previously recognized.

Significant areas (10%) of COLLIER surrounding the Ashburton River system contain hardpan (*Ch*), commonly near calcrete. Restricted leaching under semi-arid conditions has mobilized silica, which has migrated and accumulated at the limit of the soil-wetting front, whereas calcite is precipitated at the drying front (Brady and Walther, 1989). There are spectral differences in the Landsat imagery between hardpan in different parts of the map sheet. In the central part of COLLIER hardpan is derived from predominantly clastic sedimentary rocks, whereas hardpan to the north is derived from ferruginized dolerites and to the west from dolomite. Hardpan is commonly incised and has the appearance of an erosional terrain on satellite imagery. Hardpan is of limited extent in the internal and Gascoyne drainages.

Depositional-regime regolith derived from quartzo-feldspathic ferruginous rock (*Cfs*), carbonate-rich sedimentary rock (*Cks*), and quartz-rich sedimentary rock (*Cqs*) make up less than 1% of the map sheet area. They are associated with outcrops of banded iron-formation (southeast of Wonyulgunna Hill), dolomite (in the Glen Ross Anticline), and chert (south of Shamrock Bore) respectively.

Away from areas of high relief (in typically lower energy environments), colluvium gives way to sand- and clay-rich diluvium (*W*). Transportation of this material is largely by sheetwash processes and there are few streams. This environment covers over 11% of COLLIER and accounts for 10% of the regolith samples. Most diluvium is in the northeastern part of COLLIER around Lake Weelarrana. However, diluvium is also in the central and southern parts of COLLIER (Plate 3).

Depositional alluvial and lacustrine regolith units (*A, O, Ok, L*) comprise 12% by area of COLLIER, but account for 20% of regolith samples because of a sampling bias towards stream sediments. These units comprise variably sorted, mainly unconsolidated gravels, sands, and clays with altered lithic fragments. Active stream-channel alluvium (*A*) occupies a small area (3%), but accounts for 10% of the samples. Areas of overbank alluvial deposits and non-saline claypans in broad drainage floors (*O*) are more extensive in the southeastern part of the map sheet, which has extensive areas of low relief. They make up 3% by area and nearly 4% of the regolith samples. Valley calcrete (*Ok*) covers 5% of the area of COLLIER, accounts for 6% of the regolith samples, and is widely distributed along creek lines, particularly in the northern part of the map sheet. Lacustrine regolith (*L*) is in Lake Weelarrana in the northeastern part of COLLIER. This regolith type accounts for less than 1% of the area and two regolith samples.

Sandplain (*S*) is well developed on COLLIER and comprises 9% of the sheet, and over 7% of samples. However, this regolith type is only in the southern and eastern parts of the map sheet, with the main areas of sandplain overlying the Savory Group, 10 km west of Woolbunna Bore. In the eastern part of COLLIER, south-westerly orientated longitudinal dunes are developed, whereas in the western part, a sandplain veneer overlies a flat sheetwash surface.

COLLIER is characterized by roughly equal areas of erosional, colluvial, and alluvial regolith units, with about 10% of regolith being either relict (*R*) or eolian (*S*). The relief on COLLIER means that regolith formation is predominantly by lateral transport, with physical processes dominant over chemical processes.

Chemical analysis

Quality control

One thousand and eight regolith samples were analysed in five separate batches by Genalysis Laboratory Services, Perth. These comprise 758 stream sediments, 192 sheetwash samples, 54 soil samples, four lake-sediment samples, and two sandplain samples. In addition, multiple analyses of three in-house GSWA standards were carried out, along with analysis of duplicates and standards included by Genalysis. The laboratory procedures and quality-control approach are summarized in Appendices 6–10 (digital).

Forty-five replicate samples were analysed and there is commonly acceptable agreement between each sample and its replicate (Appendix 7), with only 11 samples (four As, five W, one V, and one Zr) having poor reproducibility. There is acceptable agreement between GSWA standards (Appendix 8) and laboratory standards (Appendix 9), with only Rb in the GSWA amphibolite standard being low. Twelve samples with relatively high concentrations of Au, Cu, Pt, Zn, and Pb were submitted for check analysis to Amdel Laboratories, Perth. Because of the differences in preparation techniques (Appendix 10), both Cr steel-mill and Zr mill pulps from Genalysis were analysed. There is acceptable agreement between analyses carried out at both laboratories for all but 40 samples (12 Nb, eight U, eight Th, eight As, and four Zn). Appendix 11 (digital) contains four worksheets detailing results from all the gold analyses. Batch 1 had higher levels and was re-analysed, as were some samples from batch 2. Any data at or near the detection level should be treated with caution.

Element-distribution maps

The concentration of various components on COLLIER is depicted as a series of spot-concentration maps (Figs 5 to 51), where the diameter of the circle corresponds to concentration, unless the concentration is greater than 2.5 standard deviations above the mean, when it is classified as anomalous and shown as a star. These maps are ordered in terms of major-element oxides and loss-on-ignition (LOI, in percent), then trace elements (in ppm) and ultratrace elements (in ppb) in alphabetical order. Silica is not plotted as it shows a relatively uniform distribution over the map sheet, with most samples containing between 50 and 75% SiO_2. Higher values are located over sandplains and lower values close to dolerites.

The chemistry of regolith is controlled by the combined effects of bedrock composition and physical and chemical weathering. The strong association of components such as TiO_2, P_2O_5, Na_2O, K_2O, V, MgO, Cu, Co, Cr, Ni, Pd, Rb, Sc, and Y with regolith derived from dolerite is an example of bedrock control on regolith chemistry. Higher concentrations of MgO, CaO, Na_2O, and Sr in regolith derived from dolerites is related to weathering involving the breakdown of feldspar and amphibole. Bedrock control is responsible for high Zr levels in regolith derived from quartz- and feldspar-rich sedimentary rocks, whereas the concentration of zircon as a resistate phase through weathering can produce high levels of Zr in regolith.

The majority of regolith samples with high Th and U are in the depositional regime. Lanthanum and Ce, which are associated with resistate minerals (e.g. allanite), have relatively high concentrations in colluvial and alluvial regolith units. The distribution of several components, such as CaO and Sr, is influenced by both bedrock and regolith formation. Other elements, such as In and V, appear to be concentrated in the depositional regime because of scavenging by Fe_2O_3. On a regional scale, throughout Western Australia, bedrock exerts significant control on the composition of regolith (Morris et al., 1998), and in these notes regolith chemistry is discussed in relation to bedrock.

Regolith chemistry according to bedrock

Because of the high proportion of sandplain samples over the Archaean Yilgarn Craton and Gascoyne Complex, the concentrations of most elements in regolith over these tectonic units are low relative to the Bangemall Group. Gold values are at or near the detection limit (1 ppb) and show no obvious features corresponding to any bedrock or regolith group. Palladium and platinum are commonly below detection level, except for samples GSWA 157506 (2 ppb Pd, 1 ppb Pt), GSWA 157213 (2 ppb Pd, 2 ppb Pt), GSWA 157203 (2 ppb Pd, 2 ppb Pt), and GSWA 157204 (2 ppb Pd, 2 ppb Pt), which are all close to the detection level. Other elements near the detection level in most regolith samples over the Yilgarn Craton are MnO, MgO, CaO, Na_2O, Ag, Ba, Cd, Co, Li, Mo, Ni, Rb, S, Sb, Sn, and Sr; however, regolith samples GSWA 157103 and GSWA 156909 near mafic rocks contain the highest Na_2O values (1.599 and 1.829% respectively) on COLLIER, along with high K_2O and Sr values. Base metal (Cu, Pb, and Zn) concentrations are also low and below average. Other elements that have below average values are Fe_2O_3, K_2O, P_2O_5, As, Be, Bi, Ce, Cr, Cu, Ga, In La, Nb, Sc, Se, Th, U, V, Y, and Zr. There are some elevated Fe_2O_3 values in colluvium over the Yilgarn Craton, and elevated values of Sr and Se in regolith associated with mafic subcrop. In addition, the highest W value of 4.2 ppm, in sandplain sample GSWA 157608, is from the Archaean Yilgarn Craton. Components with similar values to the average for regolith on COLLIER are Al_2O_3, LOI, and TiO_2.

Only three samples are sourced from the Bresnahan Group. GSWA Sample 157850 (*Ok*) has slightly elevated U values (4.22 ppm).

Regolith samples over the lower Edmund Subgroup have low MnO, MgO, CaO, Na_2O, Au, Ba, Ni, Pd, Pt, Sn, and Sr values relative to the rest of the Bangemall Group. Values of Fe_2O_3, TiO_2, Al_2O_3, LOI, P_2O_5, As, Bi, Ce, Co, Cu, Ga, In, La, Nb, Pb, Rb, Sc, Se, Th, U, V, Y, and Zn are lower than the average for COLLIER over the Coobarra Dome, in the central western part of the map sheet, but relatively higher in other areas of the lower Edmund Subgroup. Values of As, Be, Cd, Li, Mo, Rb, S, Sb, and Te are higher than the average for COLLIER in the Glen Ross Anticline, in the western part of the map sheet. In the western part of the Brumby Creek Anticline, in the northwestern part of the map sheet, elevated values of As, Cd, Mo, Nb, and Sb are present in colluvium and sheetwash overlying the Jillawarra Formation of the lower Edmund Subgroup. In particular, GSWA 157718 has elevated As (74 ppm), Nb (21.3 ppm), Sb (16.97 ppm), Sn (3.9 ppm), Ta (1.4 ppm), and Te (0.9 ppm), and GSWA 157859 has elevated As (85 ppm), Cd (1.4 ppm), Mo (14.8 ppm), and Sb (18.55 ppm). In the Glen Ross Anticline, regolith samples with elevated K_2O, Rb, Li, S, U, and Zn are associated with erosional-regime regolith over the Jillawarra Formation, and may be related to the Discovery Chert. Aluminium oxide is elevated in sheetwash deposits south of the Calyie Syncline (in the southwestern part of the map sheet), and three regolith samples with anomalous zinc are derived from dolerites in the Jillawarra Formation. Scattered regolith samples from the lower Edmund Subgroup have relatively high silver concentrations. Regolith samples GSWA 158020 and 158828, from north of Perry Creek, have elevated chromium values (1781 and 1545 ppm respectively), which is probably related to dolerites not shown at the published map scale.

Most element concentrations in regolith from the upper Edmund Subgroup are above the average for COLLIER. Gold, Pd, and Pt values are low in the upper Edmund Subgroup, with rare higher values near the Discovery Chert. Analyte concentrations that are above the average for COLLIER include Fe_2O_3, CaO, MgO, LOI, Ag, As, Ba, Co, Cr, Pb, Se, Th, and V, with Ba and Cr also higher in outcrops in the north. High CaO and LOI can be attributed to calcretes along the northern branch of the Ashburton River. Concentrations of In, V, and Zr are relatively high in regolith samples from hardpan, colluvium, and erosional-regime regolith between Bulloo Downs and Granny Well in the northern part of COLLIER. Values of Ag, As, Cd, Nb, Sb, and Zn are elevated in regolith close to the Discovery Chert, in the Brumby Creek Anticline, and Tangadee Syncline. Sample GSWA 157914 (*Egs*) in this area has elevated Ag (0.5 ppm), As (78 ppm), Cd (2.6 ppm), Mo (23.1 ppm), S (0.19%), and U (5.6 ppm). There are scattered high values for Pt in regolith in the upper Edmund Subgroup in the Glen Ross Anticline, and in streams draining areas of dolerite. Two regolith samples from sheetwash south of the Flat Top Range (GSWA 157465 and 157559) have elevated Al_2O_3 (16.99 and 15.78% respectively).

Dolerite intrusions into the Collier Subgroup produce heterogeneous patterns of component concentrations in regolith. Values of Pd and Pt are low in regolith from the Collier Subgroup, except in regolith close to dolerites, and GSWA 157326 (5 ppb Pt; *Cgs*) located 2 km south of Batthewmurnarna Hill. Concentrations of Cu, Pb, and Zn are typically low, apart from samples near dolerite and a number of colluvium samples from the Ilgarari mining locality. Some of the highest values for S, Sr, and CaO are in regolith from Lake Weelarrana in the northeastern part of the map sheet, and can be attributed to high levels of gypsum in the lacustrine sediments. Regolith sample GSWA 157126 (*Egs*), 2 km northwest of Weelarrana Hill, contains elevated concentrations of As, Ba, Bi, Ga, In, Te, and Th. Elevated S values in regolith are scattered throughout the Collier Subgroup and many are derived from dolerites; however, high S values in regolith south of Beyondie Bluff are not related to known areas of dolerite, although rocks in this area are locally ferruginized. In particular, sample GSWA 157106 (*Ch*) has elevated P_2O_5 (0.377%), Ag (0.6 ppm), Mo (23.4 ppm), S (0.39 ppm) and Sb (17.13 ppm), as well as elevated Ce, La, U, and W. Concentrations of TiO_2, MgO, Na_2O, K_2O, Co, Li, and Ni are typically low in regolith samples from the Collier Subgroup, unless influenced by dolerite. Gallium, Al_2O_3, Fe_2O_3, In, V, and Zr are relatively high over the Collier Subgroup, with elevated values in regolith from the Gascoyne drainage north of Beyondie Bluff, the Ilgarari mining locality, and southwest of Lake Weelarrana. Niobium, Se, Sn, Te, Th, U, and W have a similar distribution to In, V, and Zr, but at lower levels overall. Concentrations of MnO, Ba, Be, Bi, and Cd are commonly low in regolith samples from the Collier Subgroup, except in colluvium around the Ilgarari mining locality. Values of Ag, As, Ce, La, and P_2O_5 are also relatively high in regolith around the Ilgarari mining locality, as well as in four regolith samples south of Beyondie Bluff. These samples (GSWA 157001, 157106, 156914, and 157212) also have elevated Mo and Sb. Rubidium, Sc, and Y are evenly distributed throughout the Collier Subgroup, whereas Cr is higher in sheetwash than stream sediments over areas where dolerite is absent. The presence of the Kumarina mining locality is not evident from the regolith chemistry due to the sample spacing.

Regolith samples from the Savory Group typically have low concentrations of all components, although GSWA 156937 (*A*) has concentrations of Ag (0.5 ppm), Cd (0.8 ppm), and Sn (4.2 ppm) that are slightly higher than average.

As dolerite is of limited areal extent on COLLIER, relatively few samples directly sample it; however, regolith chemistry is substantially influenced by the presence of dolerite. Thus, statistical comparison of regolith chemistry between population groups chosen according to bedrock type could be misleading. Inspection of regolith chemistry suggests that dolerites are compositionally heterogeneous. Regolith derived from dolerite in the Calyie Syncline (Ilgarari Formation, Collier Subgroup) in the southwestern part of COLLIER appears to form a distinct compositional group, with higher TiO_2 and Nb than regolith sourced from other dolerite on COLLIER. Regolith samples derived from dolerites near Ilgarari Outcamp (Ilgarari Formation) contain some of the highest concentrations of Ba, Be, Ce, Co, Cu, Li, MnO, Ni, Pb, and Y on COLLIER, whereas samples of regolith derived from dolerites near Scotties mine (Backdoor Formation, Collier Subgroup) contain high values of Be, Ba, Co, and MnO. Regolith from dolerites 9 km northwest of Ilgarari Outcamp and south of Neds Gap Fault (Ilgarari Formation, Collier Subgroup) have higher MnO, Ba, Be, Ce, Co, Cu, Li, Ni, Pb, and Sr than other dolerites, although they are similar in composition to regolith from dolerites 2 km west of Scotties mine. Regolith from dolerites 5 km northeast of Bujundunna Well (Backdoor Formation, Collier Subgroup) have higher Cu, Pd, and Pt concentrations than regolith from other dolerites on COLLIER. The regolith from dolerites around Conical Hill (Calyie Sandstone, Collier Subgroup) are higher in CaO, Na_2O, Ni, Sc, and Sr, whereas the regolith from dolerites 5 km to the southeast (Calyie Sandstone, Collier Subgroup) is also higher in Na_2O than regolith from other areas. The dolerites in the Glen Ross Anticline and Tangadee Syncline (Devil Creek Formation and Backdoor Formation, Collier Subgroup) in the western part of COLLIER have elevated concentrations of Ni, Pd, and Sc, whereas the dolerites 2 km north of Dingo Bore (Ilgarari Formation and Calyie Sandstone) have elevated P_2O_5 and Y.

Statistical treatment of regolith chemical data

Element-concentration maps (Figs 5–51) permit visual comparison of regolith chemistry according to bedrock geology. In order to determine any significant differences in regolith composition over different geological and regolith units, it is necessary to compare groups of data statistically.

Most statistical tests assume data achieve a normal (or a parametric) distribution. However, many geochemical datasets (including regolith chemistry on COLLIER) follow a non-Gausian distribution, in that the majority of element concentrations are low, and only a few are high, imparting a positive skew to the distribution (Koch and Link, 1970). Transformation of the non-parametric data must be carried out so that parametric tests of population difference can be applied (e.g. Student's t-test). The most common transformation involves adding a constant to each value and taking the log, thus $y = \log (x + C)$, where x is the original element concentration and C is a constant (Rock, 1988).

On COLLIER, the Tukey's Honestly Significant Difference (HSD) for comparing multiple populations' mean difference has been used to test several geological units and regolith types (Miller and Kahn, 1962; Rock, 1988) and Spearman's Rank-Order Correlation has been used to determine element associations.

All statistical comparisons of the regolith geochemistry of COLLIER were carried out at the 95% confidence level. Analyte concentrations at low levels (average composition less than ten times detection level) are not involved in the statistical discussion, due to poor precision and accuracy at low levels.

• Statistical analysis of sandplain regolith developed on the Yilgarn Craton, Savory Group, Collier Sub-group, and lower Edmund Subgroup on COLLIER

Although it is usually assumed that sandplain is derived by eolian transport and deposition, Morris et al. (1998) compared the regolith chemistry of sandplain overlying different geological units and found evidence that variation could be correlated with the underlying geology. The distribution of sandplain on COLLIER is indicative of remnants of a more extensive cover deposited during a period of hyperaridity. Differences in chemistry appear to be related to the underlying bedrock.

Table 3 presents the arithmetic mean and standard deviation of sandplain (*S*) units overlying the Yilgarn Craton, Savory Group, and Collier and lower Edmund Subgroups. Sandplain over the Yilgarn Craton and Collier Subgroup has significantly higher Fe_2O_3, Cr, Cu, Ga, Sc, V, and Zn concentrations, but lower SiO_2 than sandplain developed over the lower Edmund Subgroup and Savory Group. The implication for regional exploration strategies in areas of extensive sandplain is that variation in chemistry may indicate different bedrock, and that the sandplain may, therefore, be of local derivation. Contrasting geochemistry may reflect locally sourced particles or biological and illuvial activity after deposition.

• Statistical analysis of regolith derived from dolerites on COLLIER

Samples with high levels of mafic-rock-related components (TiO_2, Fe_2O_3, MnO, P_2O_5, MgO, CaO, In, Sc, V, Y, and Zn) were selected and grouped into areas based on bedrock geology. The arithmetic mean and standard deviation of components with values greater than ten times the detection levels (excluding Ag, Au, Cd, In, Pd, and Pt) of these groups are presented in Table 4.

The components of the regolith derived from dolerites intruded into the lower Edmund Subgroup (Irregully, Cheyne Springs, Kiangi Creek, and Jillawarra Formations) were statistically compared. The only significant difference is between the Jillawarra and Irregully Formations for La, Li, and Rb, although there are only six samples from the Irregully Formation. In the following discussion of intergroup comparisons, these formations are grouped together as lower Edmund Subgroup dolerites (n=21).

The composition of the regolith sourced from the dolerites intruded into the Collier Subgroup (Backdoor Formation, Calyie Sandstone, and Ilgarari Formation) were statistically compared. The only significant difference between the Calyie Sandstone and Backdoor Formation is for chromium and copper, but a number of components are significantly different between the Ilgarari Formation and the other two formations (Table 4). In further intergroup comparisons, dolerites intruded into the Calyie Sandstone and Backdoor Formation are grouped together as Collier Subgroup dolerites (n=83). Compared to dolerites intruded into the Ilgarari Formation, this group appears to form a significantly different population (Table 5).

A summary of components with significantly different values for the lower Edmund, upper Edmund, and Collier Subgroup dolerites, and Ilgarari Formation dolerites is presented in Table 6. The Ilgarari Formation dolerites appear to be significantly different to all the other groups for a variety of components, and the Collier Subgroup dolerites are also significantly different to all other groups. The only element with significant differences between the upper and lower Edmund Subgroups is tungsten, and it is therefore likely that these dolerites form part of the same population.

Element associations on COLLIER

A Spearman's Rank-Order Correlation (Appendix 12) was performed on all sample analyses from COLLIER in order to determine the relationship between elements. There is a strong association for a number of elements with Co, In, K_2O, and Zn, but others (e.g. Cr) are poorly correlated with other analytes.

Among these, the following element associations can be identified:

- mafic: TiO_2–Fe_2O_3–MnO–P_2O_5–MgO–CaO–In–Sc–V–Y–Zn;
- ultramafic: Co–Cr–Cu–Ni–Pd–Pt;
- diadochic: Ga–Al_2O_3, U–Th, Na_2O–CaO–Sr, and K_2O–Rb;
- rare-earth elements (REE): Ce–La–Y;
- scavenging by Fe_2O_3: In–V.

To allow direct comparison of components, regardless of concentration, the standard scores of components were summed for both mafic and ultramafic associations, and divided by the number of components to reduce the scale. A plot of the samples with high values is shown in Figure 52.

All areas of dolerites have high summed standard scores for mafic elements, but there are also strong ultramafic–mafic associations in the Glen Ross Anticline, Tangadee Syncline, Conical Hill, and north of the Ashburton River. These areas are coincident with the statistical analysis that delineated three populations of dolerites, although the general areas identified by mafic and ultramafic standard scores appear to contain overlapping chemistry. This may be caused by the presence of sills and dykes that are not shown at the mapped scale (Brakel et al., 1982), or physiography and different physical and chemical weathering patterns on COLLIER. More-detailed field work is needed to determine the extent of bedrock influence.

Table 3. Arithmetic mean and standard deviation for sandplain regolith developed on the Yilgarn Craton, Savory Group, lower Edmund Subgroup, and Collier Subgroup on COLLIER

Element	Yilgarn Craton (n=12)		Savory Group (n=6)		Collier Subgroup (n=41)		Lower Edmund Subgroup (n=12)	
	mean	σ	mean	σ	mean	σ	mean	σ
Percent								
SiO_2	83.3	11.1	92.0	1.4	79.7	14.7	92.5	3.6
TiO_2	0.33	0.20	0.22	0.04	0.47	0.35	0.20	0.12
Al_2O_3	4.49	1.86	2.85	0.83	5.04	2.28	3.01	1.50
Fe_2O_3	9.63	8.32	2.82	0.93	9.23	6.30	2.57	1.10
MnO	0.021	0.011	0.029	0.006	0.052	0.039	0.010	0.010
MgO	0.10	0.03	0.09	0.02	0.18	0.21	0.11	0.04
CaO	0.2	0.1	0.2	0.1	0.9	4.3	0.1	0.1
Na_2O	0.029	0.017	0.010	0.010	0.051	0.128	0.020	0.008
K_2O	0.19	0.11	0.13	0.07	0.30	0.21	0.22	0.15
P_2O_5	0.033	0.020	0.020	0.011	0.042	0.021	0.021	0.009
LOI	1.91	0.73	1.27	0.32	2.46	1.23	1.34	0.80
Parts per million[(a)]								
Ag	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
As	4	4	2	2	7	5	3	1
Au (ppb)	1	1	2	2	1	1	1	1
Ba	53.0	29.6	48.9	30.1	113.6	65.2	39.3	33.3
Be	0.3	0.2	0.3	0.2	0.5	0.3	0.2	0.1
Bi	0.29	0.20	0.15	0.10	0.29	0.19	0.12	0.04
Cd	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Ce	11.52	6.26	15.47	9.76	20.25	12.91	12.54	6.31
Co	3.4	2.6	2.2	0.7	5.0	3.6	1.7	0.9
Cr	254	185	61	29	252	178	98	91
Cu	14	8	6	2	20	11	8	4
Ga	8.3	5.2	4.0	1.1	9.2	5.2	3.6	1.8
In	0.04	0.03	0.01	0.01	0.04	0.03	0.01	0.01
La	6.56	3.54	7.64	4.17	11.16	8.23	6.63	3.31
Li	4.5	2.0	5.9	1.9	7.6	3.2	4.8	1.4
Mo	1.5	1.5	0.3	0.1	0.9	0.6	0.6	0.7
Nb	4.1	2.3	3.2	0.8	5.8	2.9	3.3	1.5
Ni	11	9	5	3	16	12	12	19
Pb	10	5	7	4	13	7	6	3
Pd (ppb)	0	0	0	0	0	0	0	0
Pt (ppb)	0	0	0	0	1	1	0	0
Rb	14.19	8.72	10.58	3.97	21.20	11.75	13.16	8.76
S (%)	0.00	0.00	0.00	0.01	0.40	2.56	0.01	0.01
Sb	0.92	1.15	0.22	0.07	0.96	0.66	0.38	0.16
Sc	5	4	2	1	5	4	1	2
Se	0.4	0.6	0.1	0.2	0.4	0.6	0.1	0.2
Sn	1.0	0.5	0.7	0.2	1.2	0.6	0.7	0.3
Sr	7.66	3.64	13.89	9.92	24.42	68.43	4.40	2.49
Ta	0.2	0.2	0.0	0.0	0.3	0.2	0.2	0.1
Te	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0
Th	7.69	4.82	4.87	2.51	7.98	5.41	4.13	1.62
U	0.68	0.38	0.60	0.30	0.87	0.42	0.51	0.21
V	173	152	47	20	178	128	42	20
W	1.4	1.1	0.3	0.1	0.8	0.5	0.9	0.8
Y	3.74	2.24	4.04	2.36	5.52	3.00	2.69	1.72
Zn	13	9	9	3	21	15	9	5
Zr	97	47	100	47	117	61	68	34

NOTES: (a) Unless otherwise noted. σ : standard deviation

Miscellaneous analyses

Acidity–alkalinity (pH) and total dissolved solids (TDS)

A contour map and a histogram of regolith pH are presented in Figure 53. A plot of TDS superimposed on a digital terrain model of COLLIER is presented in Figure 54. Most regolith is variably acidic (pH<7), with only 20% of the samples being alkaline (pH>7). Areas of alkaline regolith on COLLIER are dominated by calcrete, carbonates, basic rocks, hardpan, and colluvium following the major creeks of the Ashburton River system and over Lake Weelarrana. Alkaline conditions have contributed to the more extensive development of hardpan and calcrete in this part of COLLIER. Despite the lack of extensive mafic bedrock or calcrete, there is an area of more alkaline pH around Batthewmurnarna Hill, in the southern part of COLLIER. The highest pH (9.3) is recorded in regolith

Table 4. Arithmetic mean and standard deviation for regolith derived from dolerite on COLLIER

Element	Lower Edmund Subgroup								Upper Edmund Subgroup		Collier Subgroup					
	Irregully Fm. (n=6)		Cheyne Springs Fm. (n=2)		Kiangi Creek Fm. (n=2)		Jillawarra Fm. (n=11)		Devil Creek Fm. (n=33)		Backdoor Fm. (n=71)		Calyie Sandstone (n=12)		Ilgarari Fm. (n=30)	
	mean	σ	mean	σ	mean	σ	mean	σ	mean	σ	mean	σ	mean	σ	mean	σ
Percent																
SiO_2	45.2	10.6	49.1	3.5	48.3	11.7	51.4	5.6	43.9	10.1	50.8	8.8	55.3	7.6	45.4	11.7
TiO_2	1.72	0.48	2.31	0.23	1.28	0.36	1.74	0.93	1.48	0.32	1.66	0.68	2.03	1.28	1.76	1.14
Al_2O_3	9.93	1.99	10.08	1.95	9.65	0.21	10.90	1.56	10.17	1.01	10.83	1.50	10.54	1.80	10.79	1.38
Fe_2O_3	31.80	10.85	19.73	8.41	28.98	15.31	23.20	6.98	32.47	12.00	23.91	11.27	19.47	8.17	28.43	12.93
MnO	0.147	0.048	0.185	0.031	0.209	0.068	0.183	0.098	0.245	0.209	0.377	0.456	0.446	0.597	1.116	2.107
MgO	1.59	1.74	5.34	4.11	1.46	1.34	1.89	1.30	1.62	1.83	2.29	2.21	1.87	1.83	1.46	1.41
CaO	1.97	1.69	5.65	3.46	1.25	1.06	2.35	2.51	1.86	2.56	2.58	2.72	2.71	2.84	2.14	2.35
Na_2O	0.357	0.296	1.005	0.059	0.268	0.126	0.516	0.493	0.241	0.227	0.449	0.430	0.739	0.658	0.433	0.433
K_2O	1.01	0.60	1.43	0.04	1.63	1.22	1.91	0.82	1.14	0.55	1.45	0.83	1.42	0.63	1.31	0.64
P_2O_5	0.090	0.013	0.113	0.025	0.119	0.005	0.112	0.020	0.107	0.030	0.122	0.043	0.127	0.056	0.168	0.073
Parts per million																
As	18.0	8.7	11.0	2.8	27.5	17.7	25.7	21.4	21.0	8.8	14.1	9.6	11.7	11.2	23.6	18.6
Ba	295.7	86.3	361.5	64.4	379.7	144.0	337.1	100.0	545.1	363.9	569.6	364.5	642.4	304.5	1 073.8	104.2
Be	1.4	0.5	1.3	0.2	2.2	0.9	2.0	0.9	1.8	0.5	1.7	0.6	1.6	0.8	1.8	0.8
Bi	0.64	0.31	0.23	0.18	0.60	0.29	0.45	0.29	0.66	0.31	0.47	0.27	0.32	0.20	0.70	0.47
Cd	0.1	0.0	0.4	0.4	0.3	0.1	0.4	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Ce	46.99	8.49	48.09	8.80	65.38	14.81	53.51	9.65	58.96	12.99	58.54	18.82	65.09	19.09	69.23	22.06
Co	22.6	11.4	40.0	5.6	28.6	14.2	26.0	9.9	23.9	10.6	31.3	18.4	35.0	15.5	34.5	28.9
Cr	914	706	715	251	389	11	322	282	562	266	480	298	252	158	375	263
Cu	59	13	74	15	64	27	70	19	68	16	66	21	85	25	83	33
Ga	25.8	7.7	19.2	7.6	23.2	9.3	21.4	4.7	26.3	7.3	22.7	7.9	17.7	2.9	23.9	9.3
In	0.13	0.04	0.09	0.03	0.14	0.08	0.11	0.03	0.14	0.04	0.11	0.05	0.08	0.02	0.12	0.05
La	18.89	3.11	19.87	2.55	25.93	5.46	24.86	4.01	26.81	5.70	26.19	7.35	26.13	6.60	30.15	7.10
Li	8.9	1.5	13.2	2.3	16.7	7.2	15.5	4.9	15.7	5.4	16.9	8.7	12.5	4.6	18.0	16.7
Mo	2.6	2.0	3.3	0.3	5.6	1.2	5.8	5.3	2.7	1.5	1.9	1.3	1.3	0.8	2.3	1.7
Nb	11.5	2.9	11.5	2.9	11.7	2.9	13.3	3.3	13.6	2.1	12.8	2.9	12.4	3.9	13.6	3.6
Ni	66	42	98	11	64	48	71	27	60	36	70	41	79	30	66	41
Pb	28	10	14	5	31	16	26	9	28	8	24	8	23	10	32	19
Rb	41.00	17.21	56.25	2.84	84.22	47.97	108.48	53.39	65.29	24.69	77.18	38.80	71.07	31.01	69.00	33.95
Sb	3.41	1.79	1.48	0.88	3.93	2.73	4.39	4.58	2.55	1.38	1.61	1.21	0.85	0.60	2.00	1.35
Se	0.95	1.26	0.15	0.92	1.60	1.56	1.55	1.39	1.38	0.86	0.86	1.48	0.58	1.03	1.16	1.52
Sc	21	5	28	6	20	2	19	4	21	4	22	5	19	5	19	3
Sn	2.6	0.7	2.2	0.6	2.6	0.6	2.4	0.6	2.7	0.5	2.5	0.6	2.2	0.5	2.9	1.0
Sr	44.13	26.24	106.82	15.02	41.59	24.88	63.63	34.85	46.08	27.89	72.36	47.39	94.58	71.19	87.25	65.16
Ta	0.8	0.2	0.7	0.3	0.8	0.1	0.8	0.2	0.8	0.2	0.8	0.2	0.7	0.2	0.8	0.2
Te	0.2	0.1	0.1	0.2	0.3	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.3	0.3
Th	17.80	8.15	8.63	6.55	16.72	7.33	11.65	6.70	19.84	7.80	15.46	7.13	11.63	4.15	20.66	11.26
U	2.21	0.74	1.78	0.31	2.44	0.49	2.27	0.89	2.07	0.44	1.87	0.50	1.64	0.55	2.25	0.64
V	539	98	493	149	546	346	482	171	591	217	486	209	441	204	556	228
W	1.6	0.7	1.0	0.6	1.5	0.1	1.3	0.5	1.8	0.5	1.6	0.6	1.4	0.6	2.0	0.7
Y	17.07	1.98	22.45	0.45	19.61	5.83	19.78	3.37	20.08	3.92	19.21	5.59	22.56	7.31	23.12	8.83
Zn	65	32	89	11	82	24	140	94	73	22	81	28	112	44	94	44
Zr	205	54	169	66	207	63	177	36	215	45	196	71	178	42	208	59

NOTES: σ: standard deviation; Fm. : Formation

Table 5. A summary of components with statistically different values for regolith derived from dolerites intruded into formations in the Collier Subgroup

	Backdoor Formation	*Calyie Sandstone*	*Ilgarari Formation*
Backdoor Formation	–	Cr, Cu	SiO_2, MnO, P_2O_5, Ba, Bi, Ce, Cu, La, Pb, U, W
Calyie Sandstone	Cr, Cu	–	SiO_2, Bi, In, Sb, Sn, U, Th, W
Ilgarari Formation	SiO_2, MnO, P_2O_5, Ba, Bi, Ce, Cu, La, Pb, U, W	SiO_2, Bi, In, Sb, Sn, U, Th, W	–

sample GSWA 157698 (*Ch*) from Perry Creek. There is acidic regolith in the Gascoyne River drainage and in the internal drainage on the eastern side of COLLIER. The lowest pH value of 3.3 (GSWA 157071) is in regolith, 12 km southwest of Ilgarari Outcamp. Only 12% of regolith samples have TDS greater than zero (Fig. 54). Total dissolved solid values superimposed on a digital terrain model of COLLIER indicate that most values greater than zero are associated with depositional-regime regolith in the western part of COLLIER near the Ashburton River catchment. The highest values, however, are east of the Collier Range, near Lake Weelarrana. Elevated values in the Collier Range are mostly from samples close to hardpan and consolidated colluvium, with implications for landuse purposes.

Element-index maps

Pathfinder elements and additive indices can be used to highlight areas of mineralization in arid terrains (e.g. the Yilgarn Craton; Smith and Perdrix, 1983; Smith et al., 1989). Although these studies concentrated on a limited type of sample media (predominantly ferruginized duricrust or laterite), the use of additive indices has been adapted and extended to include all media types sampled in the GSWA regional regolith and geochemical mapping program. Kojan et al. (1996a,b) showed how a greenstone chalcophile index could be used to identify areas of known and potential gold mineralization on SIR SAMUEL. Indices are commonly additive (e.g. element a + element b + element c + ...), but the relative concentration and concentration range of each element must be taken into account. The data is first log-transformed (base 10) to reduce the effect of extremely high or low values and then standardized, which involves expressing each value as a standardized normal deviate. This allows direct comparison of elements regardless of concentration (Rock, 1988).

Two element-index plots have been compiled for COLLIER. These comprise a chalcophile index (Fig. 55) and a summed total standard scores index (Fig. 56). The data have been gridded by inverse distance weighting to preserve original values.

Contoured chalcophile index

Summed standard scores for chalcophile elements (As, Bi, Cd, Mo, and Sb) are contoured in Figure 55. About 6% of regolith samples have a chalcophile index greater than ten. The lowest values are commonly in samples taken from sandplain, especially over the Coobarra Dome, Savory Group, and Yilgarn Craton. Areas with higher values (red and orange) include samples taken from south of Beyondie Bluff, the Glen Ross and Brumby Creek Anticlines, and the Ilgarari mining locality. The elevated values in the Glen Ross and Brumby Creek Anticlines are in regolith over the lower Edmund Subgroup, and form an extension to high chalcophile values on the adjoining MOUNT EGERTON

Table 6. A summary of components with statistically different values for dolerite populations based on tectonic units

	Ilgarari Formation	*Collier Subgroup*	*Upper Edmund Subgroup*	*Lower Edmund Subgroup*
Ilgarari Formation	–	SiO_2, MnO, P_2O_5, As, Ba, Bi, Cu, La, Pb, Sn, Th, U, W	MnO, P_2O_5, Ba	MnO, P_2O_5, Ba, Ce, La, Mo, Sb, Th, W
Collier Subgroup	SiO_2, MnO, P_2O_5, As, Ba, Bi, Cu, La, Pb, Sn, Th, U, W	–	SiO_2, Fe_2O_3, Na_2O, As, Bi, Ga, In, Mo, Sb, Se, Th, V, W	As, Mo, Sb
Upper Edmund Subgroup	MnO, P_2O_5, Ba	SiO_2, Fe_2O_3, Na_2O, As, Bi, Ga, In, Mo, Sb, Se, Th, V, W	–	W
Lower Edmund Subgroup	MnO, P_2O_5, Ba, Ce La, Mo, Sb, Th, W	As, Mo, Sb	W	–

sheet (Morris et al., 1998). The Ilgarari mining locality has elevated values due to relatively high levels of As and Bi. These samples are all in the Collier Subgroup, near dolerites. Sample GSWA 157318, south of Kumarina Roadhouse, is uncommonly high in all chalcophile-element concentrations and sourced from the Backdoor Formation. Values near the Kumarina mining locality, however, are only slightly elevated, due to the regional nature of the program. The region south of Beyondie Bluff has high chalcophile-index values because of elevated Mo and Sb, and these samples are also sourced from the Backdoor Formation.

Contoured summed standard scores index

Summed standard scores for all the components sampled on COLLIER have been contoured in Figure 56 as a method of identifying areas of multi-element associations independent of assumptions of natural-element associations (Downing, J., 1998, pers. comm.). As for the chalcophile index, the Coobarra Dome, Yilgarn Craton, and Savory Basin have low values (purple and blue) and the Ilgarari mining locality, and Brumby Creek and Glen Ross Anticlines still have high values (pink and red). However, unlike the chalcophile-index plot, the regolith samples south of Beyondie Bluff have lower standard scores, but high standard scores are associated with dolerites north of the Ilgarari mining locality and O'Donnell Soak, as well as south of Mingah Springs Homestead. Regolith samples south of Mingah Springs Homestead have high Al_2O_3, P_2O_5, As, Cu, In, Mo, Nb, Pb, Sb, Sc, U, Zn, and Zr, suggesting a larger amount of dolerite than previously mapped in the area, which agrees with other analyses. The samples north of O'Donnell Soak are high in CaO, LOI, Be, Ce, In, La, Mo, U, W, and Y, and reflect a calcrete association. The area north of the Ilgarari mining locality is high in most components, in particular Fe_2O_3, Be, Cr, In, Ga, Sn, Th, and V, and very low in SiO_2. This area is mainly hardpan, possibly overlying more-extensive areas of dolerite.

Integration of site observations with regolith chemistry and bedrock geology

As discussed above, it is assumed that most of the relict ferruginous regolith (*Rf*) results from in situ weathering of dolerite. Sites with abundant mafic and ferruginous clasts and known occurrences of dolerite are plotted on Figure 57. Dolerite clasts are commonly close to outcrops of dolerite, but samples with abundant ferruginous clasts have a much wider distribution.

Summed standard scores (divided by the number of components in order to scale the data) are used to designate the degree of mafic signature:
$(TiO_2 + Fe_2O_3 + MnO + P_2O_5 + ((MgO + CaO) / 2) + In + Sc + V + Y + Zn) / 10)$.

This approach integrates site information, bedrock geology, and sample chemistry. Samples with ferruginized clasts and high mafic-association chemistry are commonly near areas of mapped dolerite, in the northwestern part of the map sheet (Fig. 57). Samples with high mafic-association standard scores are also located southeast of Scotties mine and at the Ilgarari mining locality, which are possibly areas of dolerite subcrop. Abundant ferruginized clasts are located at a distance from areas of dolerite, but there is no strong mafic association in the sample chemistry. The ferruginized clasts near dolerite are from relict surfaces of ferruginized dolerite, whereas those at greater distance are more likely lithorelics, derived from sedimentary rock with secondary iron precipitated from solution.

Mineralization potential

The concentrations of the precious metals Ag, Au, Pd, and Pt are low in analysed regolith from COLLIER (Figs 15, 17, 34, and 35), and most elevated Au values above the detection level are recorded in regolith samples overlying the Collier Subgroup and the Yilgarn Craton. The few regolith samples from COLLIER with anomalous values of Pd and Pt are mostly over the Bangemall Basin, and commonly reflect material derived entirely or in part from mafic rocks.

Base metal values in regolith are typically higher in regolith samples derived from dolerite. Higher values for base metals are also returned from the Ilgarari mining locality. Regolith samples sourced from dolerite associated with fracture-hosted mineralization at the Ilgarari mining locality and the Neds Gap and Koode Magi deposits have elevated Ba, Cu, Pb, and Zn concentrations over a wide area. Low-level mineralization appears to extend northeastward through the Ilgarari mining locality. However, all base metal concentrations in regolith are low around the Kumarina and Copper Hills deposits, and the Brumby Creek copper occurrence. Regolith samples from near the Abra stratabound lead–zinc deposit are only slightly elevated in these metals, due presumably to the depth of the deposit. The highest values of zinc are in regolith samples overlying stratigraphically similar rocks in the Glen Ross and Turner Creek Anticlines, which are not located near any known mineralization. Elevated values of copper associated with samples from dolerite northwest of Cardawan Hill in the southern part of COLLIER and east of Black Magic Bore in the central part of the map sheet (which are also high in Pt) warrant further investigation.

Arsenic, Cd, Mo, S, and Sb are relatively high in regolith from the Jillawara Formation in the Brumby Creek and Glen Ross Anticlines, indicating possible sulfide mineralization. There are also elevated values of Ag, As, Cd, Mo, S, and Sb in regolith derived from the Backdoor Formation, south of Beyondie Bluff. There is possible zoning, with higher Mo and Sb concentrations further south than As and Cd. There has been little recorded exploration in this area.

The highest levels of REE in regolith overlie the Collier Subgroup and are associated with dolerite. Higher values of Th are recorded around the Ilgarari mining locality.

Summary and conclusion

The three broad divisions of regolith (relict, erosional, and depositional) have been subdivided using regolith composition, texture, and slope into 33 regolith-landform units. The depositional regime is dominant on COLLIER and covers 69% of the map sheet area — of this, colluvial units account for 36%, active drainage and sheetwash 23%, and eolian environment 10%. Erosional-regime regolith covers 30% of COLLIER. The relict-regime regolith is poorly represented, comprising less than 2% of the sheet area.

Sandplain has traditionally been considered an eolian deposit, with its composition reflecting derivation from long distances. However, sandplain on COLLIER indicates a general lithological control imposed by nearby or underlying bedrock. Sandplain developed over the Yilgarn Craton and Collier Subgroup has significantly higher Fe_2O_3, Cr, Cu Ga, Sc, V, and Zn concentrations and lower SiO_2 than sandplain developed over the lower Edmund Subgroup and Savory Group, indicative of either a local source, illuviation, or bioturbation.

Regolith from dolerite on COLLIER has been grouped according to stratigraphy. Statistical analysis of the four groups shows significant differences exist between the Ilgarari Formation, Collier Subgroup, and Edmund Subgroup dolerites. Dolerite intruded into the Collier Subgroup has higher concentrations of elements with ultramafic affinities (Co, Cr, Cu, Ni, Pd, and Pt), whereas dolerite intruded into the Edmund Subgroup is more mafic (with higher TiO_2, Fe_2O_3, MnO, P_2O_5, MgO, CaO, In, Sc, V, Y, and Zn).

Regolith pH is low in both sandplain samples and samples from the eastern side of COLLIER, and higher in regolith from dolerite or calcrete. Regolith geochemistry has also been used to construct additive-index maps (Figs 55 and 56), which highlight areas for studies of potential mineralization. Chalcophile-index values are high for regolith samples from south of Beyondie Bluff, the Glen Ross and Brumby Creek Anticlines, and the Ilgarari mining locality. The summed standard scores for all the components sampled on COLLIER also highlight the Glen Ross and Brumby Creek Anticlines and the Ilgarari mining locality, but not the area south of Beyondie Bluff. In addition, it highlights dolerite from north of the Ilgarari mining locality, and an area south of Mingah Springs Homestead has a number of elevated components.

The results of the regional regolith and geochemical mapping program on COLLIER, combined with information from previous exploration activity and bedrock geology, indicate several areas of mineral potential worthy of further investigation. These include:

- quartz-vein and shear-hosted gold mineralization in the Yilgarn Craton;
- stratiform lead–zinc mineralization in the Jillawarra Formation;
- fracture-related copper mineralization associated with some dolerites in the Bangemall Basin.

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Appendix 1

Mines and prospects on Collier prior to 16 March 1998

Mining locality	*Years mined*	*Mine / prospect / owner / name*	*Tenements*	*WAMIN deposit number*	*Location (AMG) Easting*	*Location (AMG) Northing*	*Production Ore and conc. (t)*	*Production Metal (t)*
Copper								
Butcher Bird	1916–18	Butcher Bird	ML 52/41	74	775609	7297048	37.4	8.46
Ilgarari	1914	Sons of Gwalia South	ML 52/10–11	52	759690	7302644	2.9	1.06
	1914–20	Sons of Gwalia	ML 52/9	52	759690	7302644	465.9	172.62
	1937	Ewen, E. L.	PA 52/615	52	759690	7302644	7.6	1.02
	1940	Reid, Robert	PA 52/713	52	759690	7302644	7.6	1.11
	1948	Edwards, M.	LTT 70/1103	52	759690	7302644	(a) 179.8	21.58
	1948–49	Oma, E. C.	MC 52/27	52	759690	7302644	(a) 97.0	11.36
	1952–54	Edwards, M.	MC 52/35,60	52	759690	7302644	(a) 62.5	17.27
	1955–56	North End Syndicate	MC 52/64	52	759690	7302644	(a) 214.9	20.16
	1956	Edwards, R.W.	PA 52/854	52	759690	7302644	(a) 38.3	4.33
	1959	Smith, R. J.	LTT 70/1407	52	759690	7302644	(a) 8.6	0.68
	1961	Warman, A. C. and Hilditch, A.S.	MC 52/64	52	759690	7302644	(a) 32.9	6.90
	1967	Ilgarari Copper Syndicate	MC 52/98	52	759690	7302644	(a) 26.7	3.70
	1915–16	Bulla Downs (Reward)	ML 52/36 (b)		752000	7343000	79.9	20.75
	1917–18	Burra Copper Mines Ltd	ML 52/35 (c)		760700	7302700	26.3	8.99
	1962	Koode Magi (Alac, M.)	MC 52/96	78	762149	7324685	(a) 13.7	1.75
	1965–70	Alac, M.	MC 52/97	55	760871	7303146	(a) 528.5	115.31
	1971–73	Group Explorations PL	MC 52/97	55	760871	7303146	1381.5	404.84
Kumarina	1914–15	Resurgam	ML 52/32	67	757325	7267698	26.3	9.08
	1958	Parkinson, T. L.	MC 52/63	67	757325	7267698	(a) 1502.1	234.87
	1914–15	Two Sisters	ML 52/29–31	59	756610	7266609	65.1	31.43
	1916–17	Two Sisters North	ML 52/31	59	756610	7266609	117.6	31.90
	1952–69	Parkinson, T. L.	MC 52/43	59	756610	7266609	(a) 538.8	124.26
	1956–57	Parkinson, T. L.	MC 52/43				120.4	51.89
	1917–20	Sonia and Diana	ML 52/37–38	72	758512	7267833	137.2	48.02
	1955	Parkinson, T. L.	PA 52/850	72	758512	7267833	(a) 21.3	2.98
	1948	Brown, W. H.	LTT 70/1117	70	758427	7267698	(a) 46.9	4.69
	1949	Wright, A. E.	LTT 70/1132	70	758427	7267698	(a) 53.8	4.69
	1949	White, A. J.	MC 52/34	63	756704	7266360	8.3	3.79
	1950–51	White, A. J.	MC 52/34	63	756704	7266360	(a) 78.7	19.11
	1954	Parkinson, T. L.	MC 52/59	63	756704	7266360	(a) 61.0	12.80
Nounena	1917	Hard to Find (Mountain Maid)	ML 52/46	75	751551	7313671	2.0	0.82
TOTAL							**5991.5**	**1402.22**
Lead								
Peak Hill Mineral Field	1949	Keep-it-Dark	unknown	296	758928	7326734	(d) 5.6	4.37

SOURCE: Appendix 1 is a collation of all available data from published and unpublished sources, as reported to the Department of Minerals and Energy's Royalties Branch

NOTES:
(a) Cupreous ore and concentrate
(b) Appoximate location from description in mining lease register
(c) Approximate location from sketch in application file 2083/15
(d) Contained 1.865 kg silver

Appendix 2

Gazetteer of localities

Locality	AMG (E)	AMG (N)
12 Mile Well	671220	7290800
3 Corners Bore	766780	7251852
Abra deposit	660383	7273296
Bald Hill Well	777361	7258994
Bamboo Spring	661834	7289650
Batthewmurnarna Hill	739523	7236973
Battler Well	749364	7322905
Beefwood Outcamp Well	743485	7237625
Beyondie Bluff	794686	7263743
Bidulena Bore	699120	7257930
Black Magic Bore	715730	7296752
Bloodwood Bore	790500	7286800
Bloodwood Well	771200	7328120
Bloody Rat Bore	660950	7327050
Blue Bush Bore	763799	7310933
Bluff Well	656920	7306980
Bongardner Bore	800970	7269938
Boundary Bore	705228	7332426
Boundary Bore	763083	7245605
Box Bluff	722291	7257193
Brown Well	744250	7257750
Brumby Creek deposit	674245	7313936
Brumby Hill	683511	7272724
Bubba Kail Kail Bore	668720	7244920
Bujundunna Pool	721010	7291813
Bujundunna Well	719441	7291706
Bull Well	766720	7339900
Bulloo Downs Homestead	761598	7342943
Bungarra Bore	723945	7315257
Bunningunna Bluff	737720	7296300
Butcher Bird mine	775609	7297048
Cadgie Well	765380	7301550
Cardawan Hill	723389	7258739
Carson Bore	670620	7327200
Charley No 2 Well	714992	7316087
Charley Well	717996	7314540
Chilibubba Pool	710817	7302197
Conical Hill	697804	7320518
Copper Hills deposit	773785	7243537
Corner Bore	765930	7310320
Crabholes Bore	759850	7340600
Crooked Bill Well	684520	7247800
Cudulung Pool	653900	7245250
Dalungunng Pool	661780	7244420
Dead End Bore	659747	7248460
Dingo Bore	656100	7315720
East Bluff	694900	7318220
ESR No 13 Well	705060	7333165
ESR No 14 Well	724809	7336733
ESR Well No 11	661950	7329650
ESR Well No 12	683750	7329050
ESR Well No 15	656419	7304698
Fig Tree Spring	705275	7316334
Fork and Lever Bore	738000	7324900
Garden Well	691680	7251280
Gidgey West Bore	734578	7246819
Glen Camel	654054	7343133
Godsend Well	659190	7260116
Grand Junction	672476	7325905
Granny Well	717131	7335690
Gununurra Pool	706578	7307255
House Well	695757	7298783
Ilgarari Hill	772038	7314169
Ilgarari Outcamp	761915	7305104
Ilgarari mining locality	759690	7302644
Irrigation Well	675467	7241948
Jam Tin Bore	685086	7242191

Locality	AMG (E)	AMG (N)
Jaydina Bore	763720	7260150
Jibboongunna Pool	737000	7239000
Jilgoonah Pool	732287	7236406
Jubilee Well	762264	7240824
Kangaroo Spring	727645	7324207
Keep-it-Dark mine	758928	7326734
Kelley Well	691550	7297300
Koode Magi deposit	762149	7324685
Kumarina mining locality	756604	7266595
Kumarina Roadhouse	763682	7264434
Lanes Bore	685250	7236150
Larger Bore	708641	7316100
Mardinardya Well	751309	7312820
Marked Tree Well	715800	7282600
McKay Well	798649	7337096
Mickey Spring	685018	7330121
Mingah Gap	674283	7247051
Mingah Springs Homestead	672869	7239402
Minnaritchie	775779	7277785
Monkey Well	733592	7319613
Montharra Bore	740549	7314292
Monty 36 Well	782433	7280236
Morrisey Junction	724140	7335563
Mulangulbungalla Spring	733323	7306342
Mungajerry Well	766400	7298150
Namboongunna Pool	670200	7241300
Neds Gap deposit	759514	7317633
Nicken Bore	670450	7258650
Nicken Spring	676800	7260920
No 14a Well	655572	7278654
No 34 Govt. Well	762695	7251504
No 35 Govt. Well	765638	7272763
No 36 Govt. Well	774914	7284717
No 39 Govt. Well	802248	7340767
No 88 Well	716668	7289249
Nugglegunna Pool	750897	7240935
Nugglegunna Well	753471	7241291
Nuninga Spring	749648	7313102
O'Donnell Soak	661919	7329142
Old Cardawan outstation	738480	7256443
Old Letterbox Bore	776450	7317460
Rabbit Bore	661796	7258832
Richards Bore	760500	7336200
Rocker Bore	671270	7253420
Saltwater Well	653417	7309919
Scotties mine	770623	7338166
Scotty Well	778970	7332020
Shamrock Bore	655705	7238919
Shepherds Well	744650	7261800
Spinifex Bore	693073	7242807
Stoney Point Bore	690450	7253650
Table Hill	741128	7325823
Tangadee Homestead	696577	7298733
Ti Tree Well	759335	7329889
Top Trough Well	764300	7333800
Vince Bore	750400	7266150
Wannangunna Spring	690097	7311030
Weelarrana Hill	797205	7339008
West Bluff	663220	7312350
White Hill Spring	694300	7310850
Wonyulgunna Hill	779279	7252368
Woolbunna Bore	791463	7294131
Woolbunna Pool	788523	7294040
Woomera Hill	680461	7272714
Yandilgunna Pool	663000	7243950
Yanneri Well	779226	7294725

Appendix 3

Open-file geochemical surveys

KEY

ID no.:	Project reference number allocated for these notes (see Plate 2)
M no.:	GSWA project reference number. An asterisk beside the M number indicates that not all the samples for the listed activities fall within COLLIER; that is, the total number of samples includes some taken on adjacent sheets.
Year:	The year that the report was written.
I no.:	The Item number, or Department of Minerals and Energy library reference number for a group of related open-file reports on microfiche; this number replaces the M number for project identification.
A no.:	GSWA report reference number.
Activity ID:	The number allocated by GSWA's SPINDEX (spatial index) database to identify exploration activities within projects.
Activity type:	The geochemical exploration activity (drilling details are only included if analytical samples are taken within 0–4 m depth): DIAM: Diamond drilling NGRD: Includes rock chip, lag, costean (up to 4 m depth) and grab samples. RAB: Rotary air blast drilling RC: Reverse circulation drilling SOIL: Surface or shallow soil samples SSED: Stream sediment
No.:	The number of analytical samples.
Method:	The analytical method used to determine the elements listed. AAS: Atomic absorption spectroscopy BCL: Bulk cyanide leach ICP: Inductively coupled plasma Neutron: Neutron activation XRF: X-ray fluorescence
Activity elements:	The elements for which analyses were carried out. #: Indicates anomalous analytical result
Description:	Various sample details such as the sieve size fraction, sample density, etc., depending on the information provided in the report. When these details are provided in italics, the exploration activity has not been used to compile the exploration activity areas on Plate 2. This is usually due to poor sample location in the report.

NOTES: For public use all open-file company reports are provided on microfiche in the Department of Minerals and Energy's (DME's) library at Mineral House. To locate a particular report on microfiche, the relevant Item number and A number are required.

Appendix 3 Open-file geochemical surveys

ID no.	*M no.*	*Year*	*I no.*	*A no.*	*Activity ID*	*Activity type*	*No.*	*Method*	*Activity elements*
1	*62	1965–67	3227	*574*	*1036*	*NGRD*	*18*		*Au#,Pb#,Cu#*
				980	*643*	*SSED*			*Cu,Pb,Zn,Ni*
				980	*1049*	*SOIL*	*3 750*		*Cu,Pb,Zn,Co,Ni*
				980	1050	SSED	8 200		Cu#,Pb,Zn,Ni
				980	*1054*	*NGRD*	*20*		*Cu#,Pb#,Zn#,Ni*
2	*144	1966	48	1552	2994	SSED	7 000		Cu,Ni,Pb,Zn,As
3	149	1967	1004	995	3158	RC	75		Cu#,Ag,Ni
4	1133	1973	313	3477	3150	SOIL		AAS	Cu,Pb,Zn,Co
				3477	3151	NGRD	37		Cu#,Co,Ni,Mo,Zn
				3477	3153	RC	21		Cu#,Zn,Pb,Co,Mo
5	*1609/2	1976–83	4641	7071	2730	SSED	205		Cu#,Pb#,Zn#
				7071	2731	NGRD			Ag,Cu#,Pb#,Zn#
				7071	2732	SOIL			Cu,Pb,Zn,Mn,Ag
				7976	3508	SSED	350		Cu#,Pb,Zn#
				7976	3509	RC	1		Cu,Pb,Zn,Ag,Mn
				7977	2975	SSED			Cu,Pb,Zn,,Mn,As
				14148	3574	SSED			Au,Cu#,Pb#,Zn#
				31356	3542	NGRD	35		Cu#,Pb#,Zn,Au,Ag,Ba,Co,As
				31356	3543	SSED	500	AAS	Ag,Au,Bi,Cu,Pb,Zn
						"		XRF	As,Ba,W
	1609/6	1993	7218	39406	3593	SSED	106	AAS	Cu,Pb,Zn,Fe,Mn#,Co,Ni,Ag,As,Bi
6	1644	1974	1053	5374	3060	NGRD	96		Cu,Pb,Zn
7	2161	1978	962	8040	3074	NGRD	68		P,Mn#,Fe,Al_2O_3,SiO_2
8	2196	1979	932	8399	3071	NGRD	1 824		Co,Cu,Pb,Zn
				8399	3072	SSED		AAS	Cu#,Pb,Zn#,Ag,Cd
9	2577	1980	935	8811	3018	NGRD	71		Cu#,Pb#,Zn#,Mn
10	2657	1981	2043	10011	2528	NGRD	47		Cu#,Pb,Zn#,Ag,Au,U,Mn
11	2771/2	1981	2048	10419	3021	SSED			Cu#
12	3923	1985	2612	15999	2925	NGRD	115		Ni,Cu,Zn,Pb,Mn,Cr,Ag,Co,Bi,V,Mo,Sr,La,Y,Be,Ce,Zr,Sn
				15999	2927	SSED	88	ICP	Ni,Cu,Zn,Pb,As,Mn,Cr,Fe,Al_2O_3,MgO,CaO,Na_2O,K_2O,
						SSED			TiO_2,P_2O_5,Ag,Co,Bi,V,Sr,La,Y,Be,Ce,Zr,Sn
				15999	2928	RC	5		Cu,Zn,Pb,Ba
				16541	2934	NGRD			Ni,Cu,Zn,Pb,As,Mn,Cr,Fe,Al_2O_3,MgO,CaO,Na_2O,K_2O,
						NGRD			TiO_2,P_2O_5,Ag,Co,Bi,V,Mo,Sr,La,Y,Be,Ce,Zr,Sn
				16664	3042	NGRD		ICP	Cu#,Pb#,Zn#,Ba#,,Al_2O_3,MgO,Cr,Ni,V,Bi,Mo,Sn,La,Ce, Y,Zr,Ag,As
				16664	3043	SSED		XRF	Ba,Cu#,Pb#,Zn#,Ba,Al_2O_3,CaO,MgO,Fe,V,Cr,Ni,Sn,La, Ce,Y,Zr,Cr,Bi,Ni
				16664	3045	RC	16		Cu,Pb,Zn,Ba#

for COLLIER as at March 1998

Description

Gossan and grab samples. No plans included.

Fraction -80 mesh fraction. (1:2400; 1:10 200; 1:6000)
Fraction -80 mesh. (1:12 000; 1:10 200; 1:47 520; 1:2400)
Costean (1:240)

Minor Cu anomalism,but did not reach above 5 times background level. (1:40 000)

Percussion — 75 holes totalling 3200 m. Sampled at 1.5 m intervals. Best intersection: 9.5 m @ 2.68% Cu. (1:1200)

Collected using hand auger on lines 244 m apart and at 30 m intervals; -80 mesh fraction. (1:6000)
Costeans and grab samples. Sampled at 1.5 m intervals. (1:6000)
Percussion — 21 holes totalling 1051 m. Sampled at 1.5 m intervals. Best intersection 22.4 m (4.6 – 27 m) @ 5712 ppm Cu. (1:6000)

To follow up Discovery Chert and aeromagnetic anomalies -10+80 mesh fraction was found to be the most suitable. (1:20 000)
Grab sampling along the strike length of the Discovery Chert. Highest assay values were 980 ppm Cu#, 420 ppm Zn#, 2.5 ppm Ag. (1:20 000)
Sampling at Abra prospect at 20 m intervals on lines spaced 160 m apart; -30+80 mesh fraction. (1:20 000)
Reconnaissance sampling; fraction -20+30# (1:20 000)
One percussion hole 200 m deep at Abra prospect to test a ground magnetic anomaly; 2 m intervals assayed. (1:100 000)
Reconnaissance in Manganese Range area. Detailed surveys in Kiwi Gorge and Manganese Range. -20+80# fraction collected at 10 m intervals. (1:20 000; 1:10 000)
Reconnaissance sampling. Au bulk sampling also collected from Fencers prospect — anomalous value of 12.19 ppb from southern end of prospect. (1:25 000)
Collected during geological mapping; majority from gossanous veins in the Gap Well Formation. (1:25 000)
Orientation survey conducted at Copper Chert prospect. Fractions -1180,+600,-600,+300,-300,+150,-150,-2000+1180 collected. Fraction -2000+1180 used for assays.
Samples collected from the Gap Well and West Creek Formation with a density of 6 samples per sq km. (1:25 000)
2 kg samples, -4 mm fraction. 10 duplicates.

Rock chip — most from ferruginous or siliceous outcrops near faults.

Sampling from pits in Manganiferous laterite. Fractions: +12.7 mm,-12.7+3.18 mm,-3.18 mm. Estimated reserve of 5 million tonnes of shale enriched in Mn. (1:20 000)

Continous rock chip along approx. 1 km-spaced lines perperdicular to regional strike; 3 m composites. Low order anomaly associated with siltstone–shale units. (1:1000)
Sample density 4.8 samples per sq km; -80 mesh fraction. (1:25 000)

Grab and gossan. (1:5000)

Rock chip — highest values: 4.9% Cu,530 ppm Zn. (1:50 000)

Mesh -80 fraction. Although some anomalism reported in assay values,rechecking did not repeat results. Not all samples located on map. (1:100 000)

Rock chip over INPUT anomaly collected along 7 traverses. Mainly cherts. (1:40 000)
Collected from creeks draining Mount Vernon scarp in the vicinity of an INPUT anomaly; -2000+805 micron fraction. (1:40 000)

Percussion — 5 holes totalling 321 m drilled to test the SIROTEM conductor. Holes bottomed in dolerite. Sampled every 2 m.
Grab sampling — mainly gossan. No significant mineralization. Also sampling on stratigraphic sections. (1:350 000)

Rock chip sampling with geological mapping. (1:40 000)

Density of 4 samples per sq km; -2000+850 micron fraction. (1:40 000; 1:22 000)

Percussion — 16 holes totalling 2165 m; sampled at 2 m intervals. (1:40 000)

Appendix 3

ID no.	*M no.*	*Year*	*I no.*	*A no.*	*Activity ID*	*Activity type*	*No.*	*Method*	*Activity elements*
13	3991	1987	3689	21295	2940	RAB	41		Au
14	*6402	1989	4138	29115	2896	NGRD	26		As,Au
				29115	2897	SOIL	124	BCL	Au,Cu,Pb,Zn,Ag,Mo,Cr,Cd,Sn,Bi,Sb,Se,Te
15	*6773/1	1990–94	8550	31334	3143	SOIL	7	BCL	Au
				31334	3144	SSED	118	BCL	Au
				31334	3146	RAB	59		Au
				33615	3264	SSED	32	BCL	Cu#,Pb,Zn#,As,Au#
				33615	3265	SOIL	55	BCL	Cu#,Pb,Zn,As,Sb,Bi,Sn,W,Au
				33615	3266	NGRD	373		Cu#,Au#,Pb,Zn,Sb,As,Bi,Sn,W
				33615	3269	RAB	1 893		Au
				35715	3271	SOIL	28		Cu,Pb,Zn,Ni,As,Au
				35715	4701	NGRD			Au#
				36580	3277	RAB	35		Au
				38480	3275	NGRD	5		Ba,Rb,Sr,Pb,Th,U,Cu,Zn
				41420	3276	SOIL	755		Cu,Pb,Zn,Au,Ag,Cr,Ni,Co,Bi,Sb,Cd,As,Mn,Mo
				41995	*3282*	*RAB*	*10*		*Cu,Pb,Zn,Ag,Au,As,Sb,Bi,Cd,Mo,Cr,Co*
	6733/2	1991	7762	33700	2839	RAB	5		Au
16	6754/1	1990–92	6909	31467	2807	NGRD	128		Cu#,Mn#,Pb,Zn,Au,Ag,U
				31467	2808	SOIL			Cu,Pb,Zn,Mn,Au
				31467	2809	RC	94		Cu,Pb,Zn,Ag,Au
				31467	2810	DIAM	12		Cu#,Pb,Zn,Ag,Au
				37022	2812	NGRD	7		Mg,P,Ti,Cr,Mn,Ni,Cu,Sr,Y,Zr,Nb,Ag,Ba,La,Ce, Nd,Sm,Au
17	7331	1992	6712	35541	2783	NGRD	31	neutron	Au
						NGRD		ICP	P,K,Ti,Mn,Ni,Cu#,Zn#,Y,Zr,Nb,Mo,Ag,Au,Pb,Sc,Cr,Fe,
						NGRD		ICP	As,Se,Br,Rb,Sb,Cs,Ba#,La,Ce,Sm,Eu,Yb,Hf,La,Ir,Th,U
				35541	2784	SOIL	30	neutron	Au
						SOIL		ICP	P,K,Ti,Mn,Ni,Cu,Zn,Y,Zr,Nb,Mo,Ag,Au,Pb,Sc,Cr,Fe,As,
						SOIL		ICP	Se,Br,Rb,Sb,Cs,Ba,La,Ce,Sm,Eu,Yb,Hf,La,Ir,Th,U
				35541	2785	SSED	30		P,K,Ti,Mn,Ni,Cu,Zn,Y,Zr,Nb,Mo,Ag,Au,Pb,Sc,Cr,Fe,As,
						SSED			Se,Br,Rb,Sb,Cs,Ba,La,Ce,Sm,Eu,Yb,Hf,La,Ir,Th,U
18	7777	1992–93	7634	36993	2830	RAB	111		Au
				39677	2836	NGRD	49		TiO_2,MgO,K_2O,Ba,Sr,Zr,Cr,Ni
19	10233	1996–97	9202	48863	3944	SSED			Ag,As,Au,Ba,Bi,Cd,Co,Cr,Cu,Fe,Mn,Mo,Nb,Ni,Pb,Pd, Pt,Sb,Ti,U,Zn,Zr
				48863	3945	NGRD			Ag,As,Au,Ba,Bi,Cd,Co,Cu,Fe,Mn,Mo,Ni,Pb,Pd,Pt,Sb,
						NGRD			U,Zn

SOURCE: Department of Minerals and Energy's SPINDEX and WAMEX databases, March 1998

(continued)

Description

41 holes sampled at 1 m intervals. (1:50 000)

Rock chip. All assay values close to detection limit. (1:100 000)
Sample density of 1 per sq km. 5 kg of -80# fraction material collected at each site. Highest Au value 2.2 ppb. (1:100 000)

(1:20 000)
Highest value of 9.5 ppb Au. (1:20 000)
59 holes totalling 2510 m. All angle holes at 240 m intervals on grid lines 4 km apart. Sampled at 4 m intervals. Best intersection 15 m @ 0.15 ppm Au. (1:5000)
4 kg samples sieved to -2 mm fraction. Also 1 kg archive sample. (1:20 000)
0.5 kg samples every 50 m; sieved to -2 mm fraction. Composites of 4 kg samples assayed. Highest value 1.2 ppb Au.
Rock chip and ironstone sampling. Highest values: 110 ppb Au, 6050 ppm Cu. (1:20 000)
190 holes totalling 7292 m on 400 m spaced lines. All angle holes. Best intersection: 44–46 m (2 m) @ 7.46 g/t Au. Sampled at 4 m intervals. (1:20 000)
Three 10 kg samples per site on 2 x 2 km grid. (1:50 000)
Rock chip — some silicified BIF units, quartz veins within BIF and ferruginous quartz sericite and muscovite schists. Some anomalous gold and base metal values.
35 holes totalling 1194 m, 250–500 m intervals Sampled for 4 m composites. (1:50 000)
Rock chip. (1:20 000)
Sampled at 40–50 m intervals. (1:20 000)
Aircore — 10 holes totalling 595 m. 4 m composites. (1:20 000)
5 holes totalling 226 m. Reconnaissance traverse along the Resolute Resources exploration track. All angle holes. 4 m composite assay samples. (1:20 000)

Rock chip sampling conducted in several phases especially to sample copper-bearing veins and manganese-bearing shale horizons. (1:50 000; 1:2000)
Sampling of 'B soil horizon' at 25 m intervals. (1:2000)
94 holes totalling 5291 m. Several phases of drilling involved to test high-grade Cu mineralization. Selected holes were sampled at 1 m intervals. (1:1000)
12 holes totalling 695 m to evaluate high-grade Cu mineralization. Logs reported for 9 holes. Sampled at 1 m intervals. Best intersection: 2.9 m @ 9.59% Cu. (1:2000)
Rock chip sampling from the magnetic bulls eye anomaly. (1:2000)

Rock chip — samples varied from quartz veins to ironstones.

Sampled over a 3 x 1 km grid at 500 m intervals. Sample depth 2–30 cm, 500 gm, -2 mm fraction. (1:50 000)

Collected from creeks draining selected targets. 100 to 200 g of -20+40# fraction. (1:50 000)

111 holes totalling 2616 m. 4 m composite samples collected & assayed or treated for indicator minerals. Microdiamonds recovered from Hole BH1. (1:20 000; 1:50 000)
Grab sampling for whole rock analyses to identify kimberlitic affinities. (1:50 000)

Fraction -2 mm collected in the tenement using helicopter support. Most elements show a strong association with Fe and Mn. (1:50 000)

Rock chip collected during geological traversing. Most rock chip results were of low tenor with an ironstone developed on dolomite returning highest assays of 360 ppm Cu, 640 ppm Zn, and 235 ppm Ni. (1:50 000)

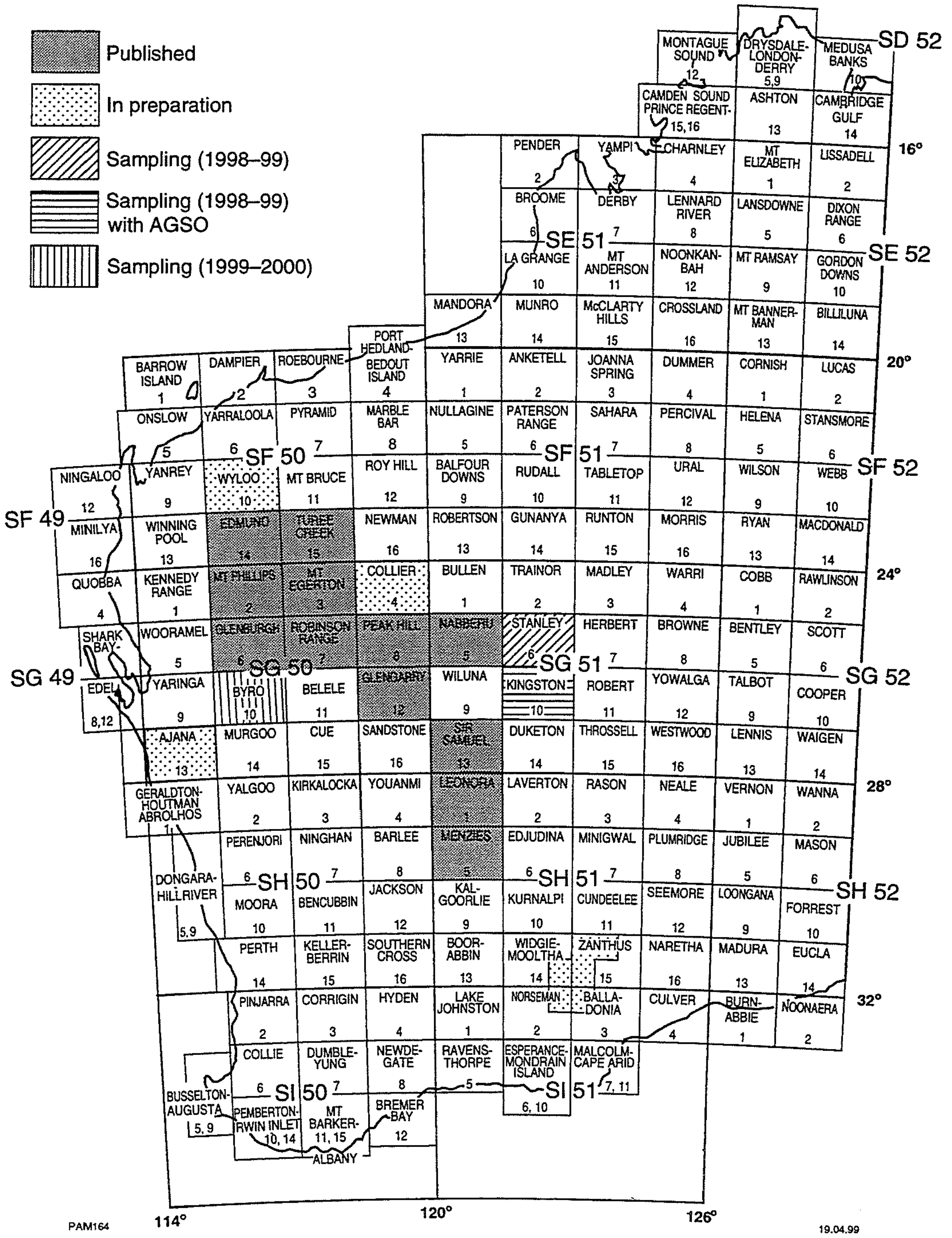

Figure 1. Status of regional regolith and geochemical mapping program maps and explanatory maps

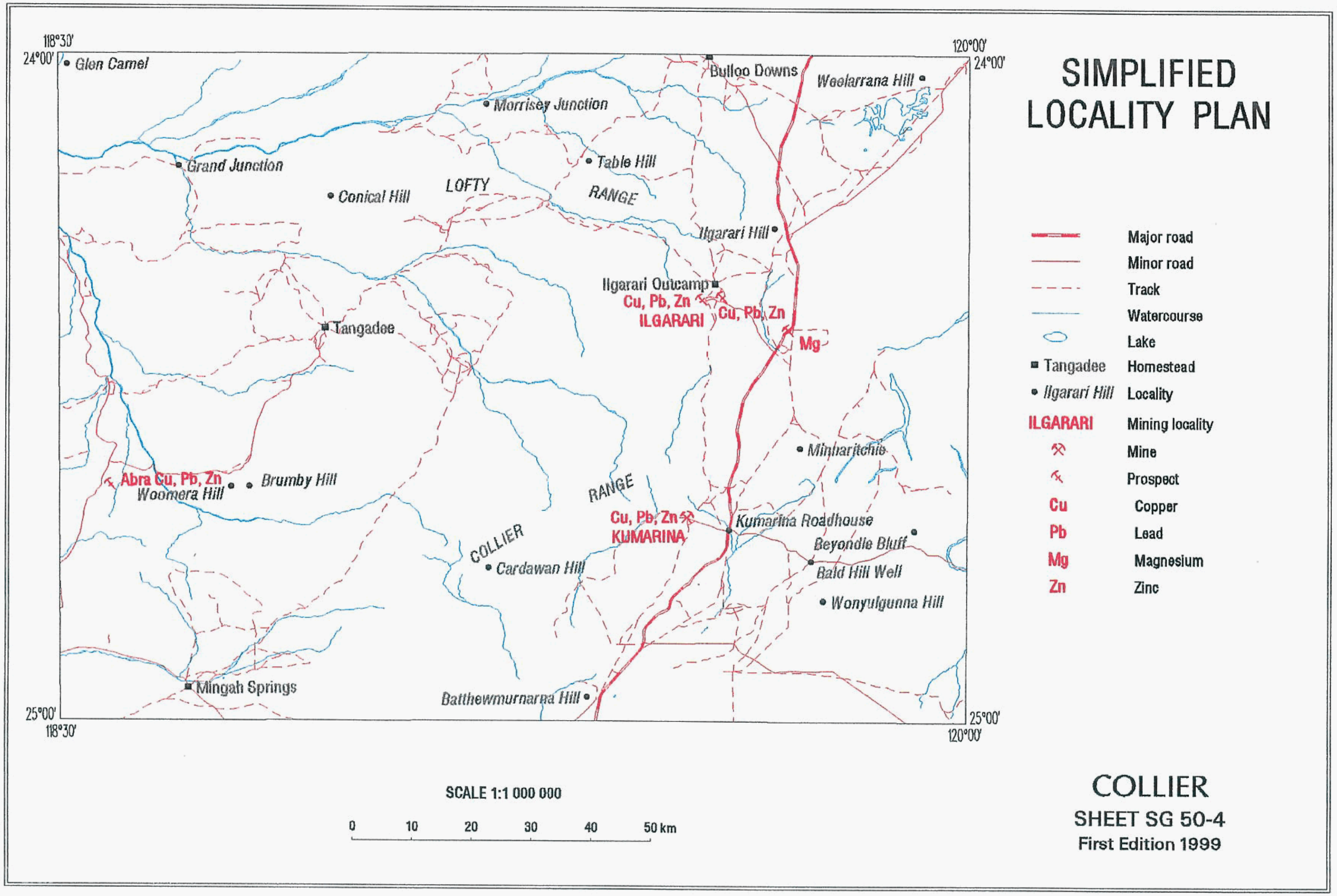
SIMPLIFIED
LOCALITY PLAN
118°30'
24°00'
120°00'
24°00'
25°00'
118°30'
25°00'
120°00'
Glen Camel
Bulloo Downs
Weelarrana Hill
Morrisey Junction
Table Hill
Grand Junction
Conical Hill
LOFTY
RANGE
Ilgarari Hill
Ilgarari Outcamp
Cu, Pb, Zn
ILGARARI
Cu, Pb, Zn
Mg
Tangadee
Minbaritchie
Abra Cu, Pb, Zn
Woomera Hill
Brumby Hill
RANGE
COLLIER
Cu, Pb, Zn
KUMARINA
Kumarina Roadhouse
Beyondie Bluff
Bald Hill Well
Cardawan Hill
Wonyulgunna Hill
Mingah Springs
Batthewmurnarna Hill
Major road
Minor road
Track
Watercourse
Lake
Tangadee Homestead
Ilgarari Hill Locality
ILGARARI Mining locality
Mine
Prospect
Cu Copper
Pb Lead
Mg Magnesium
Zn Zinc
SCALE 1:1 000 000
0 10 20 30 40 50 km
COLLIER
SHEET SG 50-4
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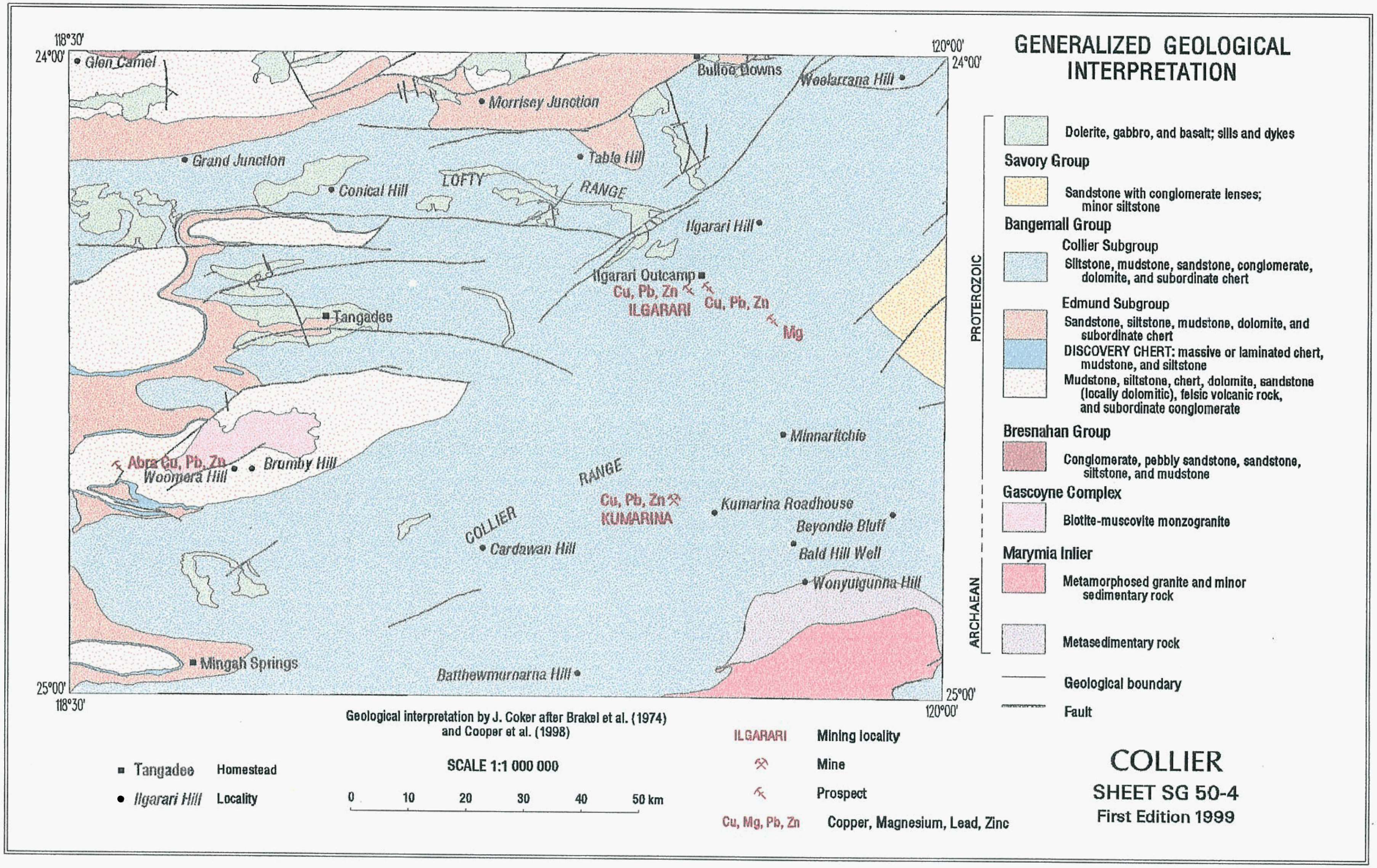
Figure 2.



GENERALIZED GEOLOGICAL INTERPRETATION
Dolerite, gabbro, and basalt; sills and dykes
Savory Group
Sandstone with conglomerate lenses; minor siltstone
Bangemall Group
Collier Subgroup
Siltstone, mudstone, sandstone, conglomerate, dolomite, and subordinate chert
Edmund Subgroup
Sandstone, siltstone, mudstone, dolomite, and subordinate chert
DISCOVERY CHERT: massive or laminated chert, mudstone, and siltstone
Mudstone, siltstone, chert, dolomite, sandstone (locally dolomitic), felsic volcanic rock, and subordinate conglomerate
Bresnahan Group
Conglomerate, pebbly sandstone, sandstone, siltstone, and mudstone
Gascoyne Complex
Biotite-muscovite monzogranite
Marymia Inlier
Metamorphosed granite and minor sedimentary rock
Metasedimentary rock
Geological boundary
Fault
PROTEROZOIC
ARCHAEAN
118°30'
24°00'
120°00'
25°00'
Glen Camel
Morrisey Junction
Bulloo Downs
Woolarrana Hill
Grand Junction
Table Hill
Conical Hill
LOFTY
RANGE
Ilgarari Hill
Ilgarari Outcamp
Cu, Pb, Zn
ILGARARI
Cu, Pb, Zn
Mg
Tangadee
Minnaritchie
Abra Cu, Pb, Zn
Woomera Hill
Brumby Hill
RANGE
Cu, Pb, Zn
KUMARINA
Kumarina Roadhouse
Beyondie Bluff
COLLIER
Cardawan Hill
Bald Hill Well
Wonyulgunna Hill
Mingah Springs
Batthewmurnarna Hill
Geological interpretation by J. Coker after Brakel et al. (1974) and Cooper et al. (1998)
Tangadee Homestead
Ilgarari Hill Locality
SCALE 1:1 000 000
0 10 20 30 40 50 km
ILGARARI Mining locality
Mine
Prospect
Cu, Mg, Pb, Zn Copper, Magnesium, Lead, Zinc
COLLIER
SHEET SG 50-4
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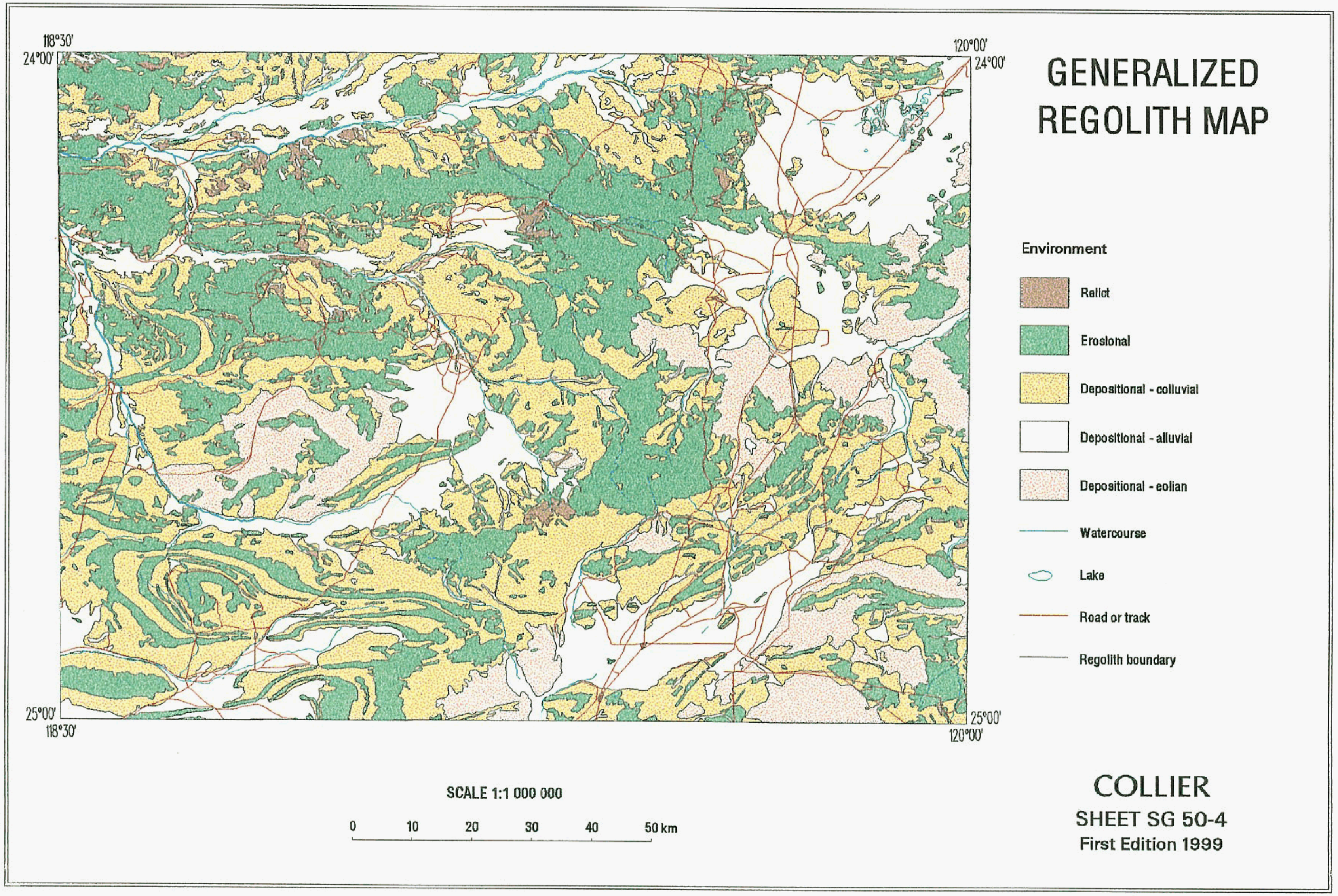
Figure 3.



GENERALIZED REGOLITH MAP
118°30'
24°00'
120°00'
24°00'
25°00'
118°30'
25°00'
120°00'
Environment
Relict
Erosional
Depositional - colluvial
Depositional - alluvial
Depositional - eolian
Watercourse
Lake
Road or track
Regolith boundary
SCALE 1:1 000 000
0
10
20
30
40
50 km
COLLIER
SHEET SG 50-4
First Edition 1999

Figure 4.

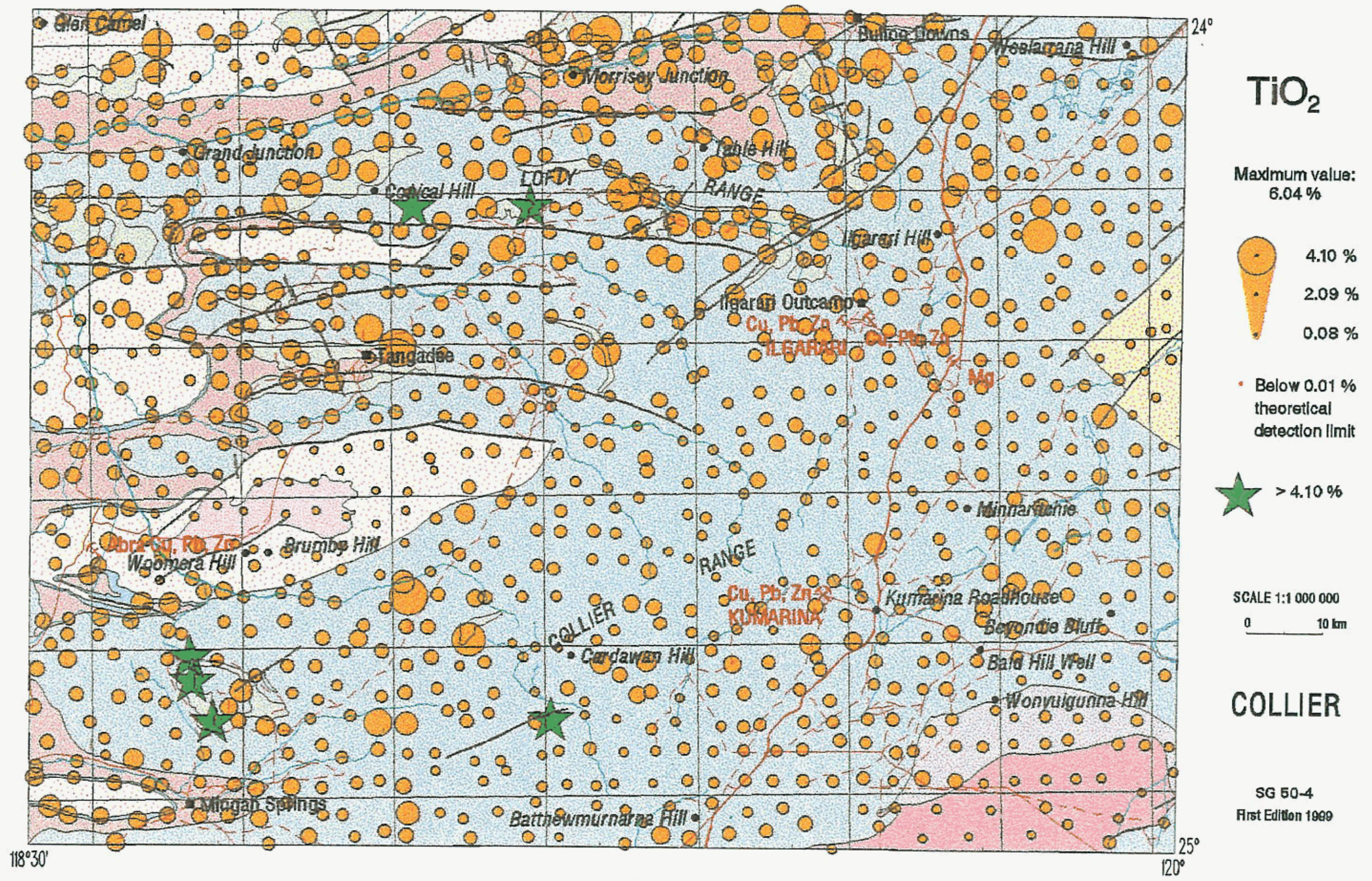


Figure 5

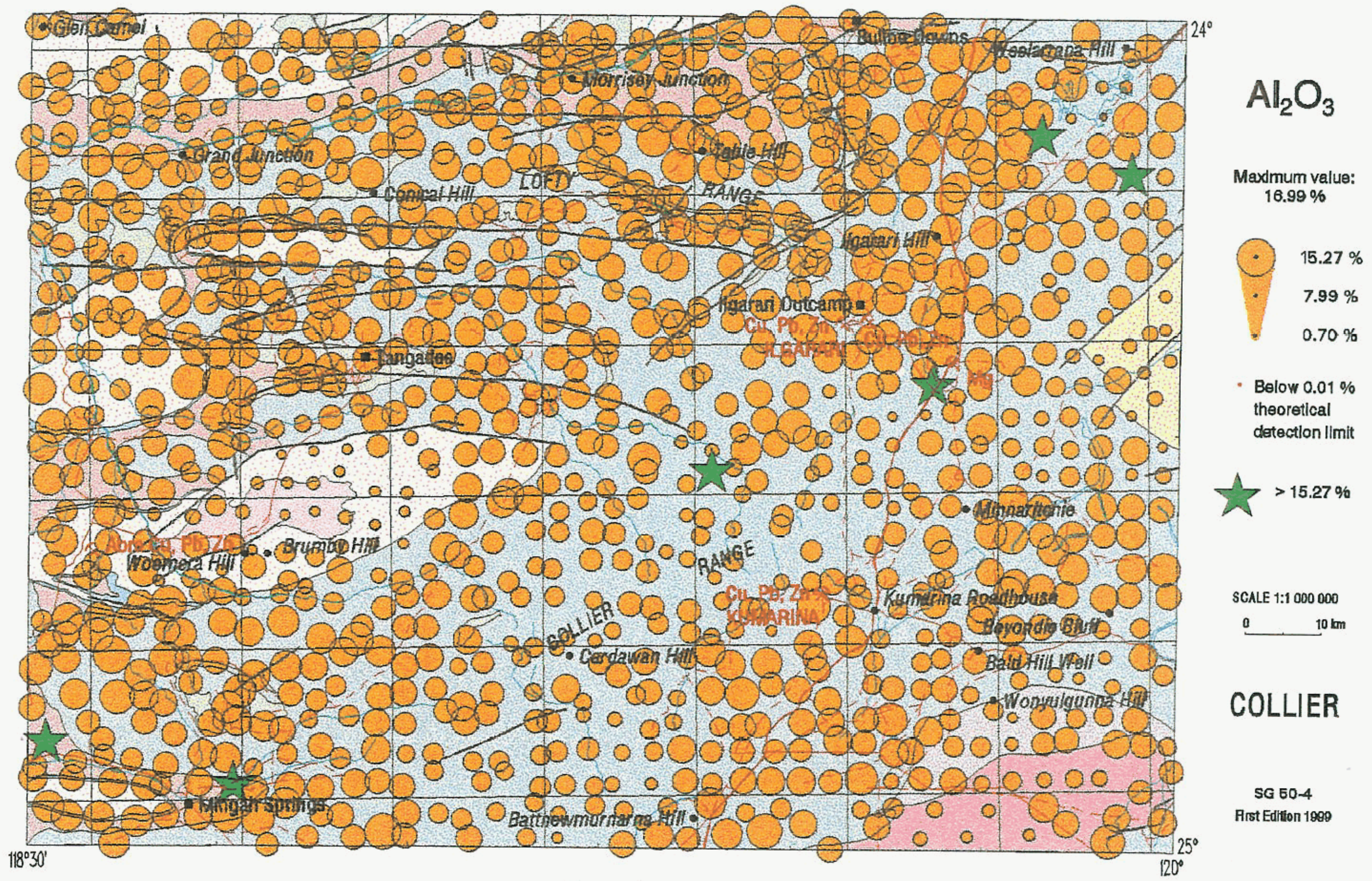


Figure 6

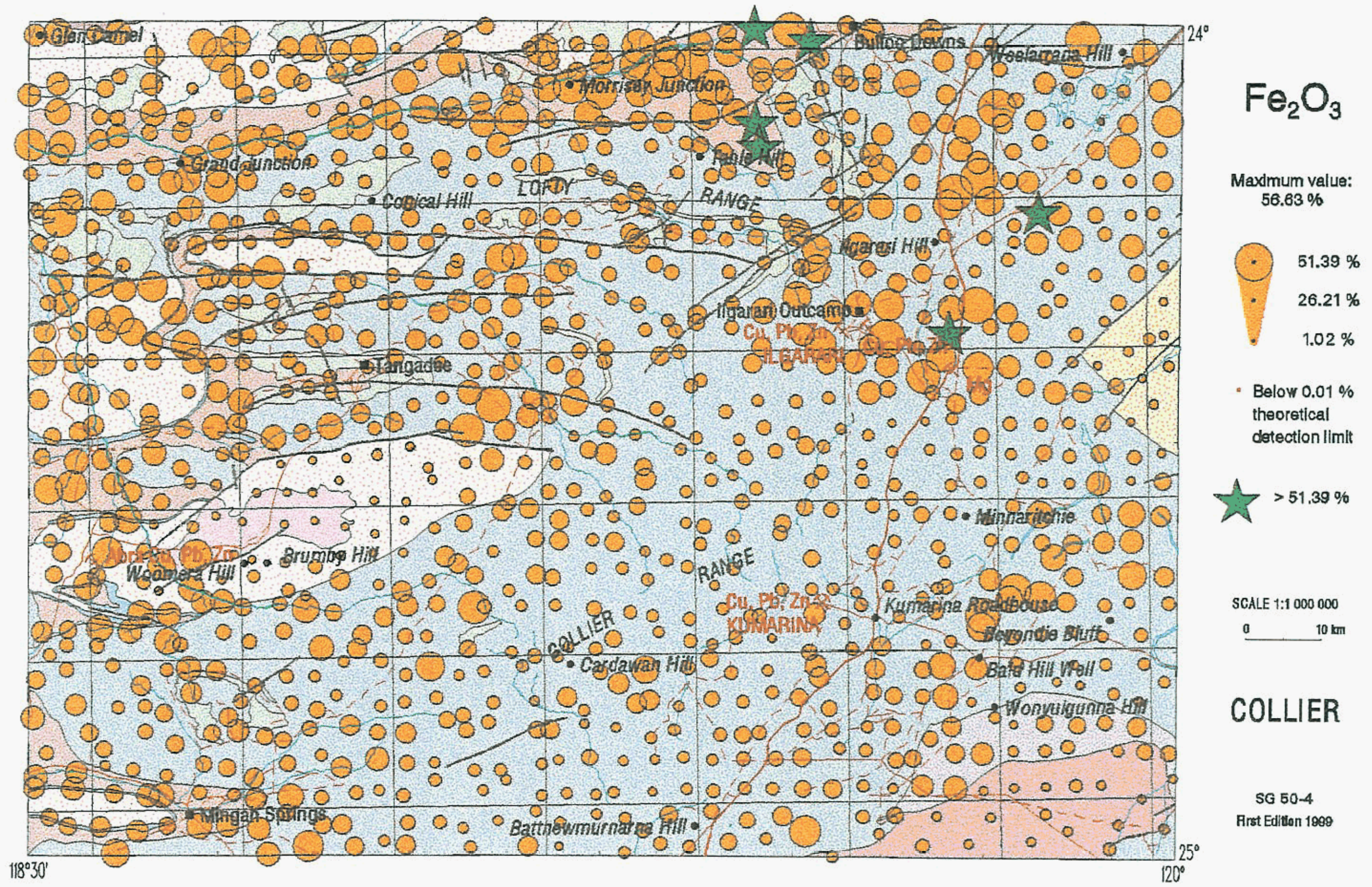


Figure 7

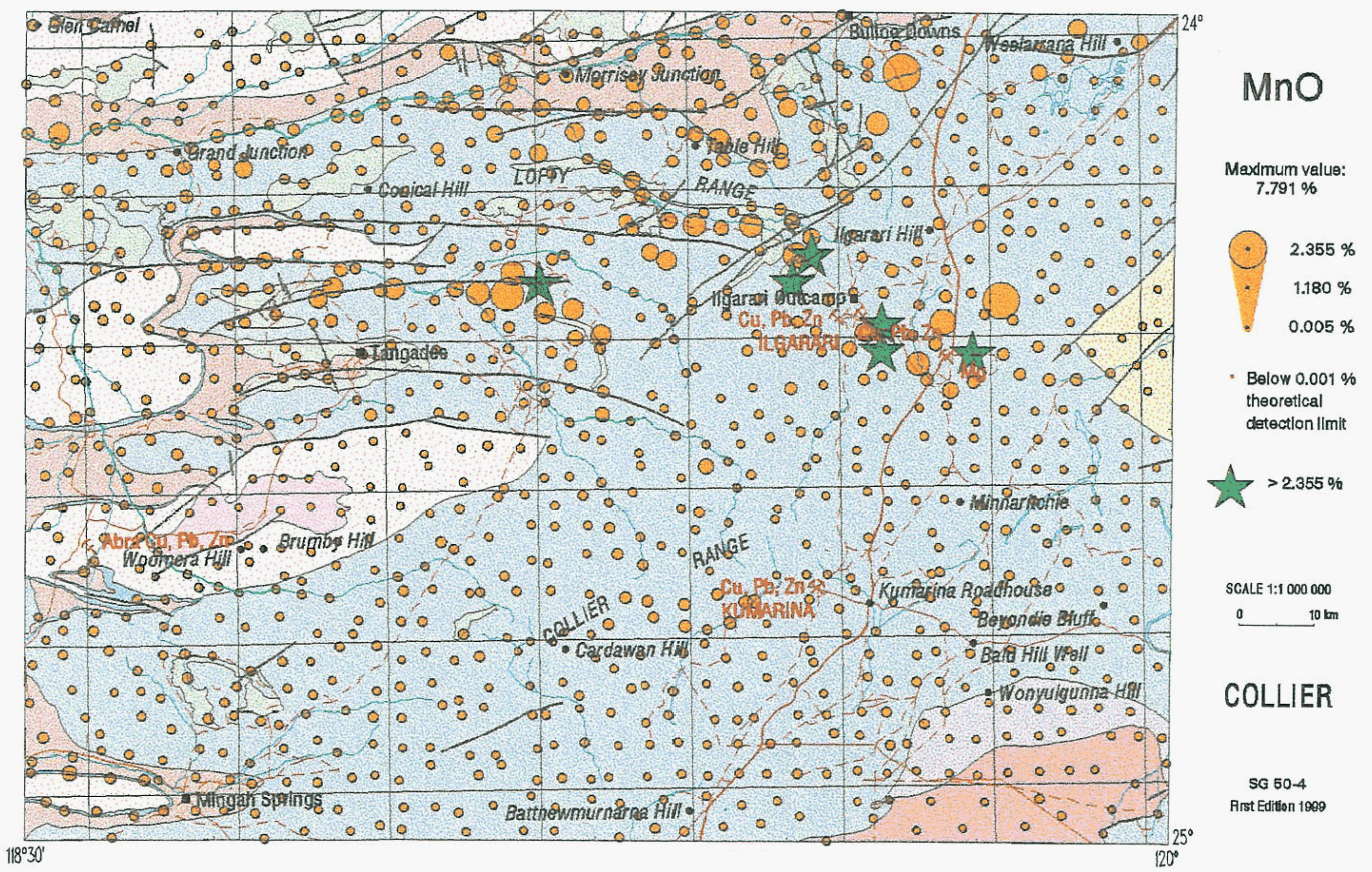


Figure 8

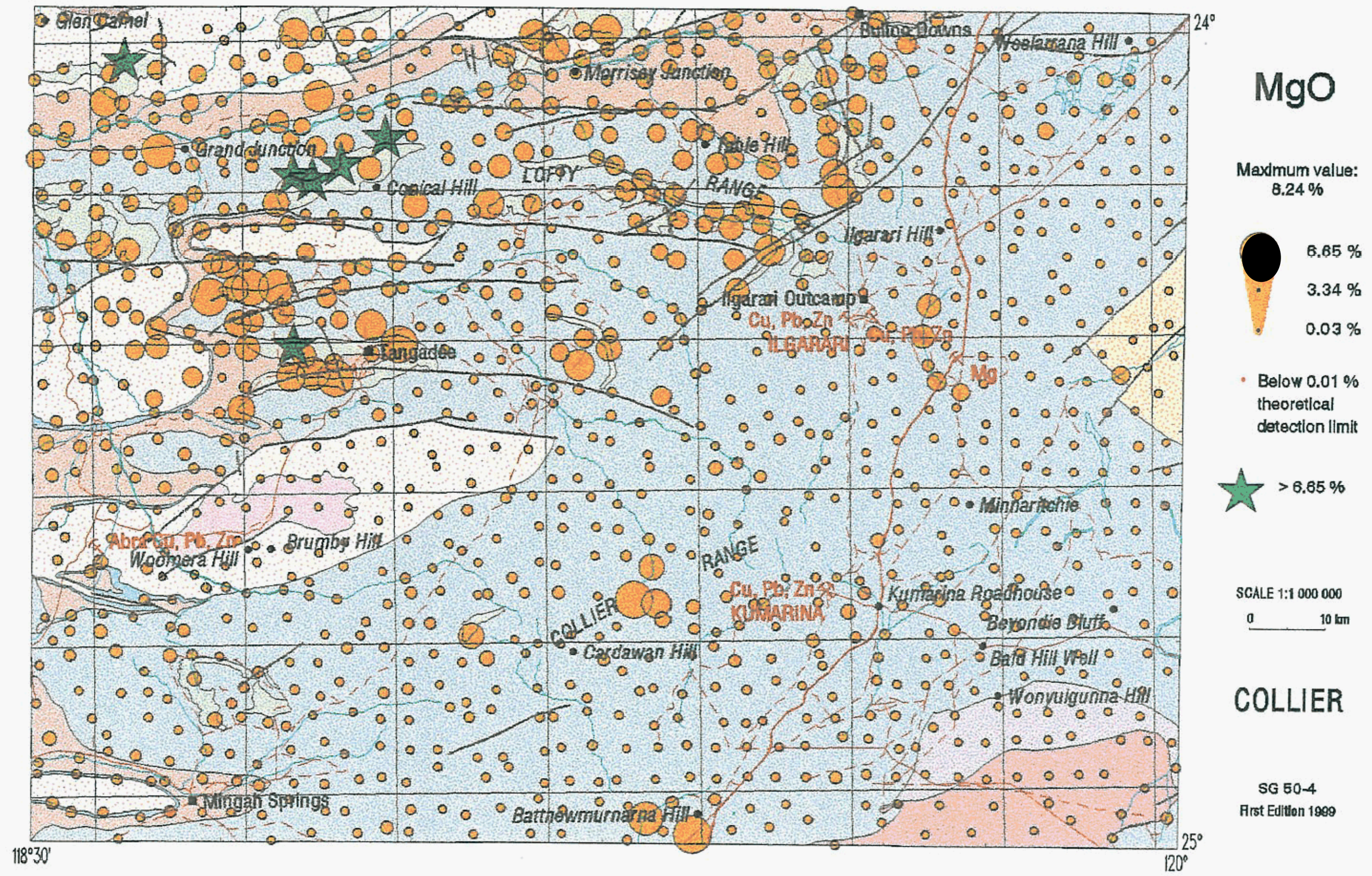


Figure 9

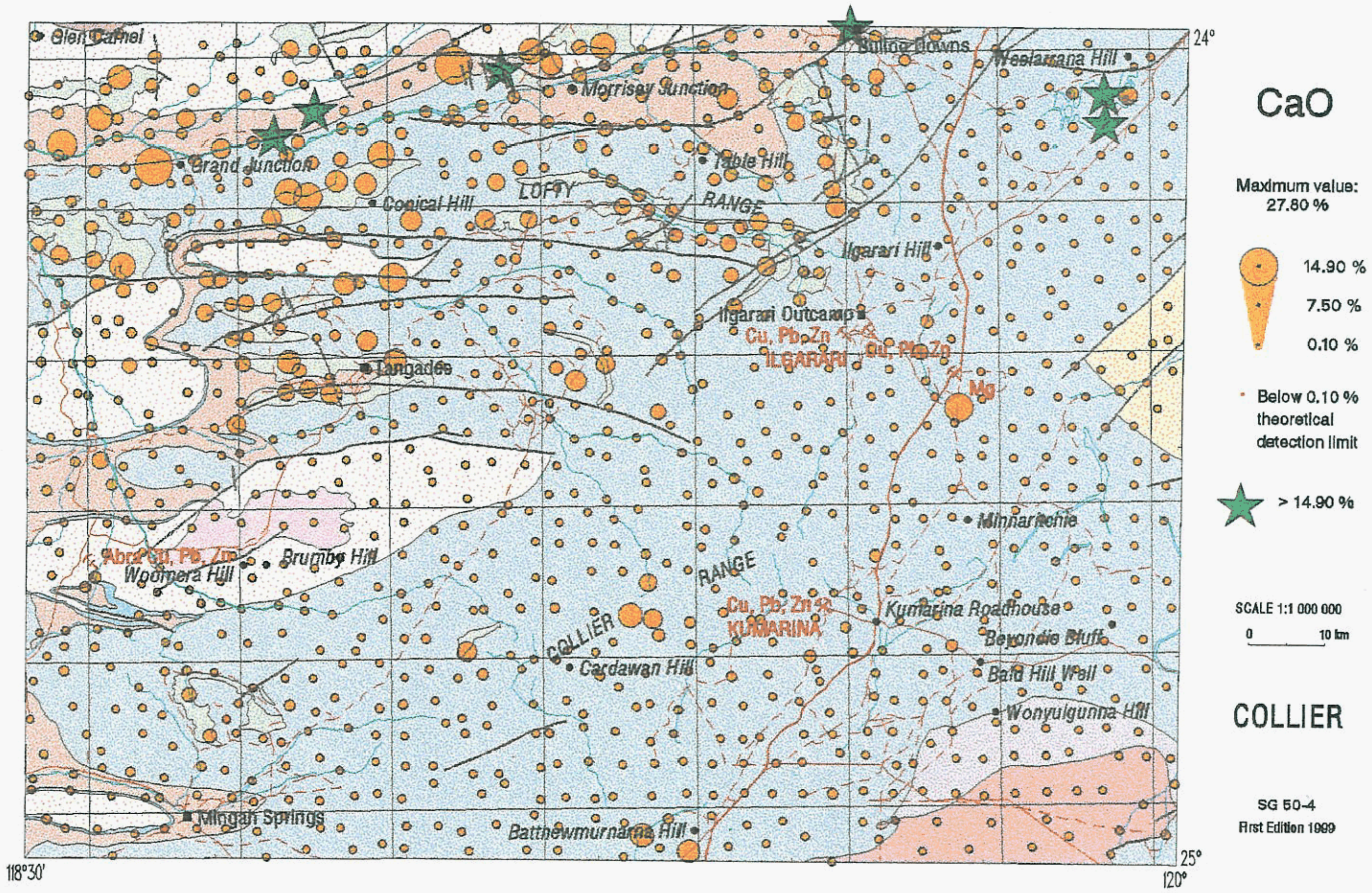


Figure 10

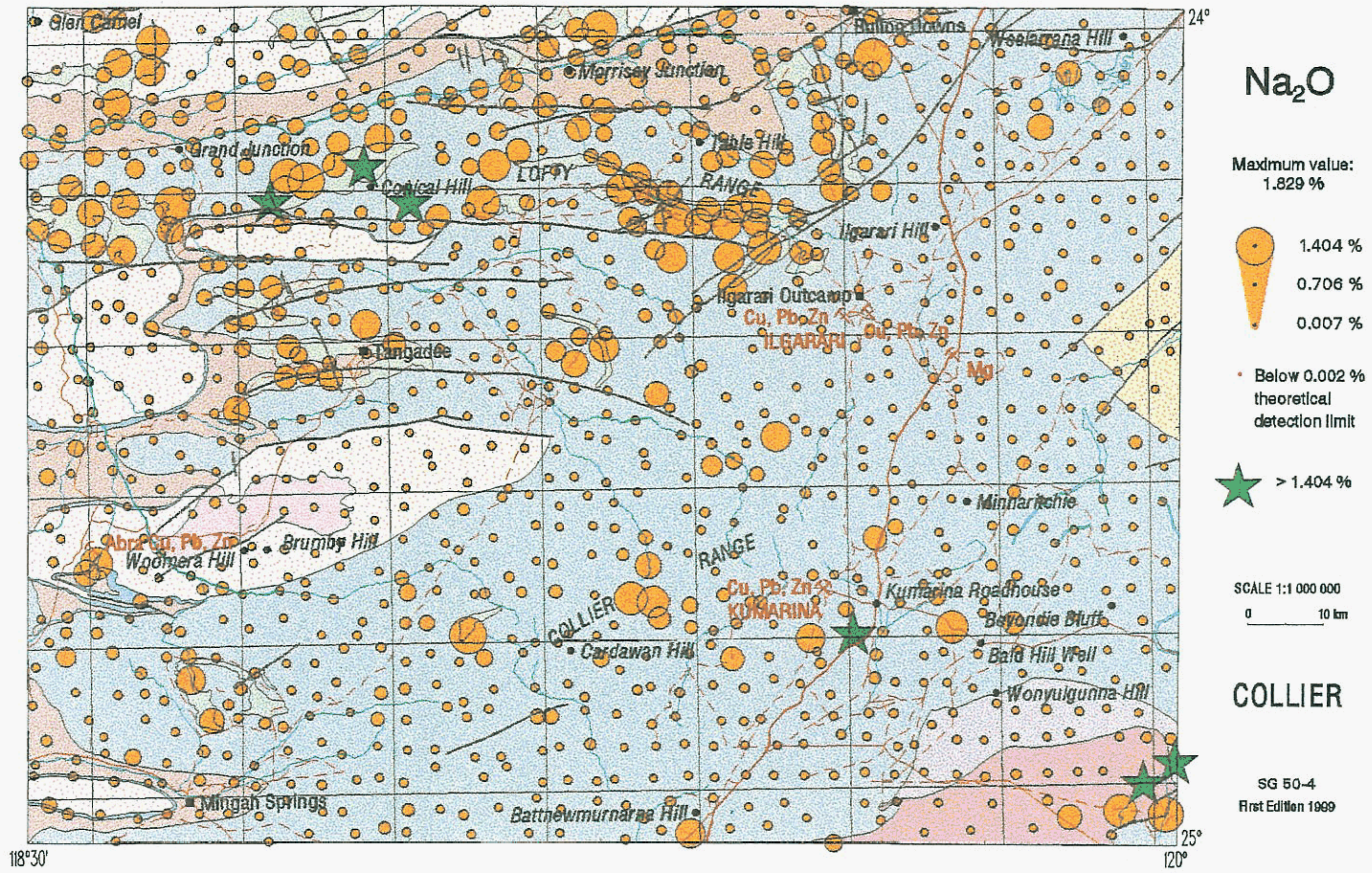


Figure 11

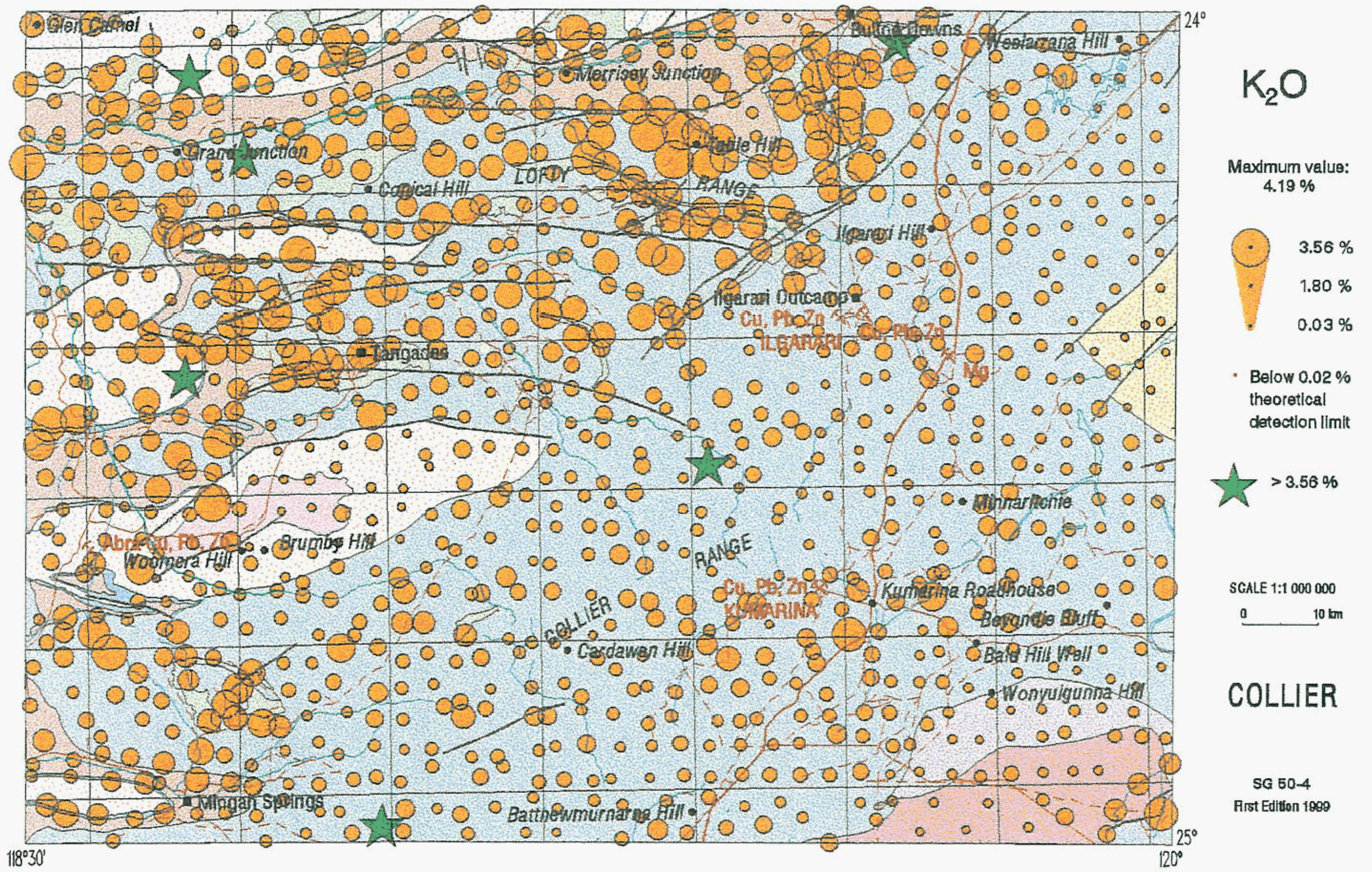


Figure 12

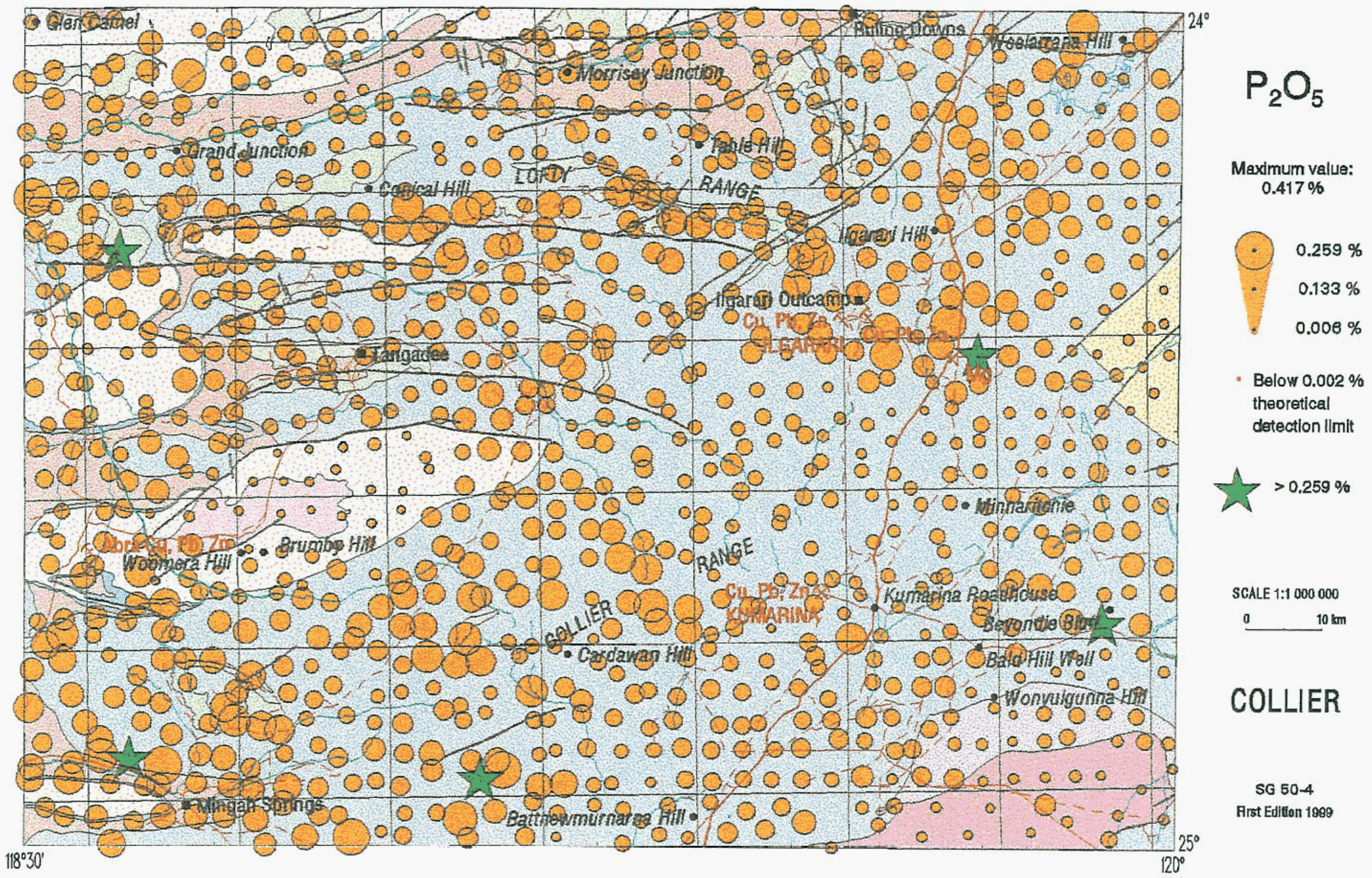


Figure 13

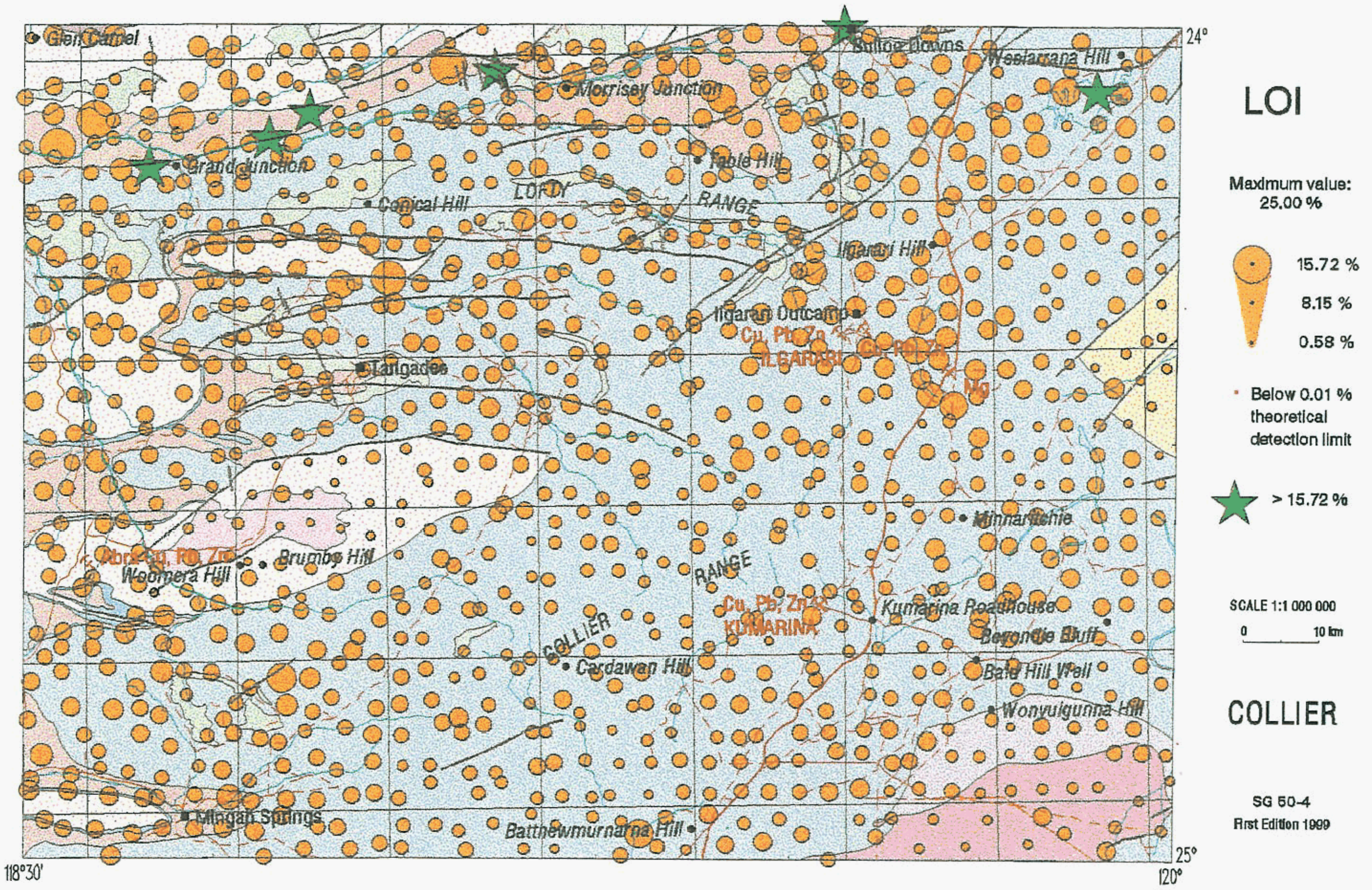


Figure 14

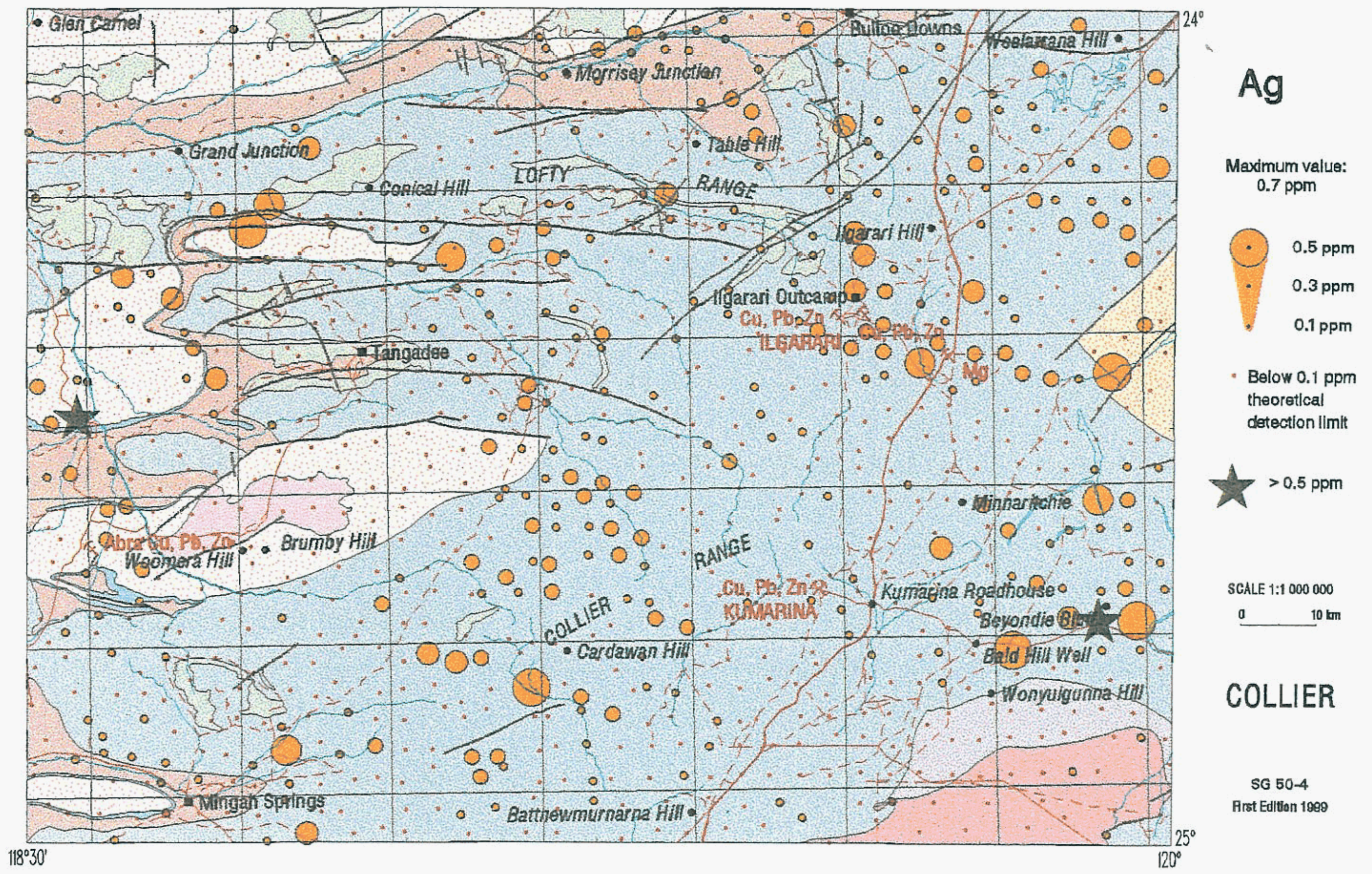


Figure 15

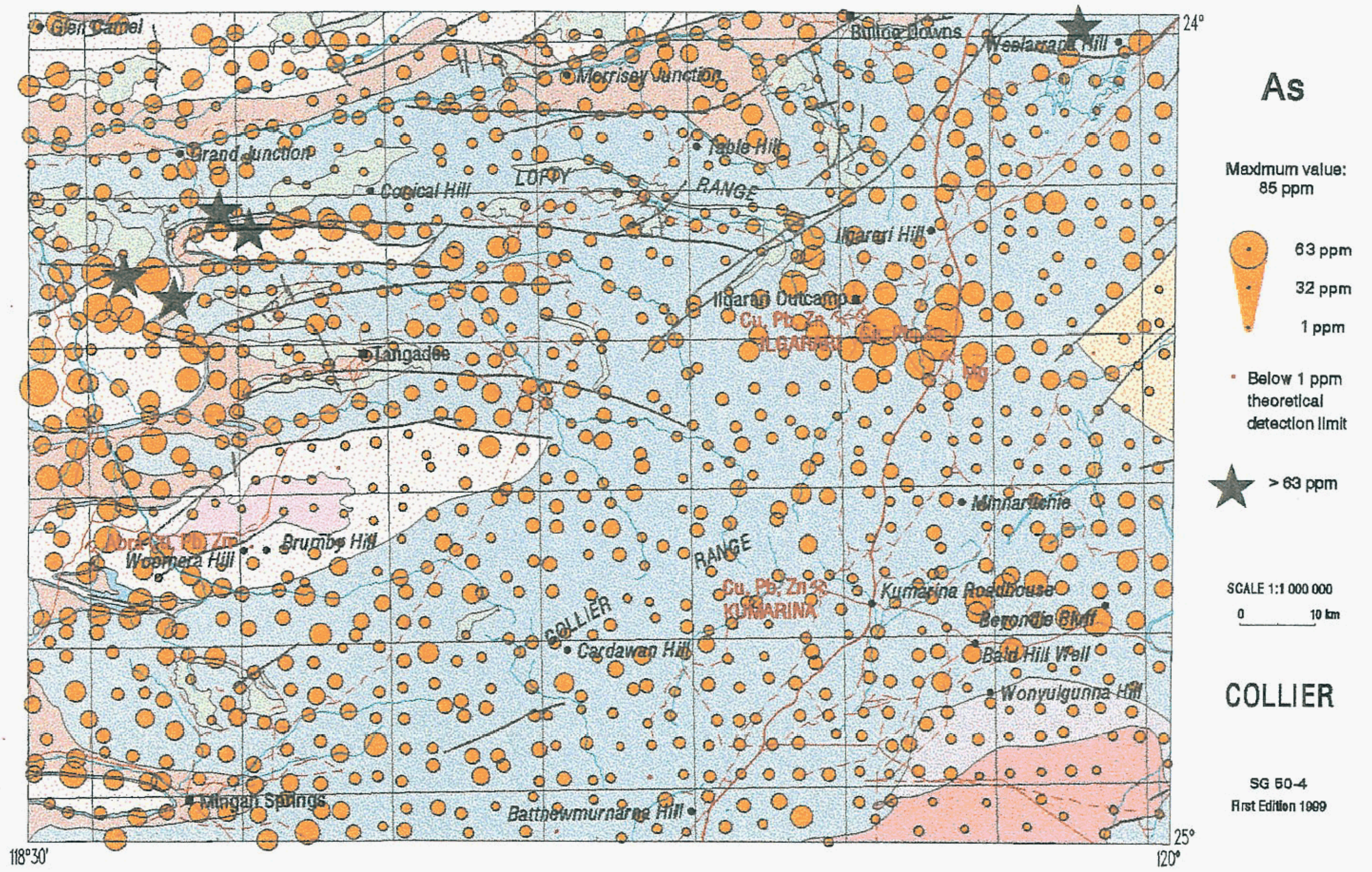


Figure 16

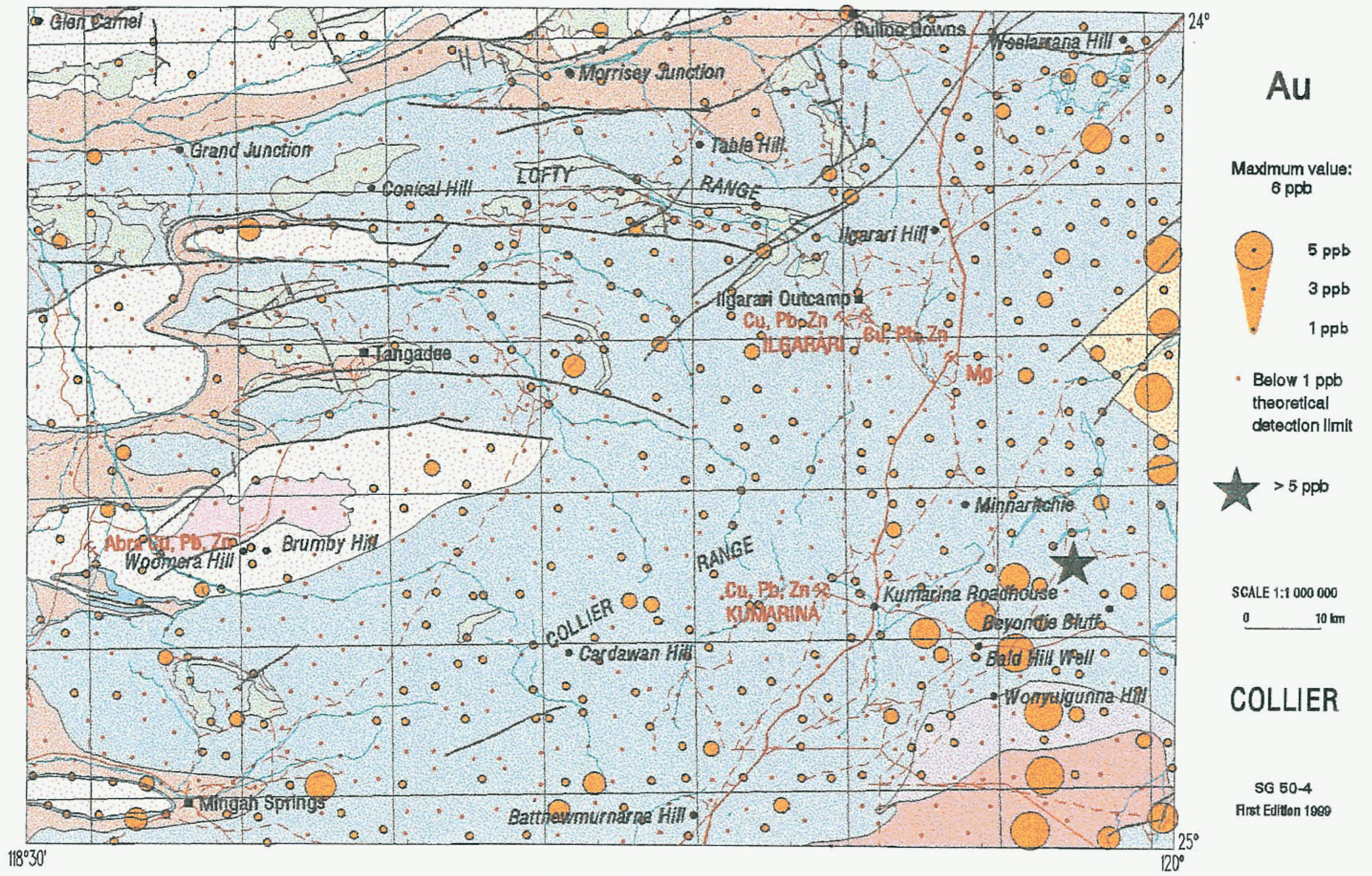


Figure 17

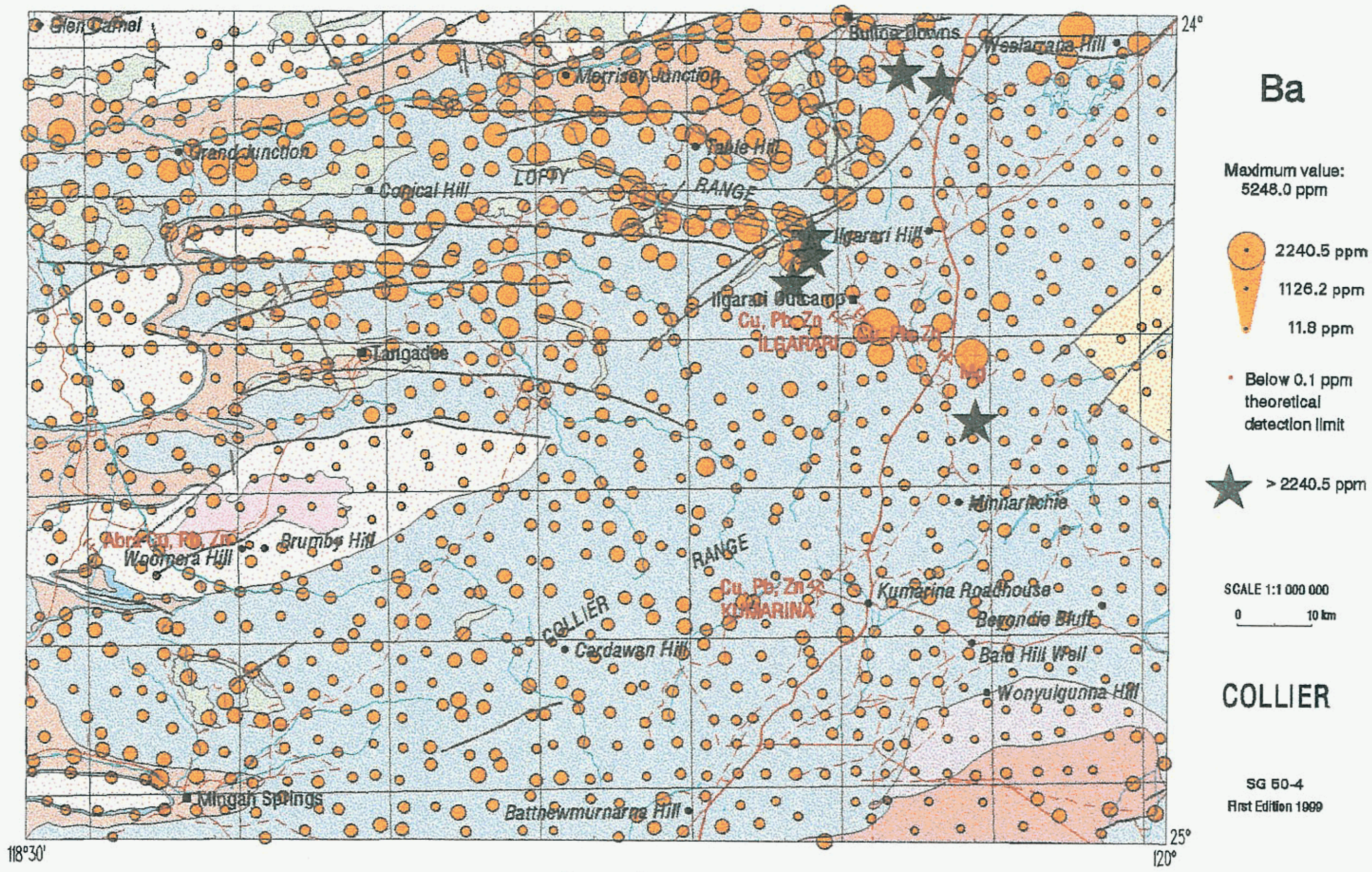


Figure 18

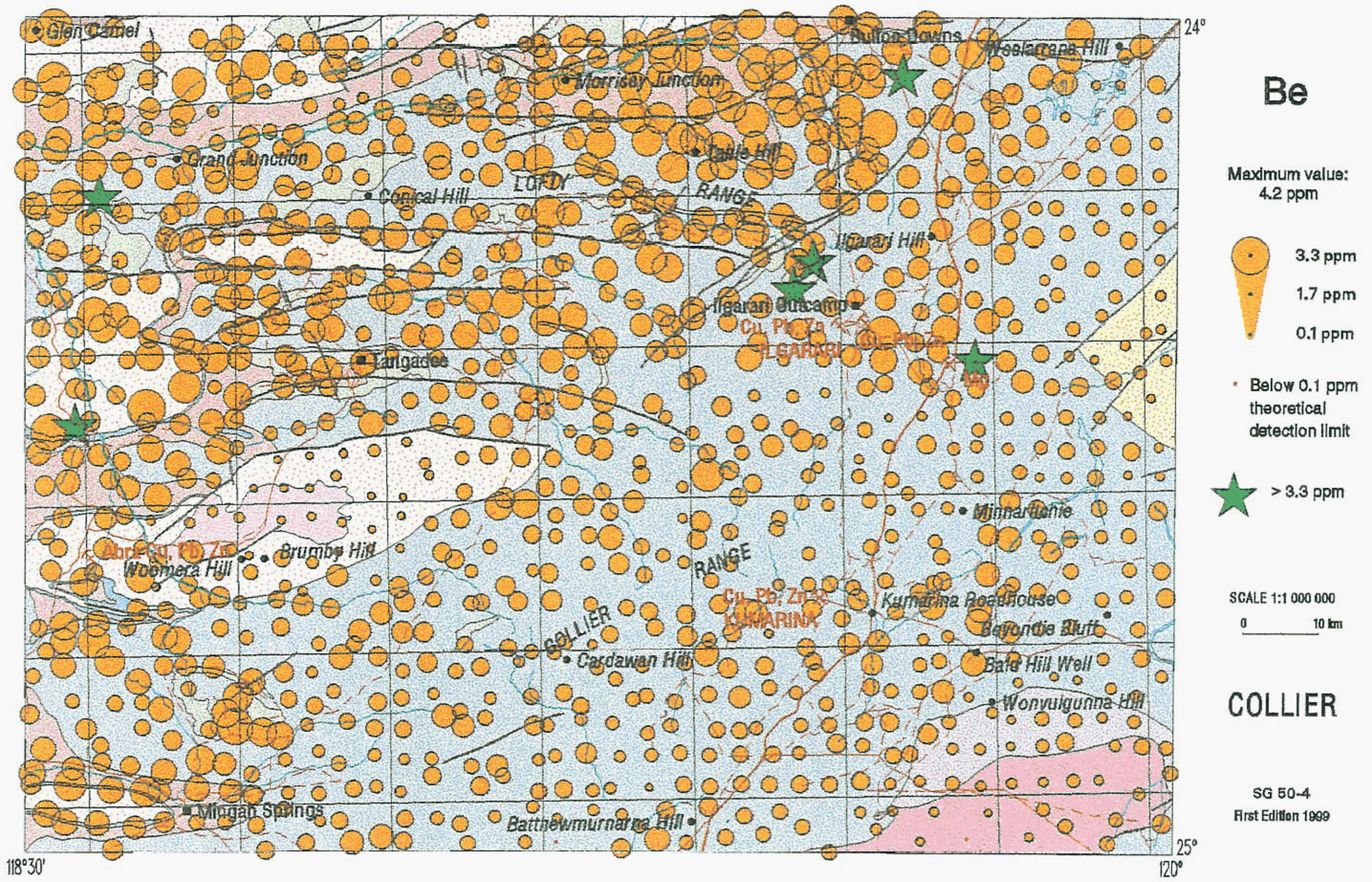


Figure 19

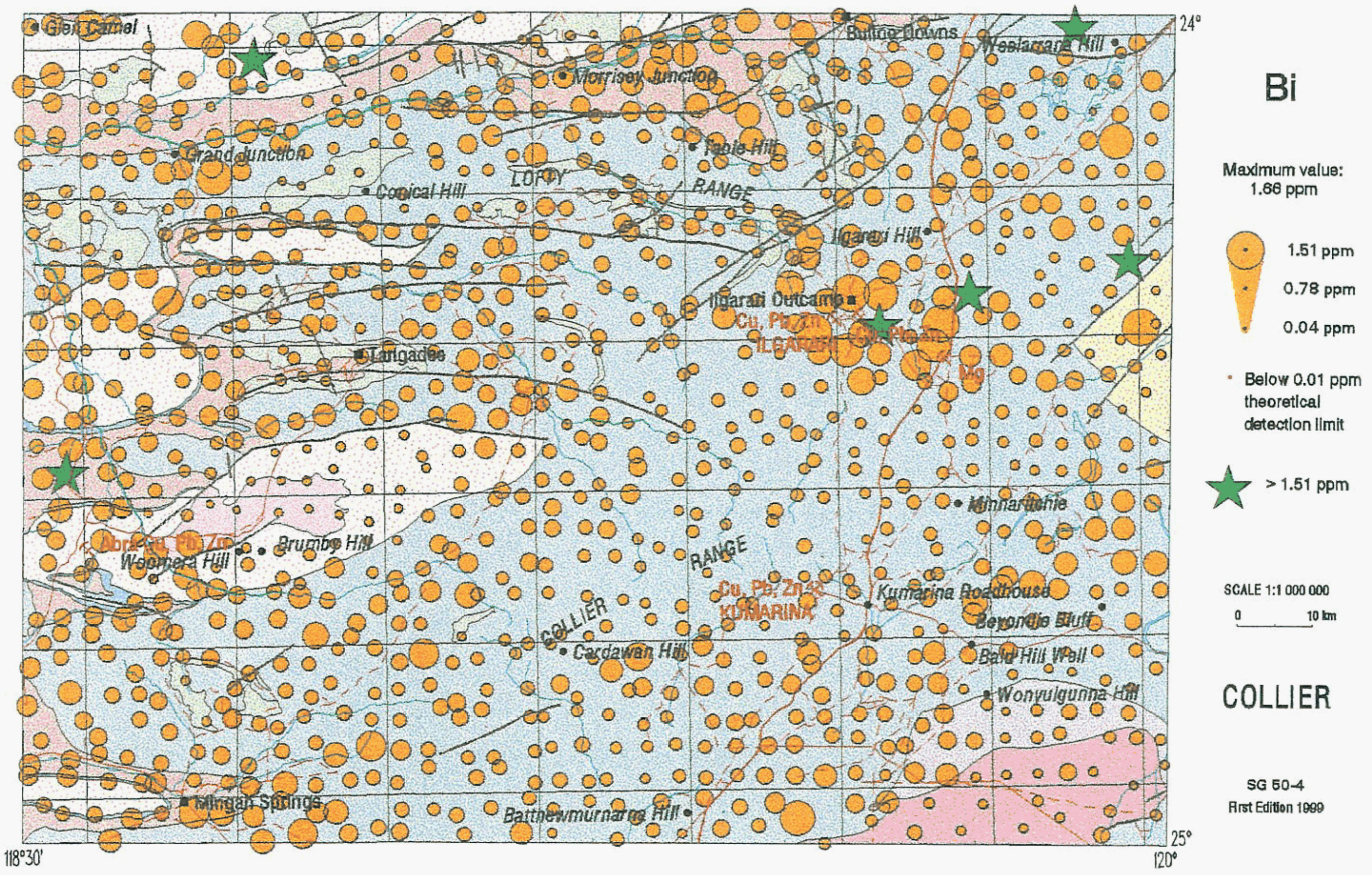


Figure 20

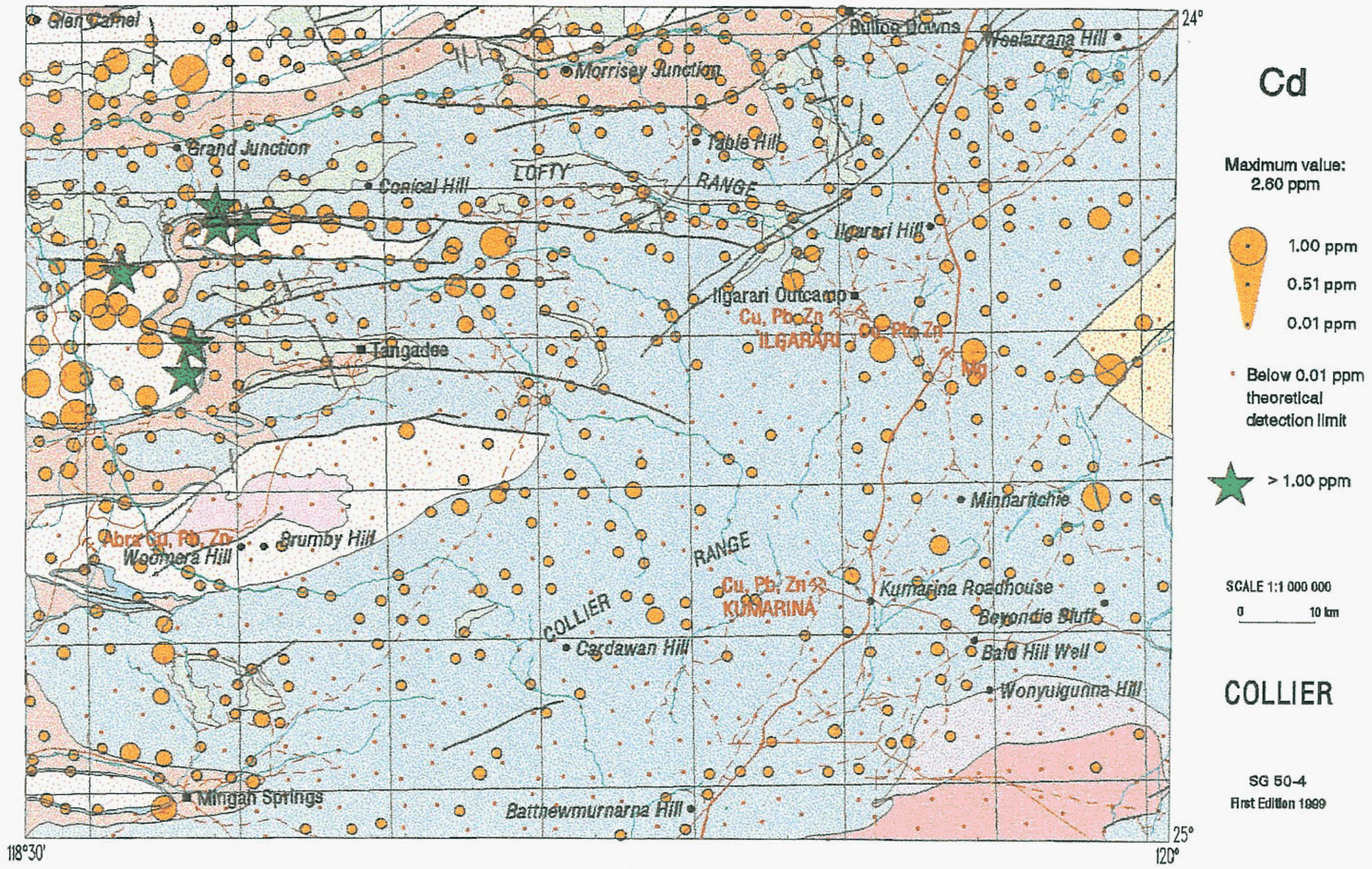


Figure 21

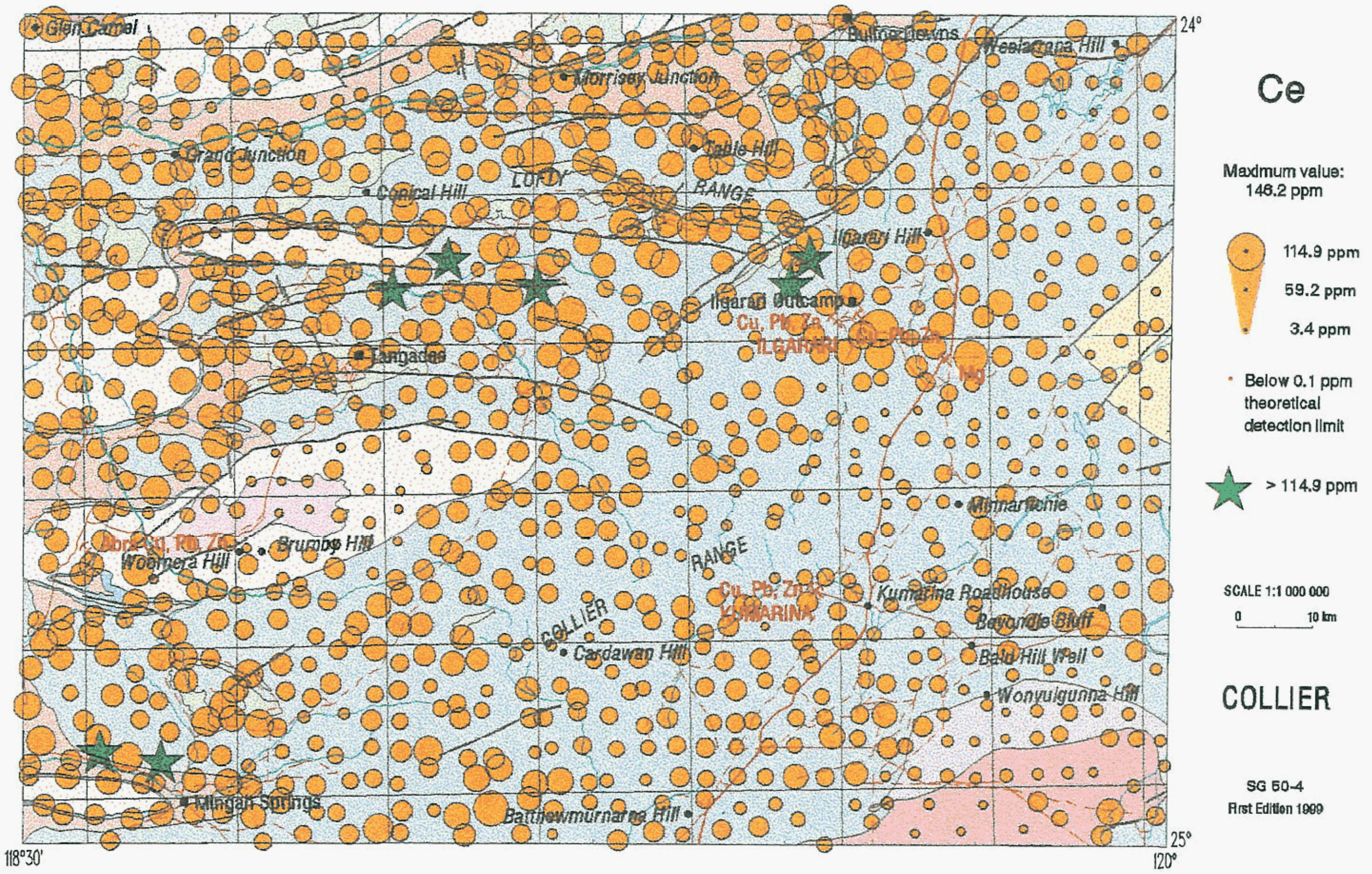


Figure 22

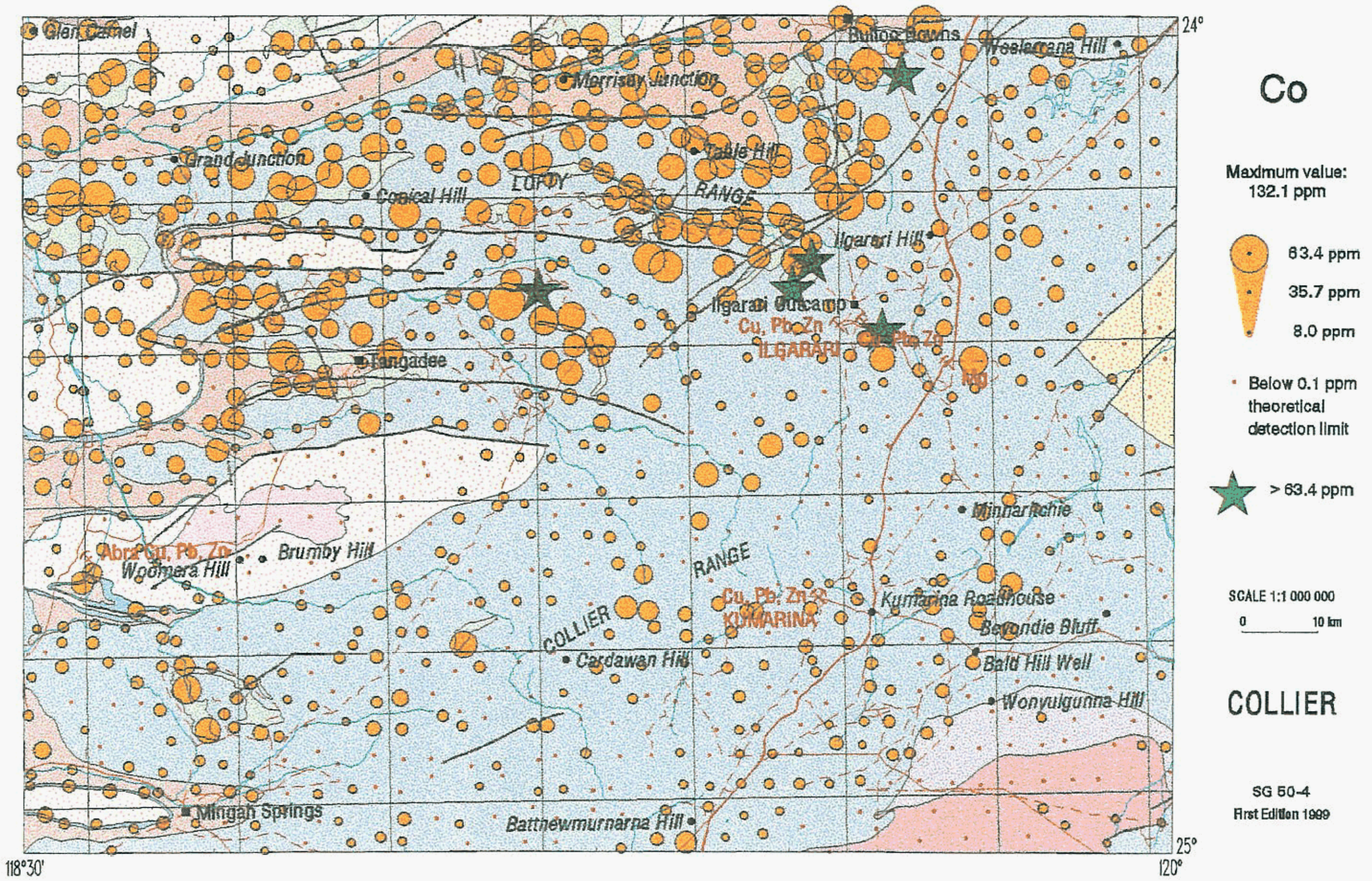


Figure 23

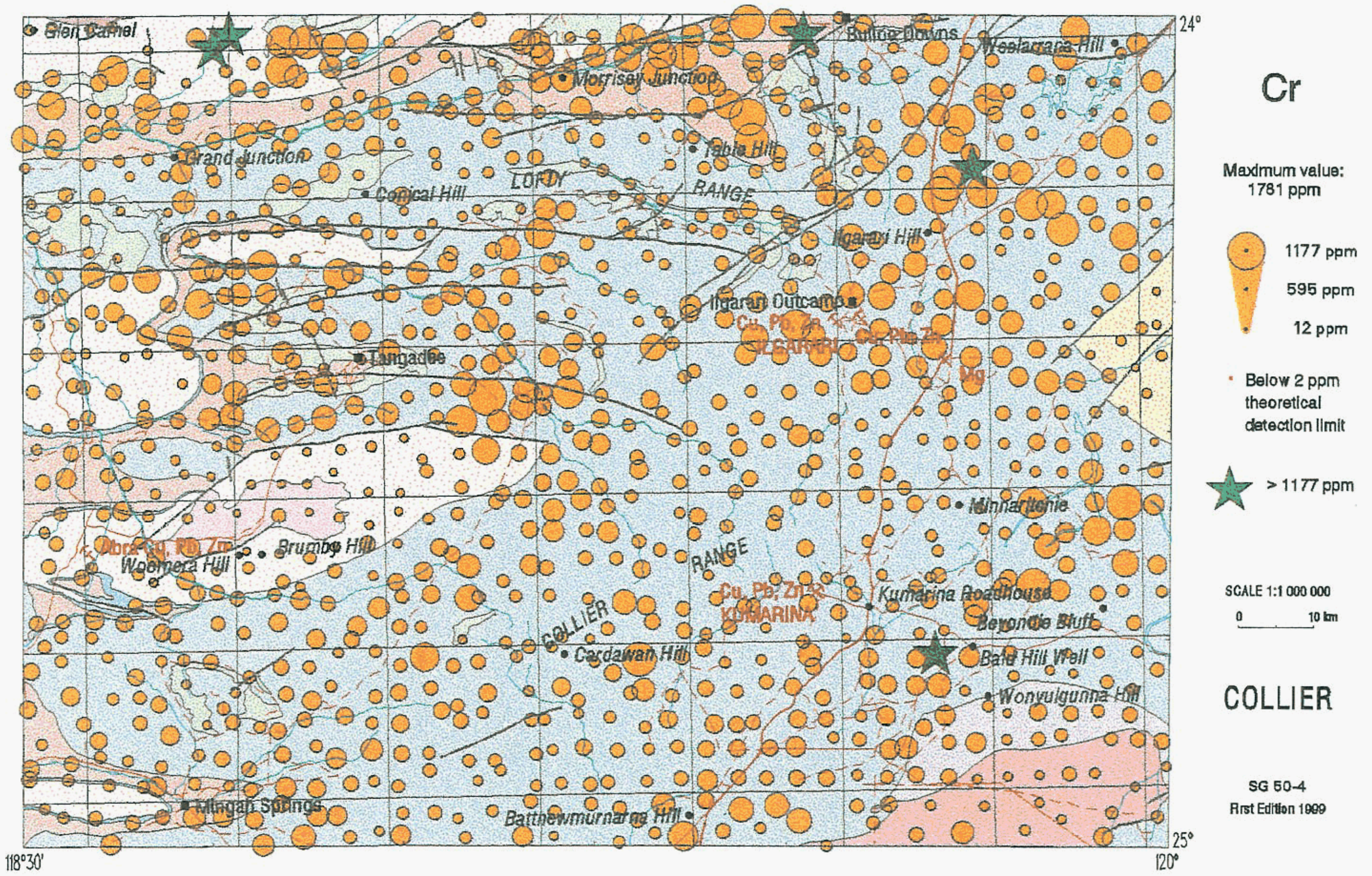


Figure 24

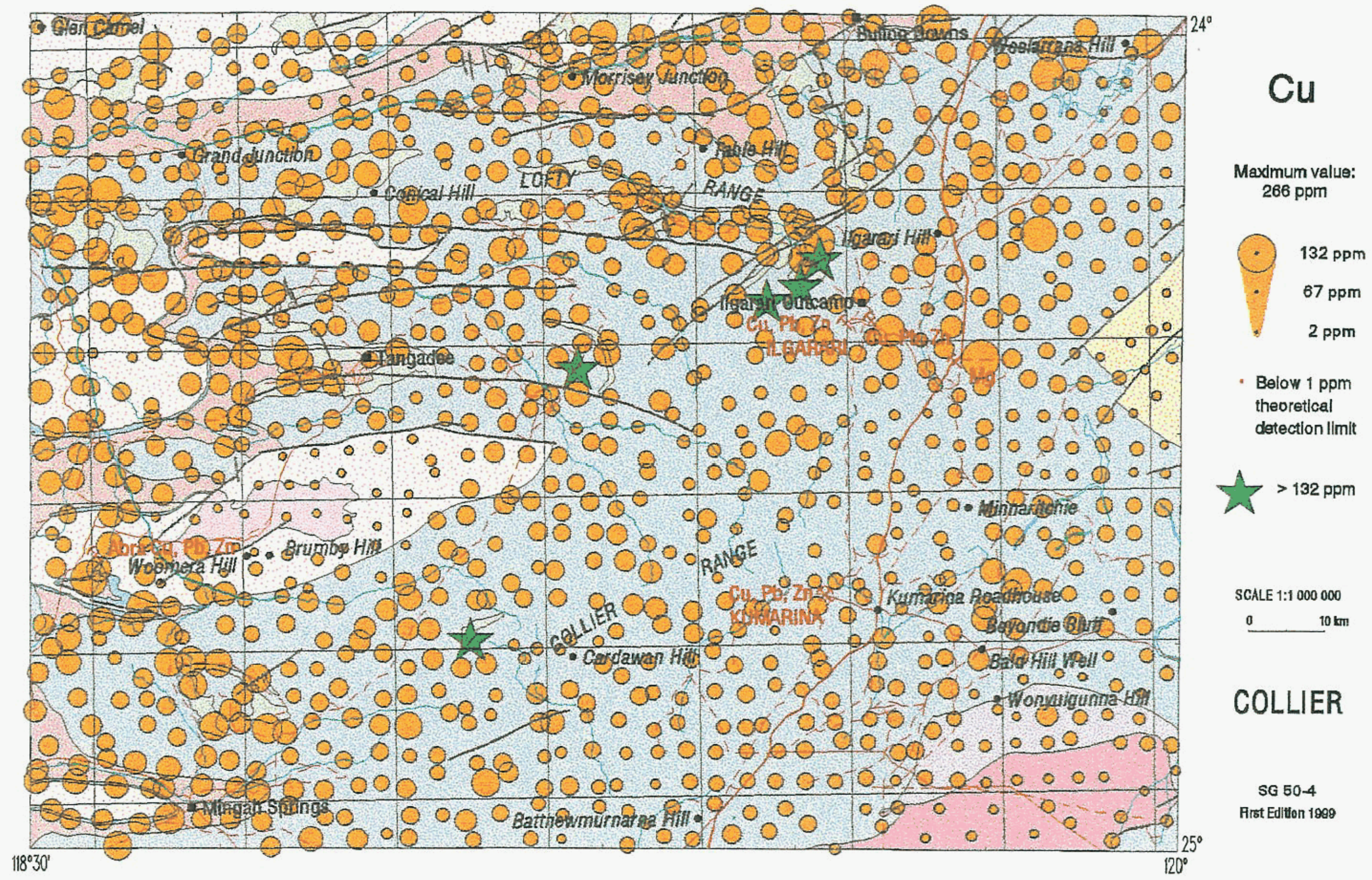


Figure 25

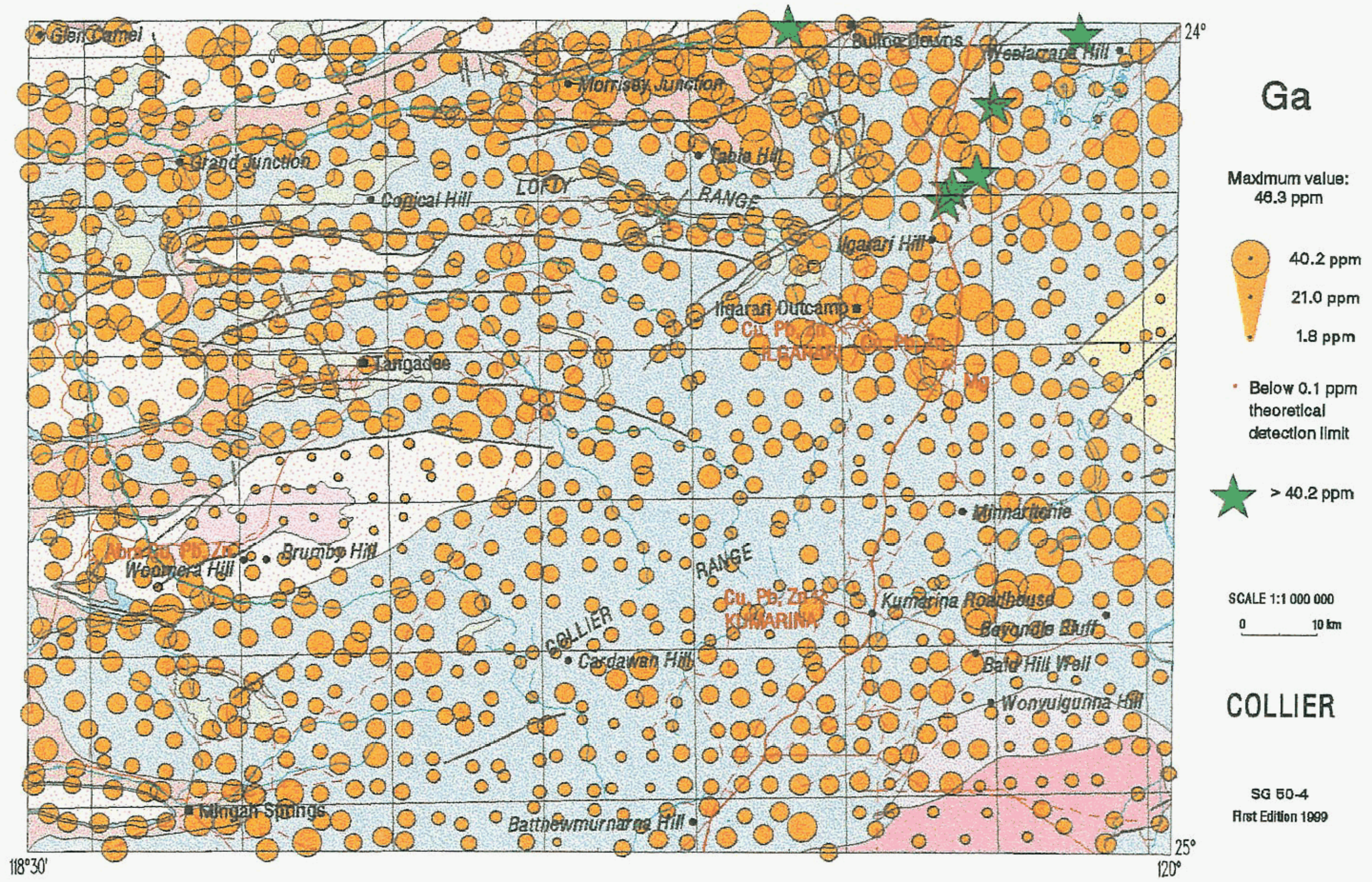


Figure 26

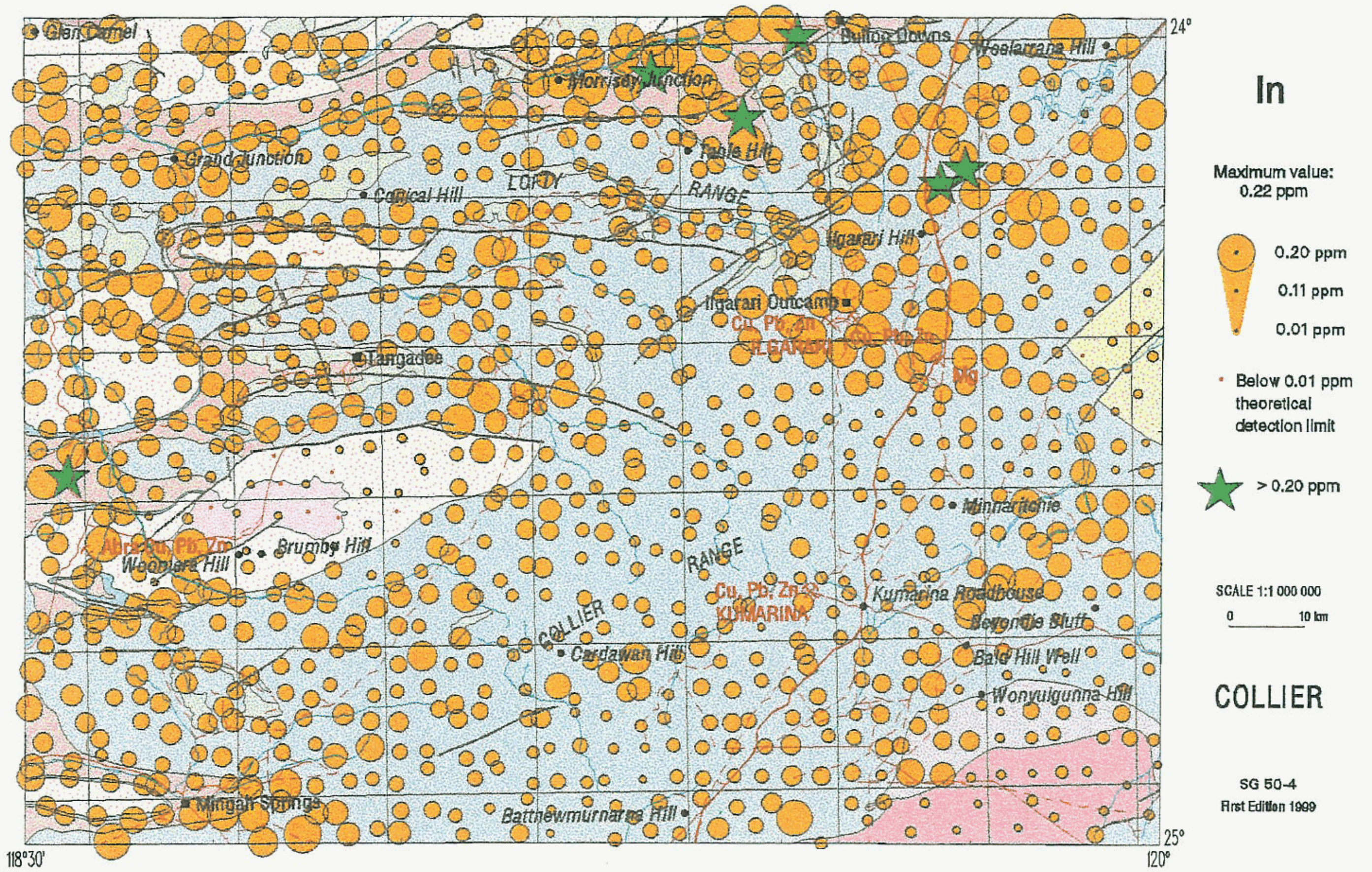


Figure 27

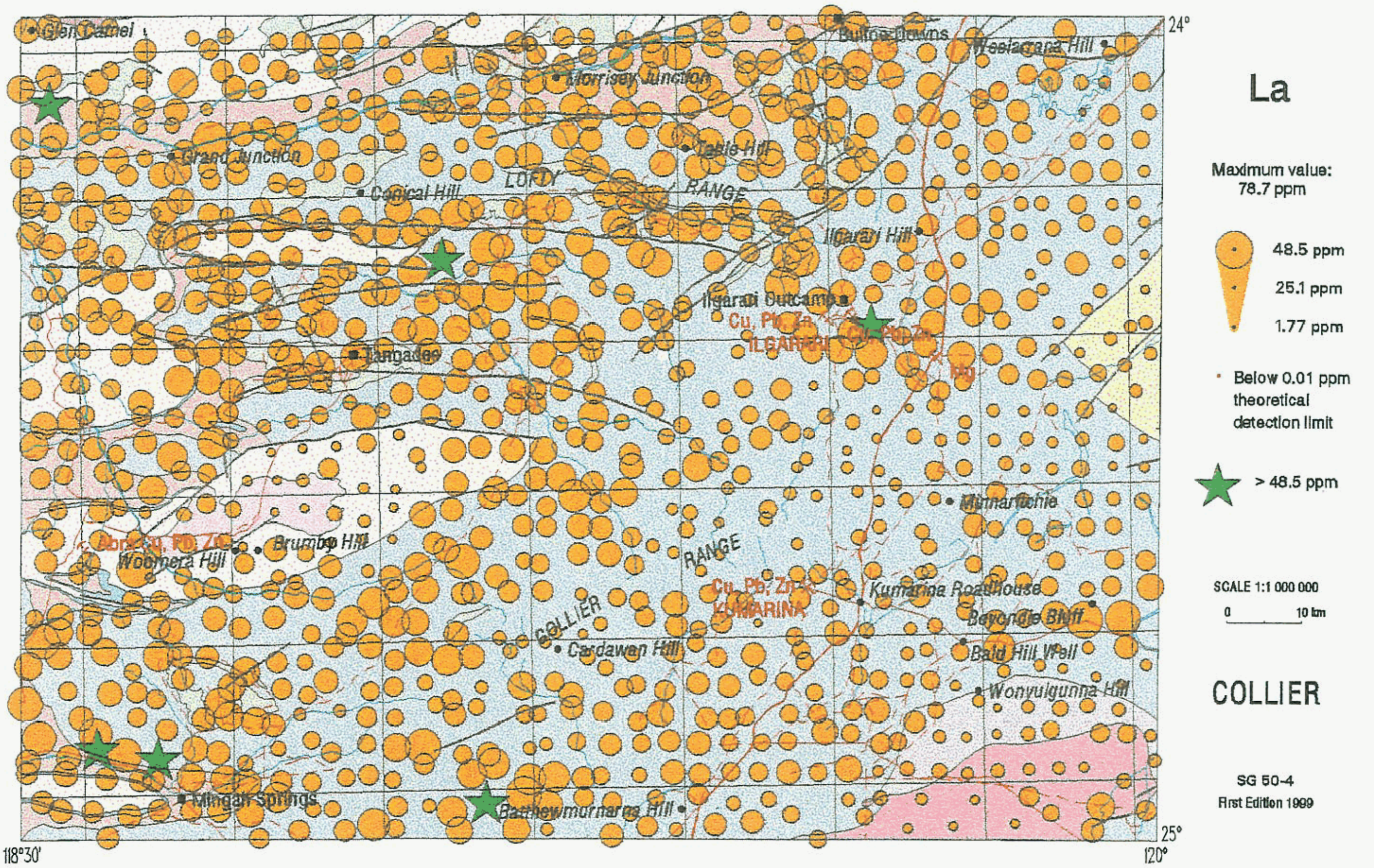


Figure 28

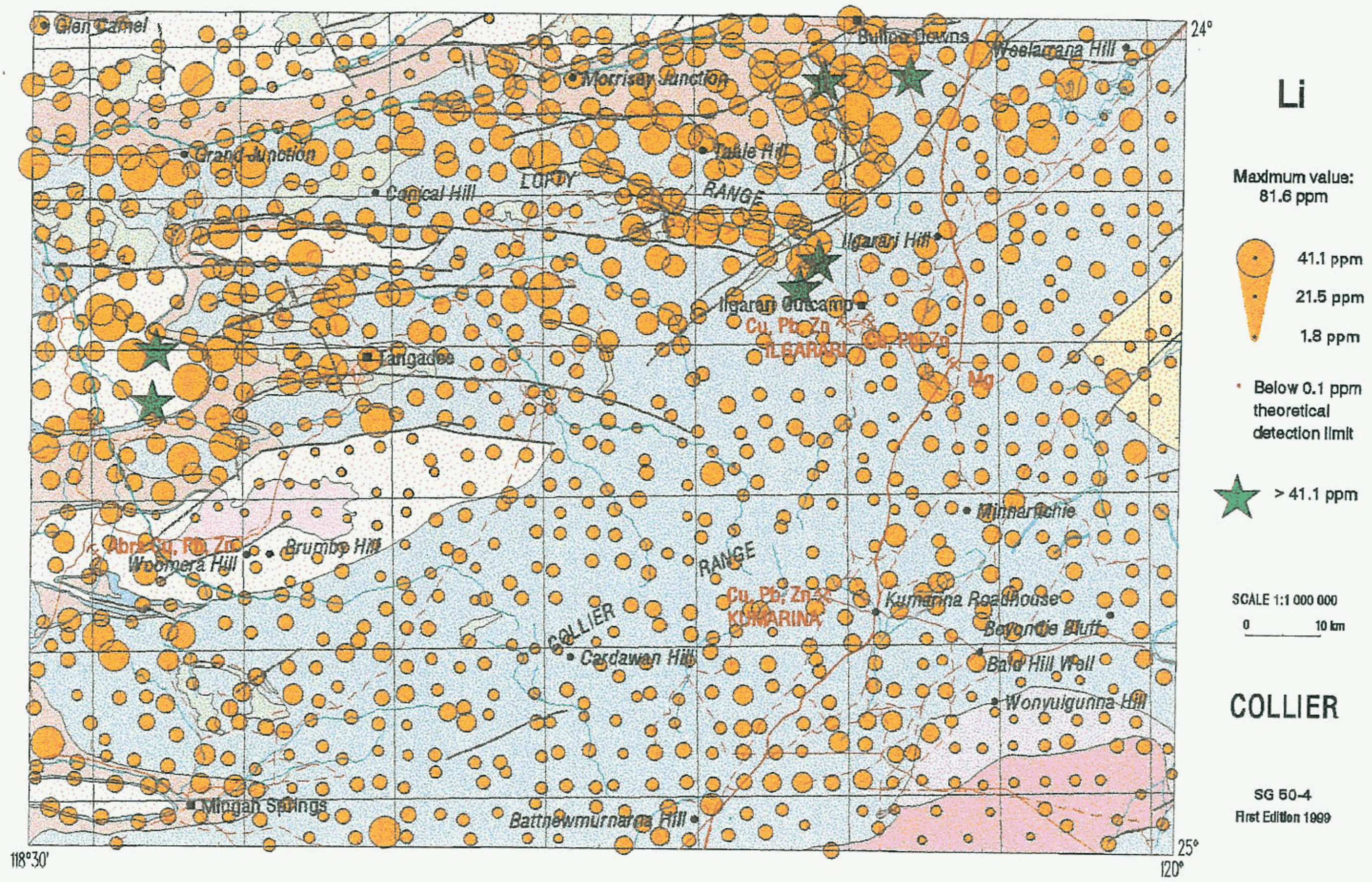


Figure 29

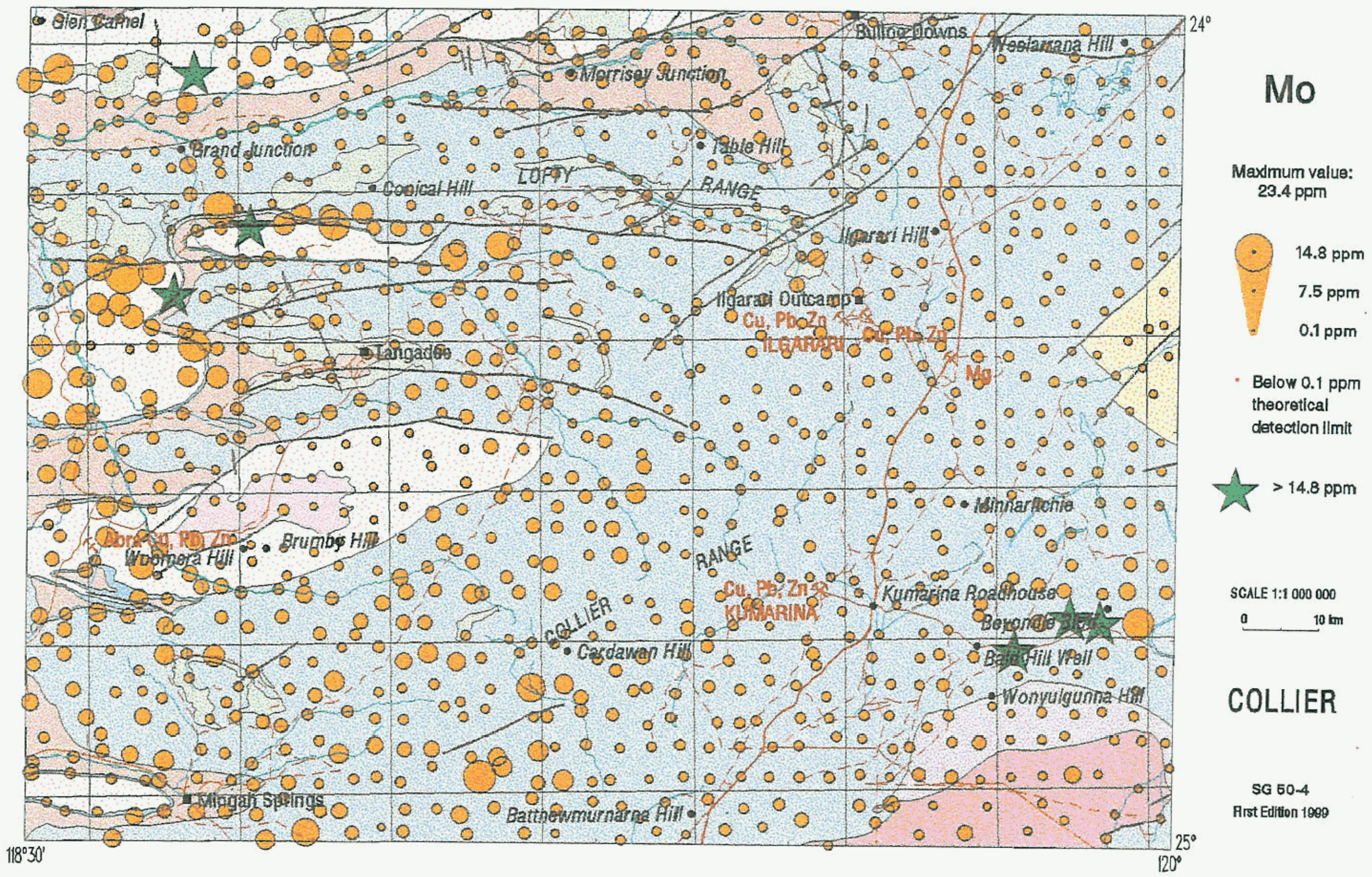


Figure 30

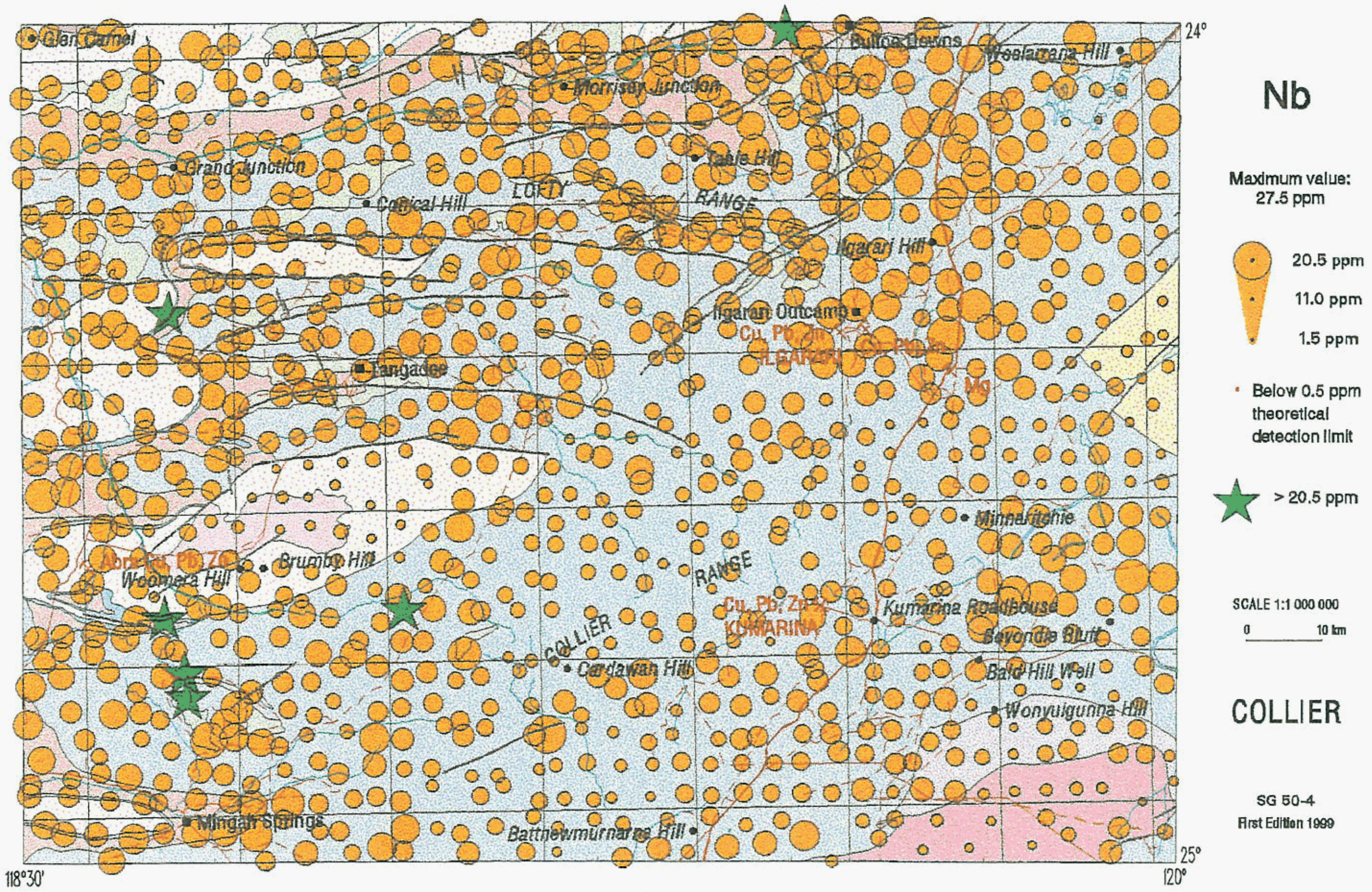


Figure 31

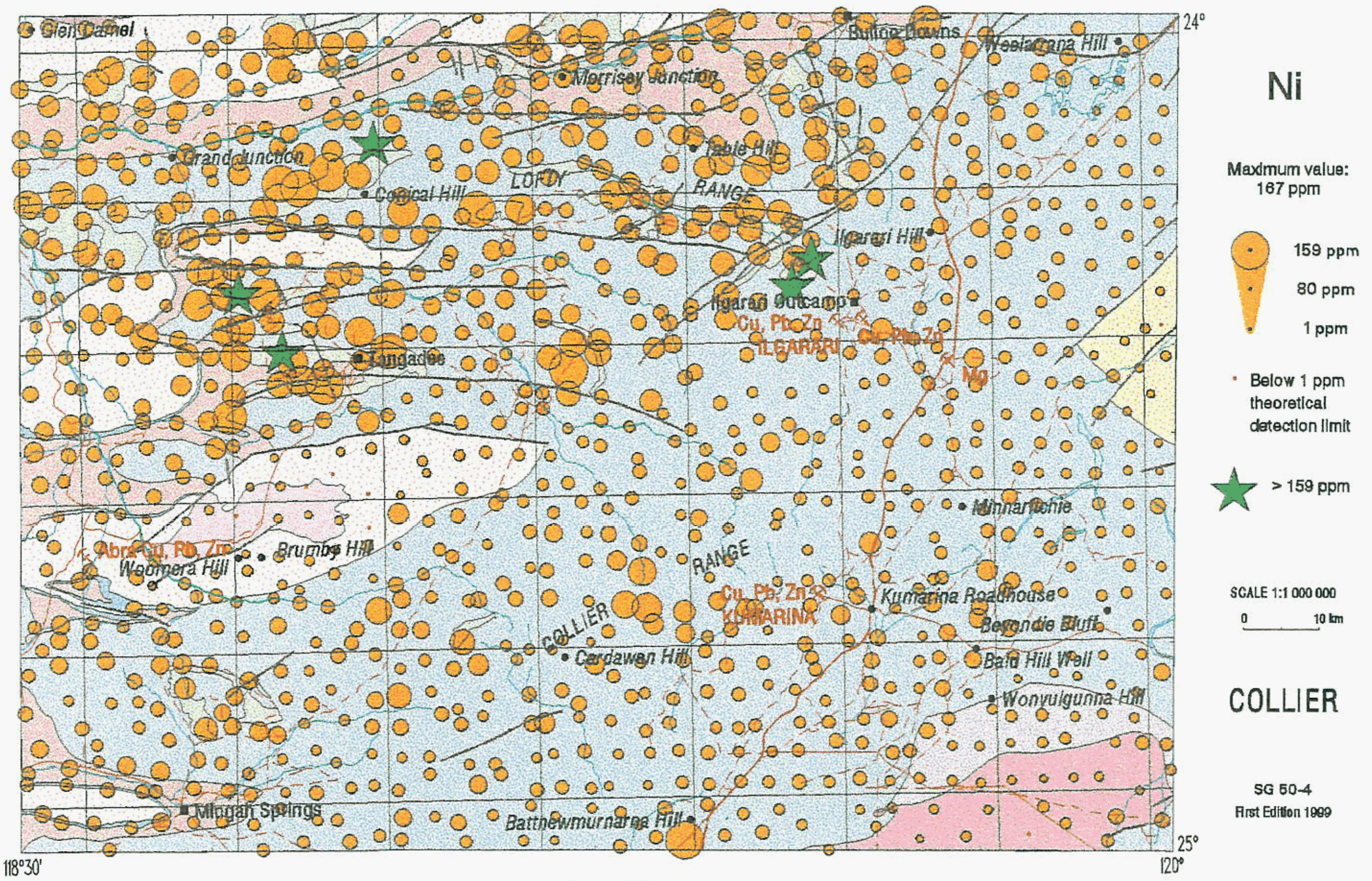


Figure 32

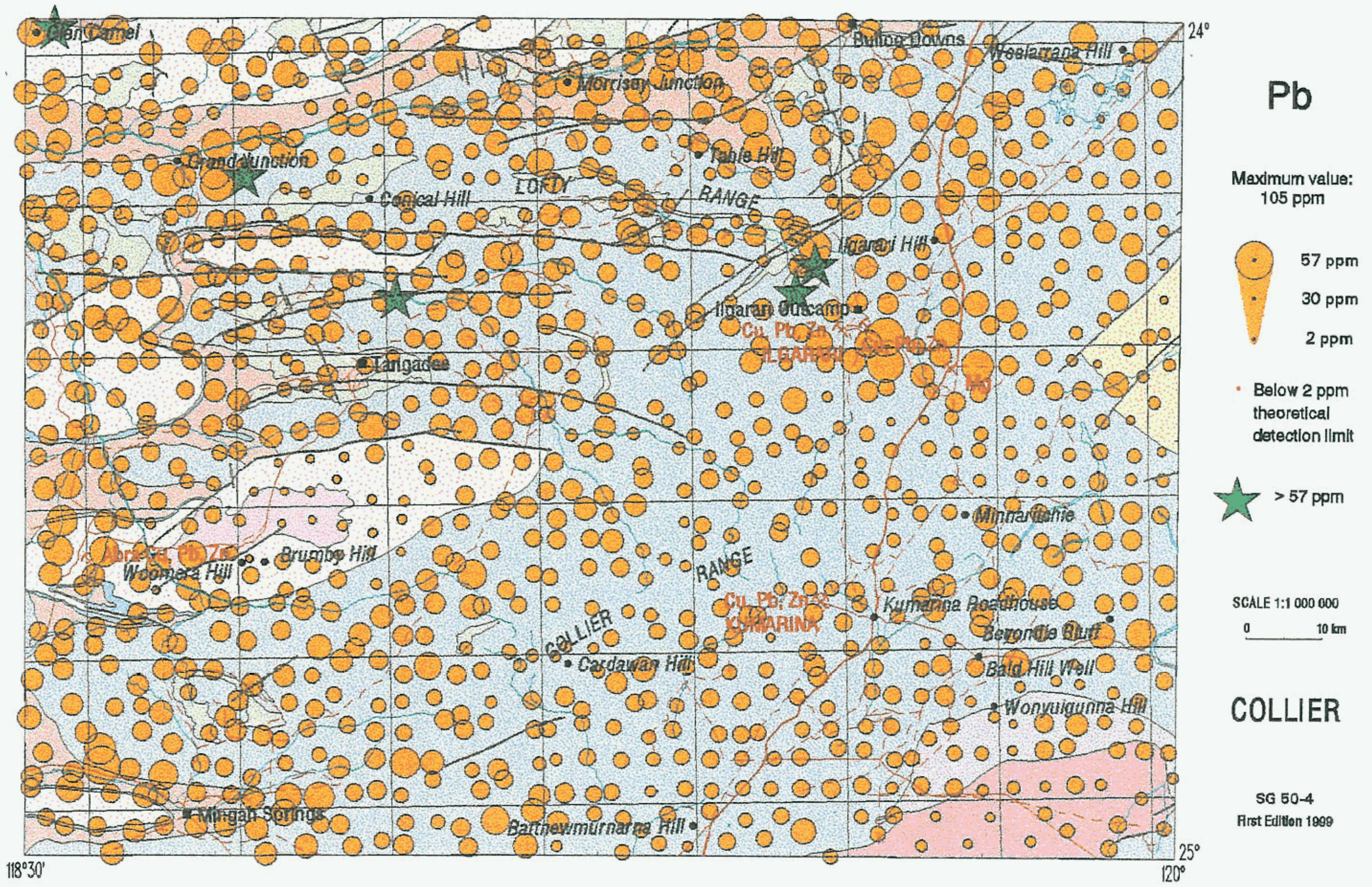


Figure 33

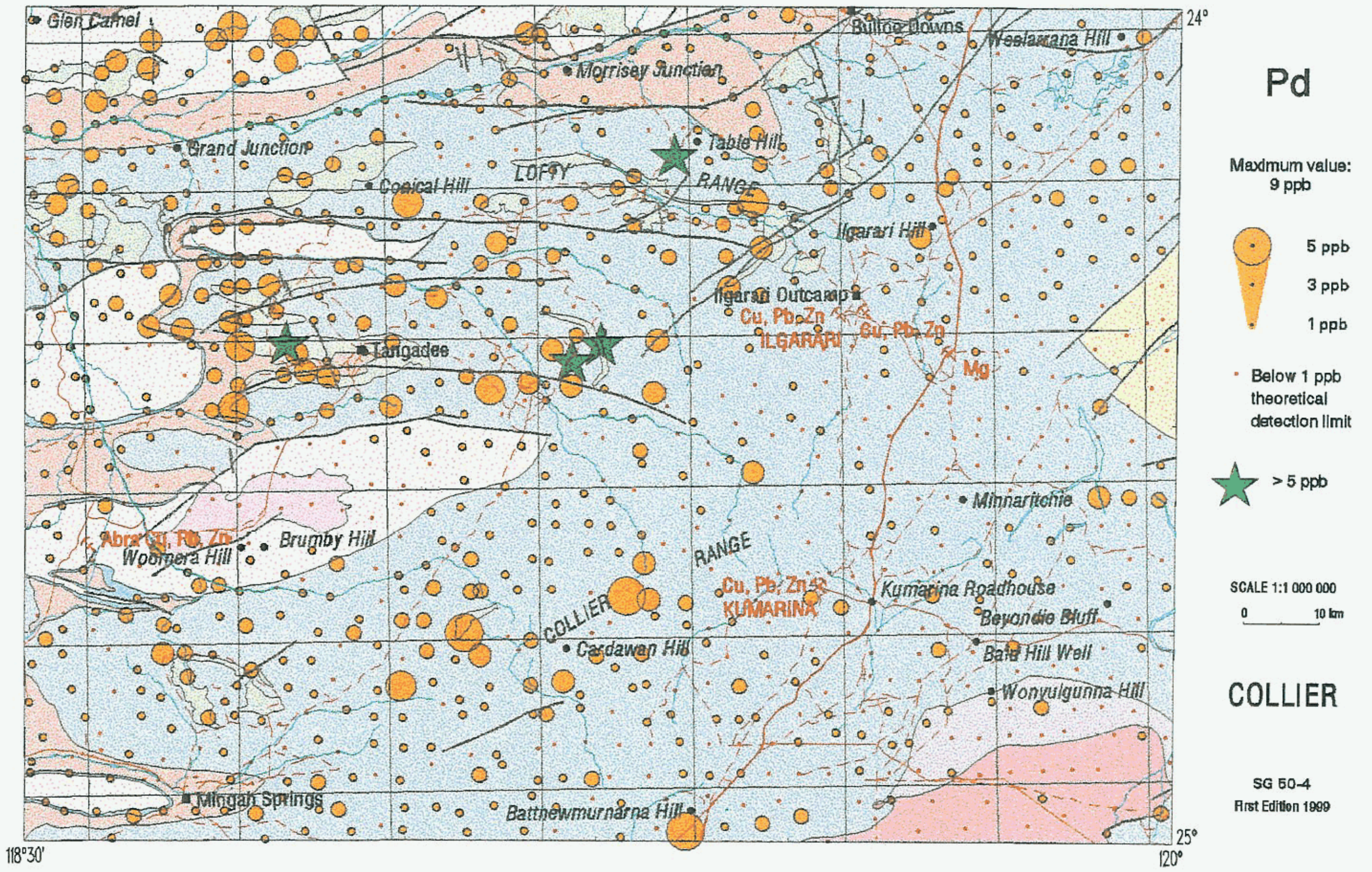


Figure 34

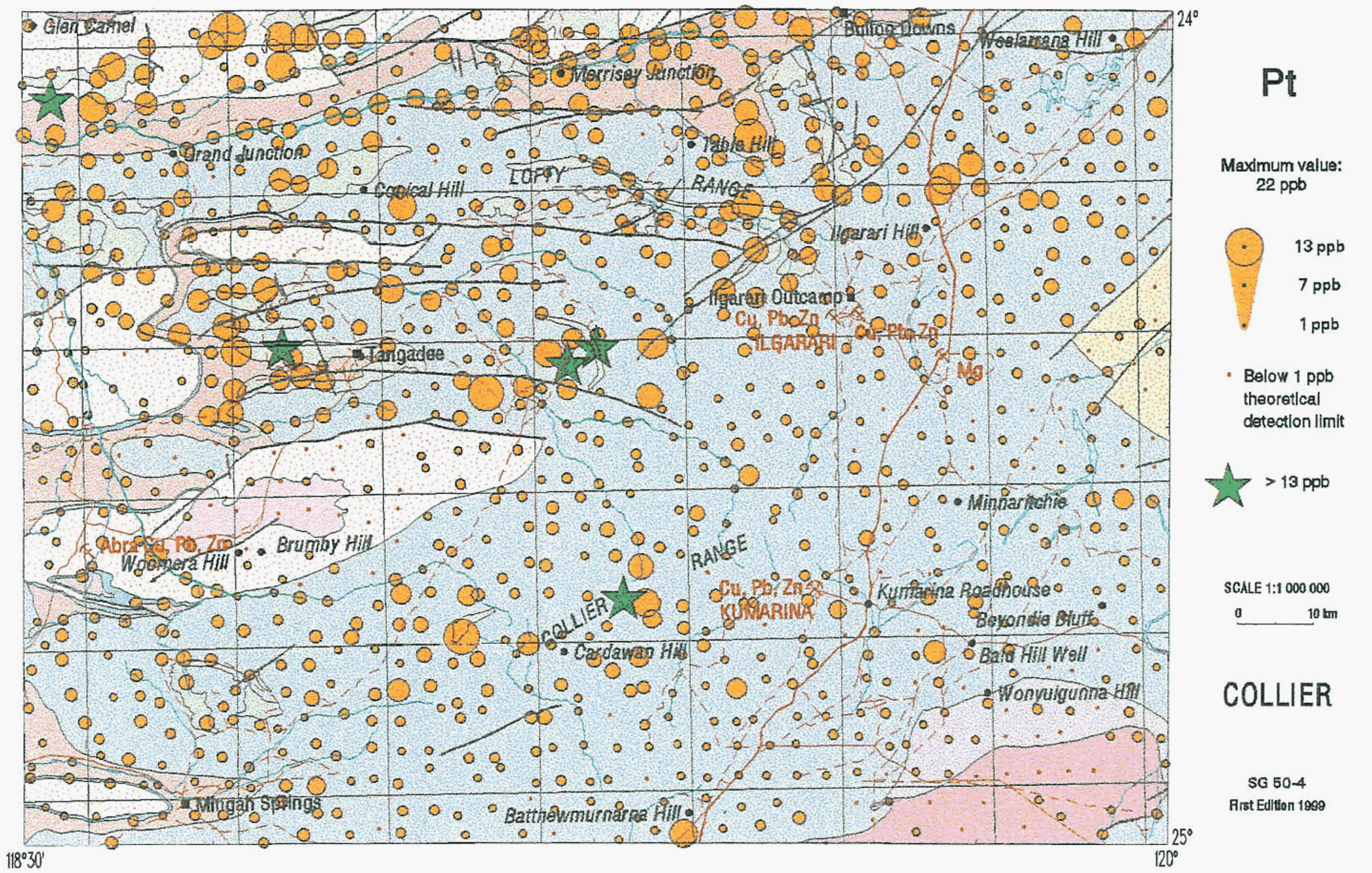


Figure 35

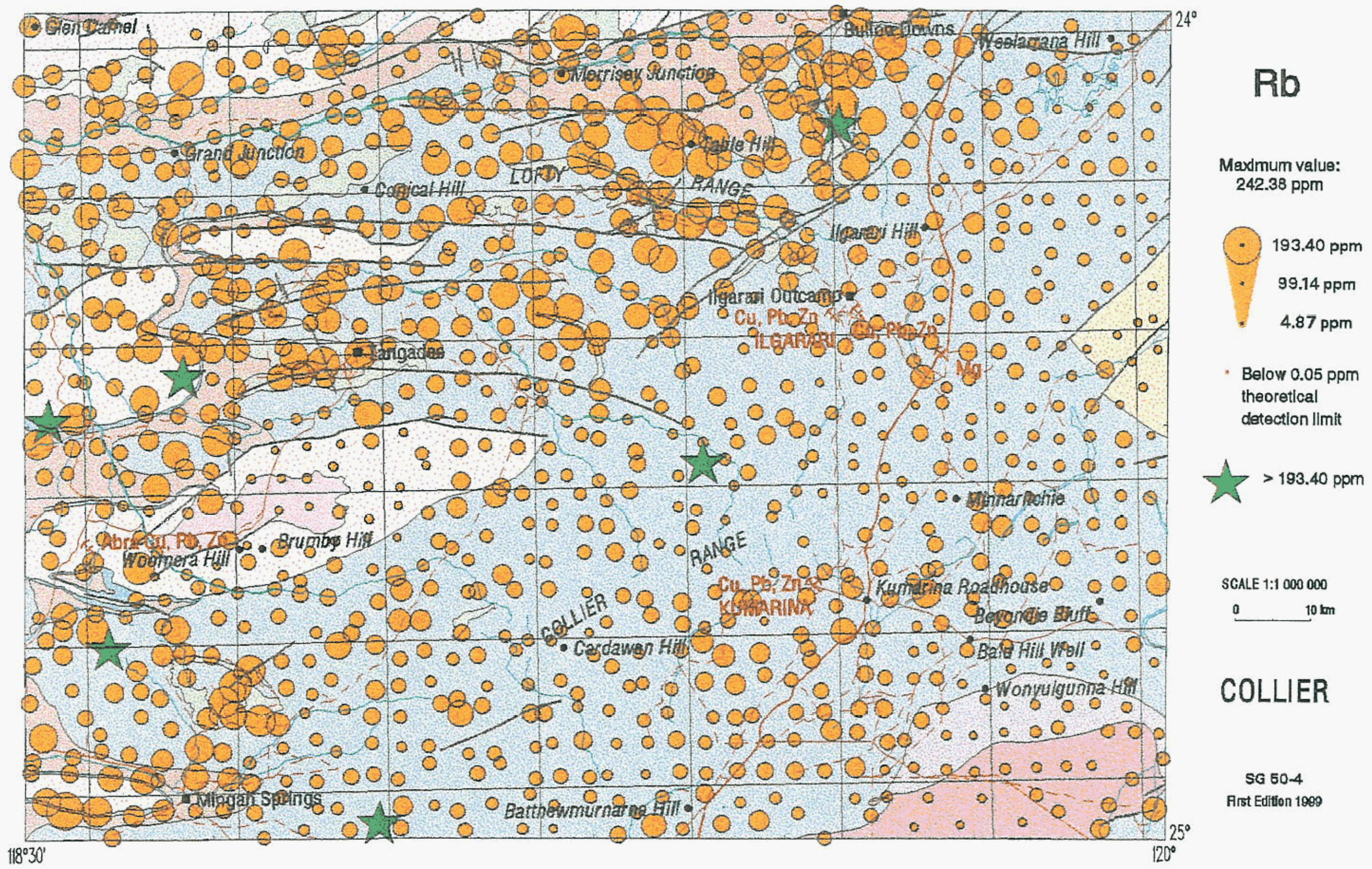


Figure 36

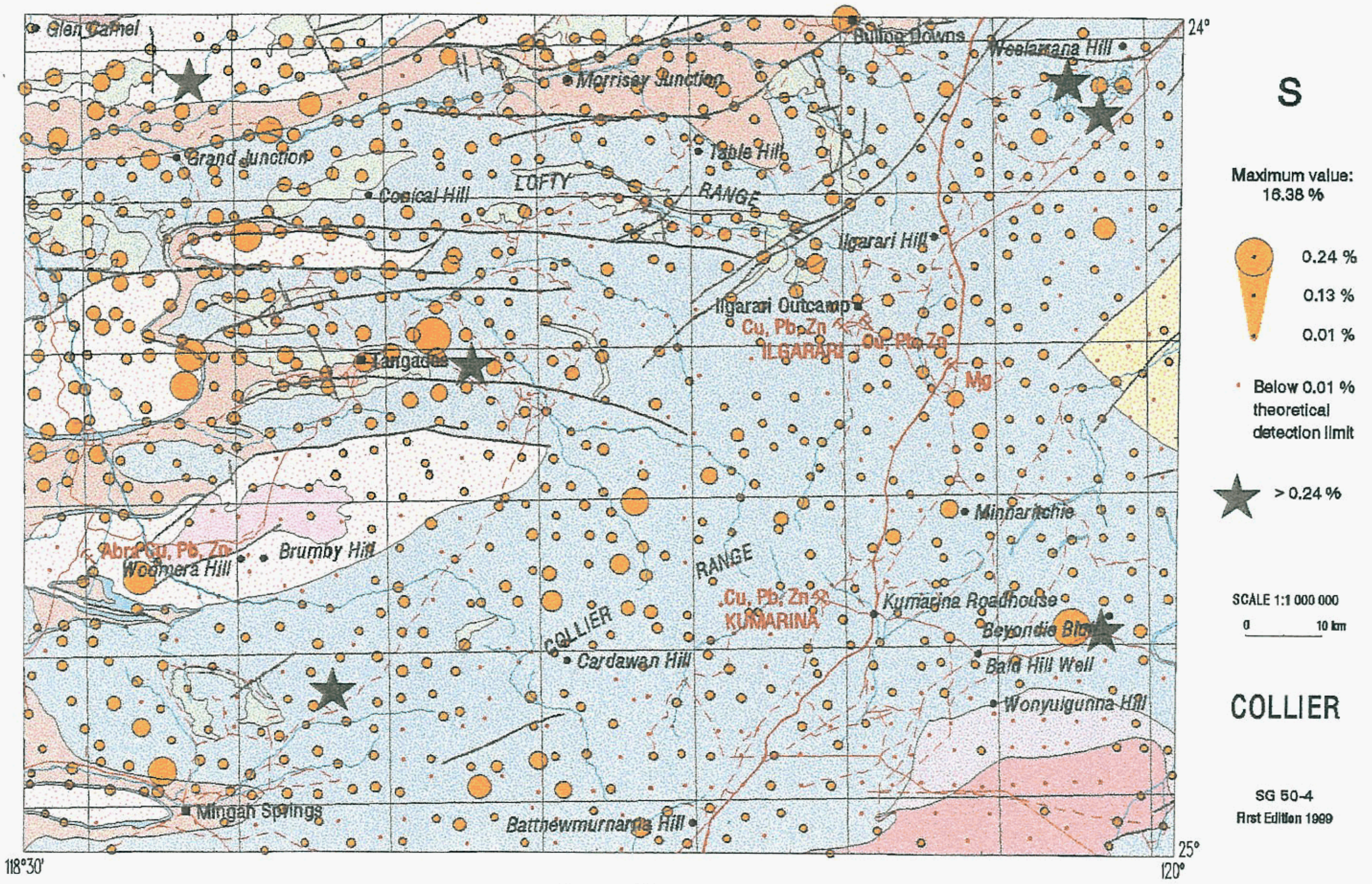


Figure 37

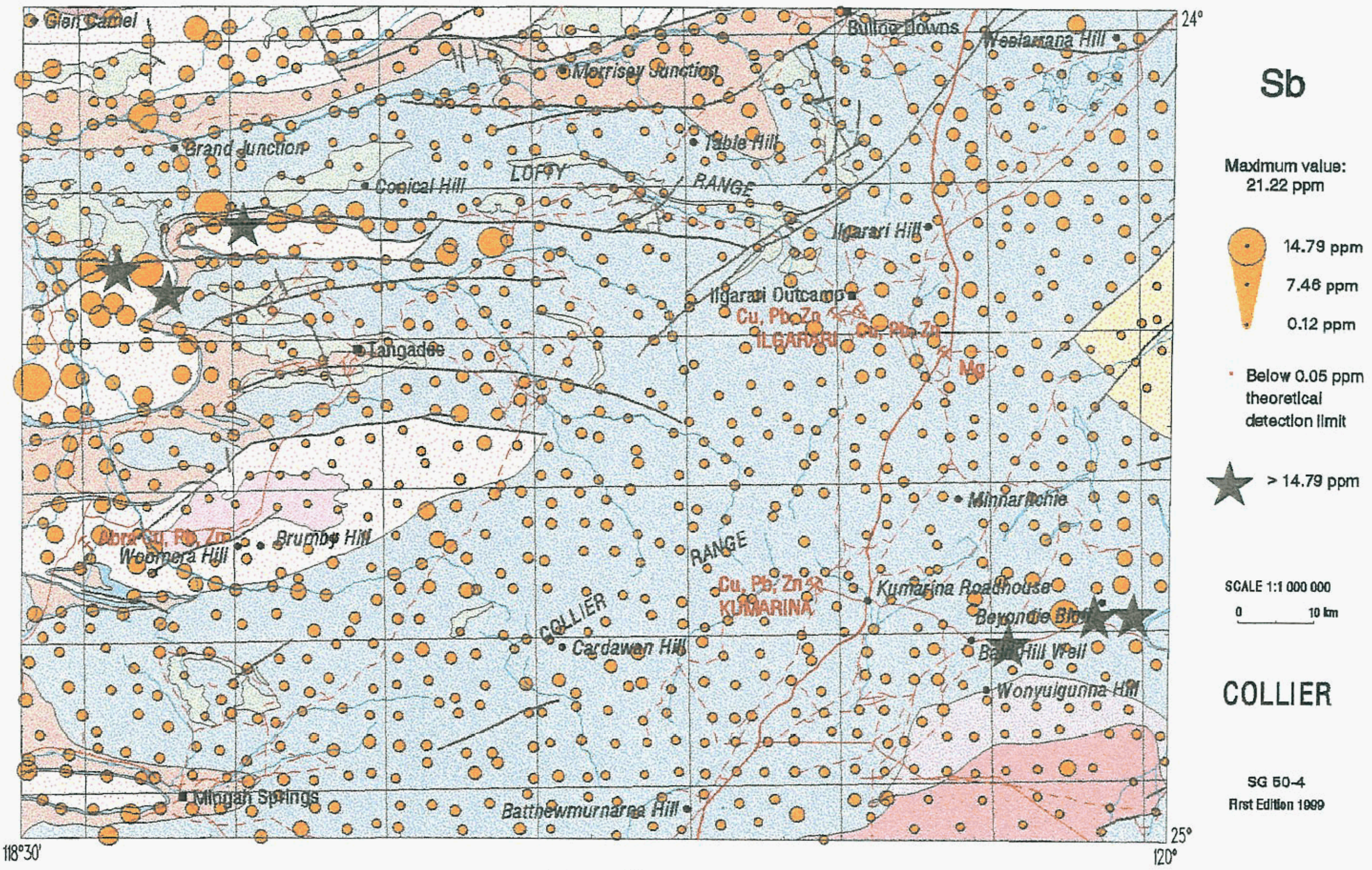


Figure 38

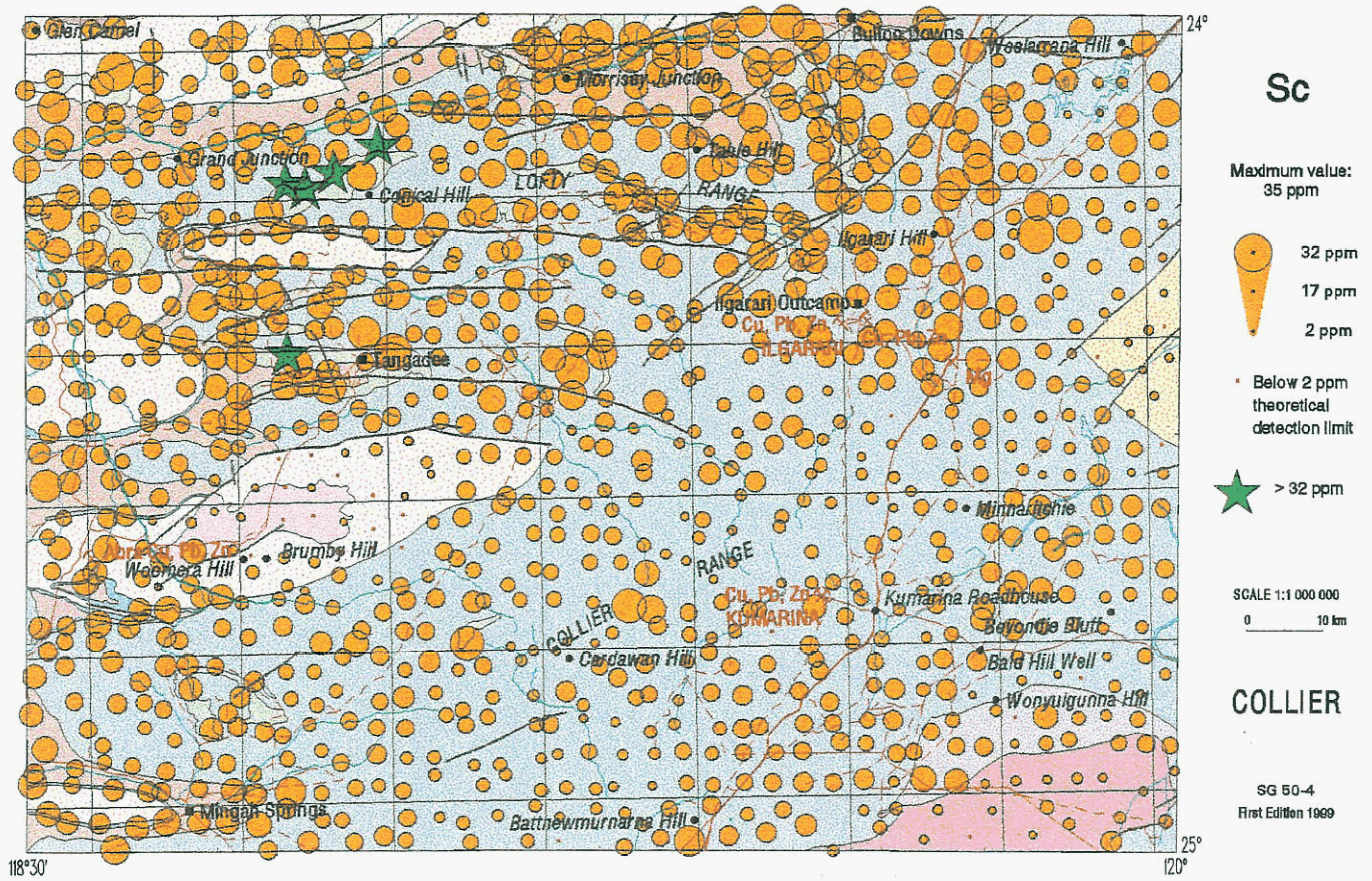


Figure 39

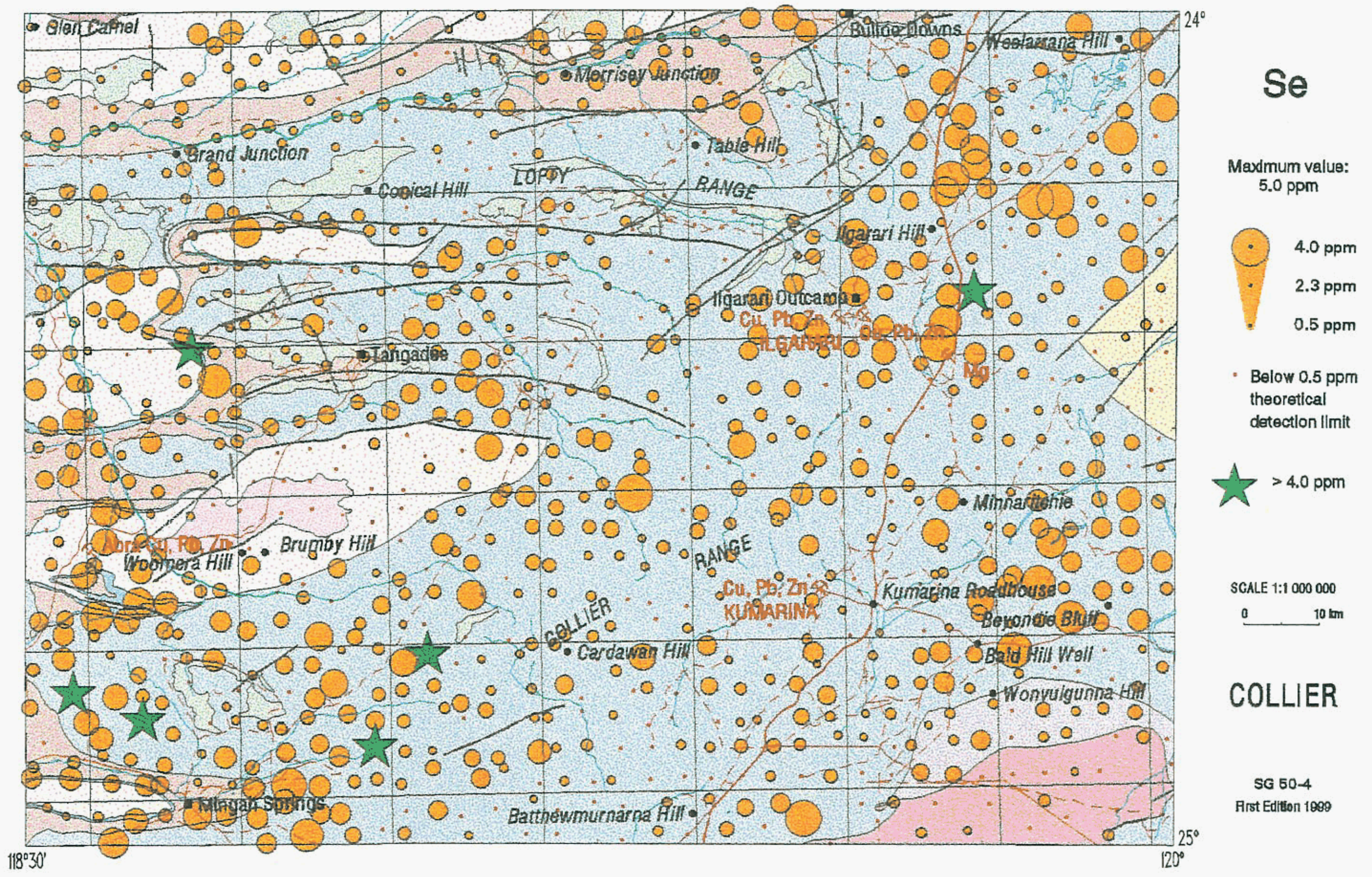


Figure 40

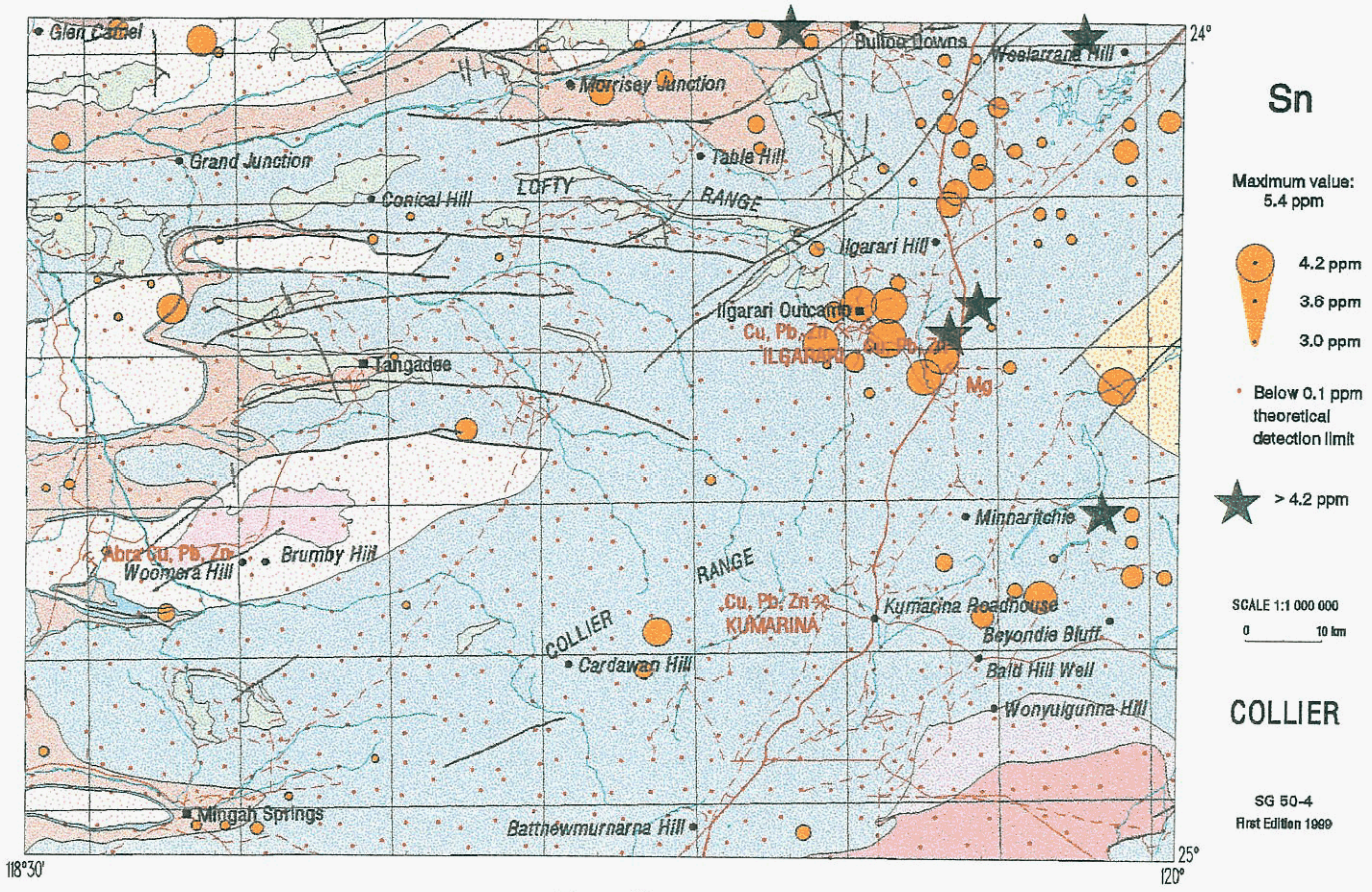


Figure 41

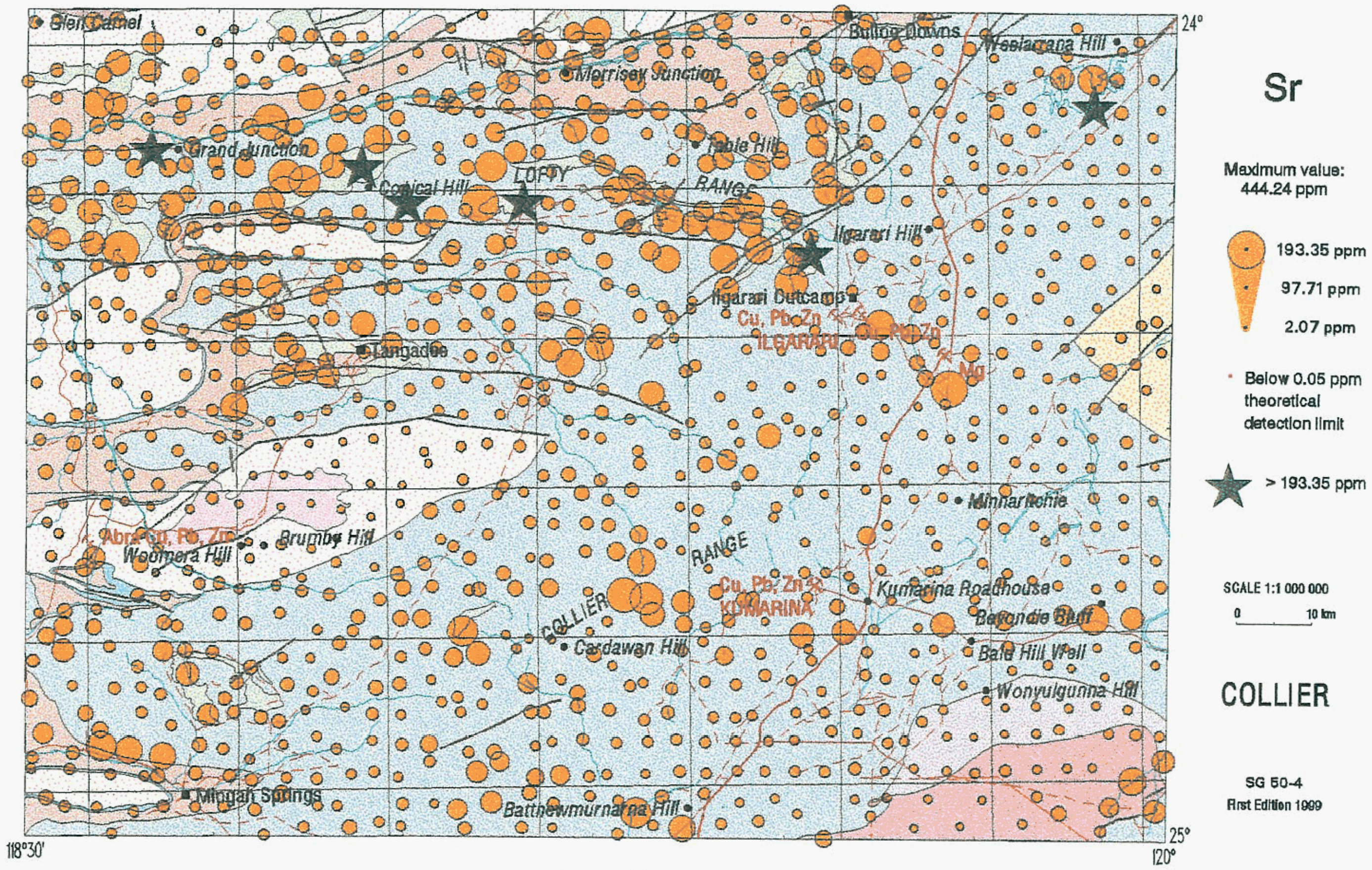


Figure 42

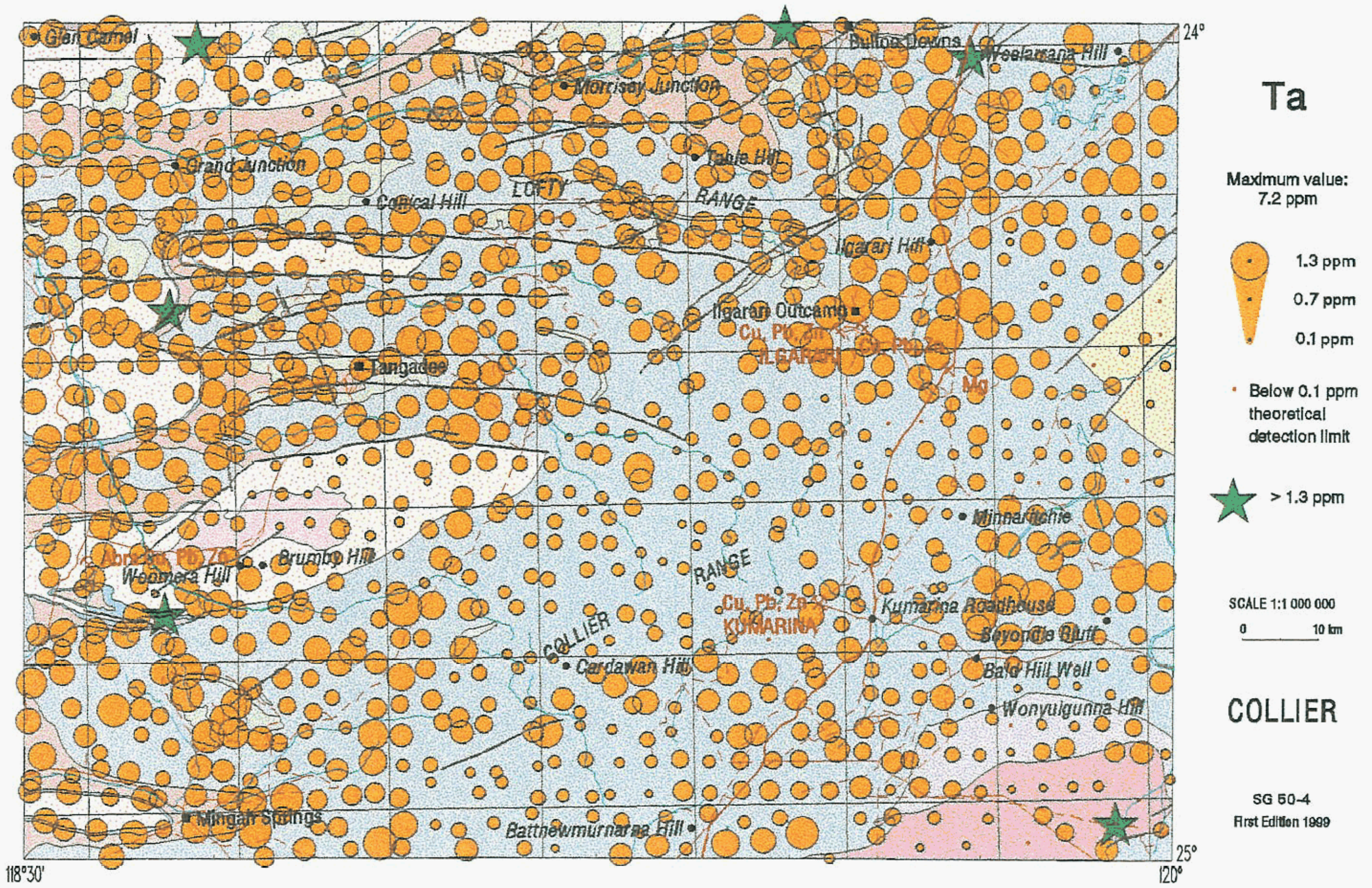


Figure 43

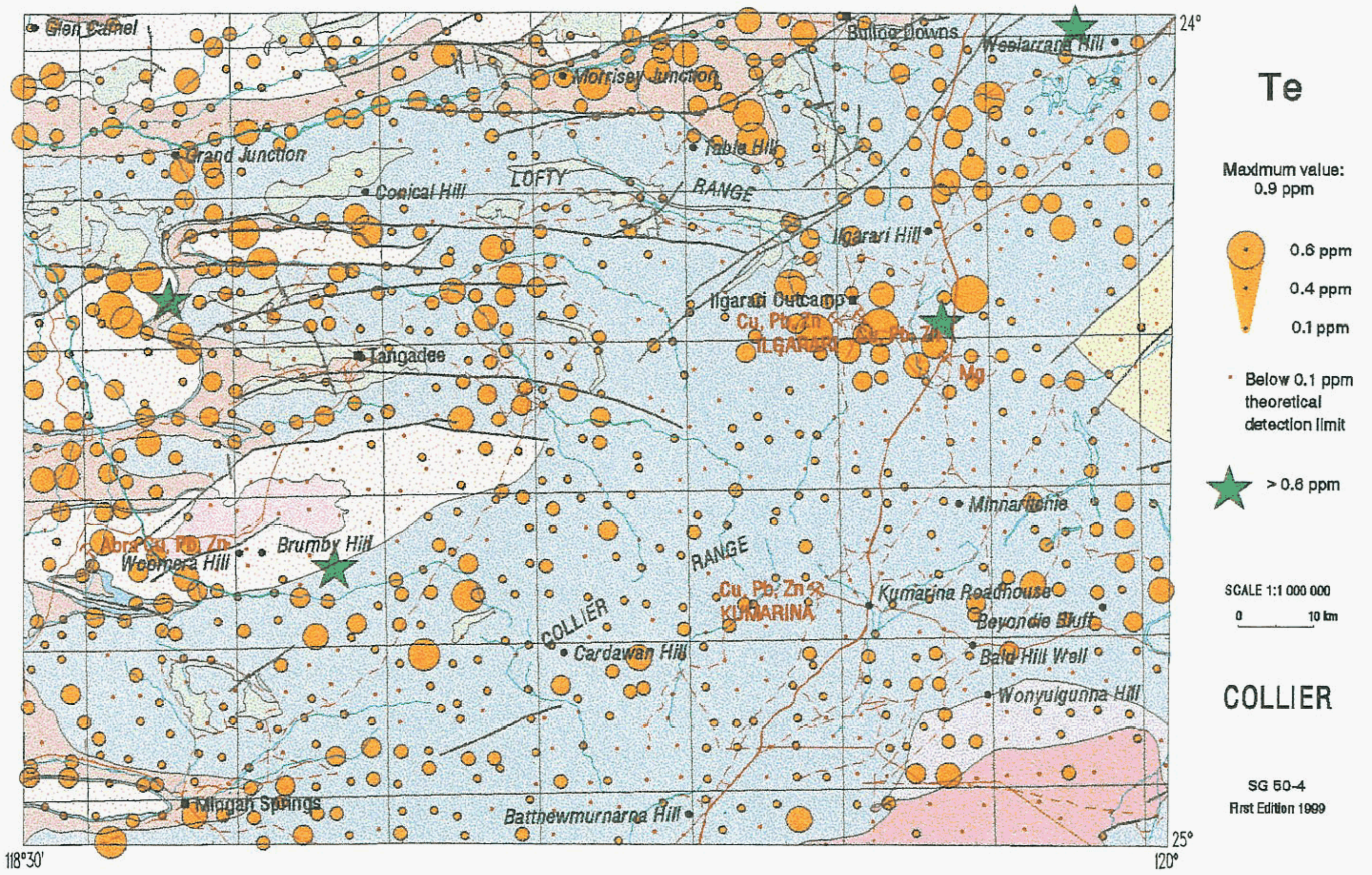


Figure 44

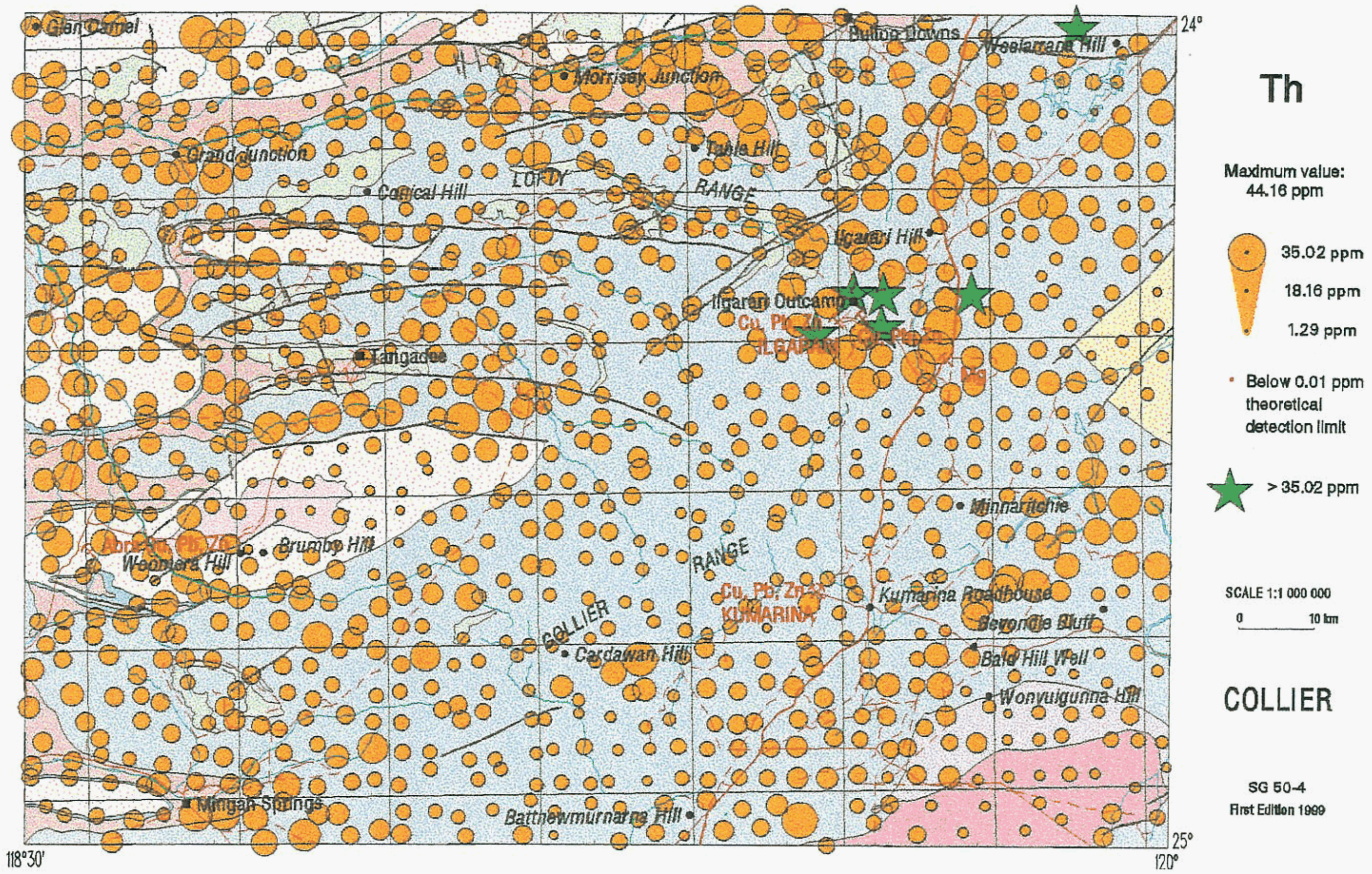


Figure 45

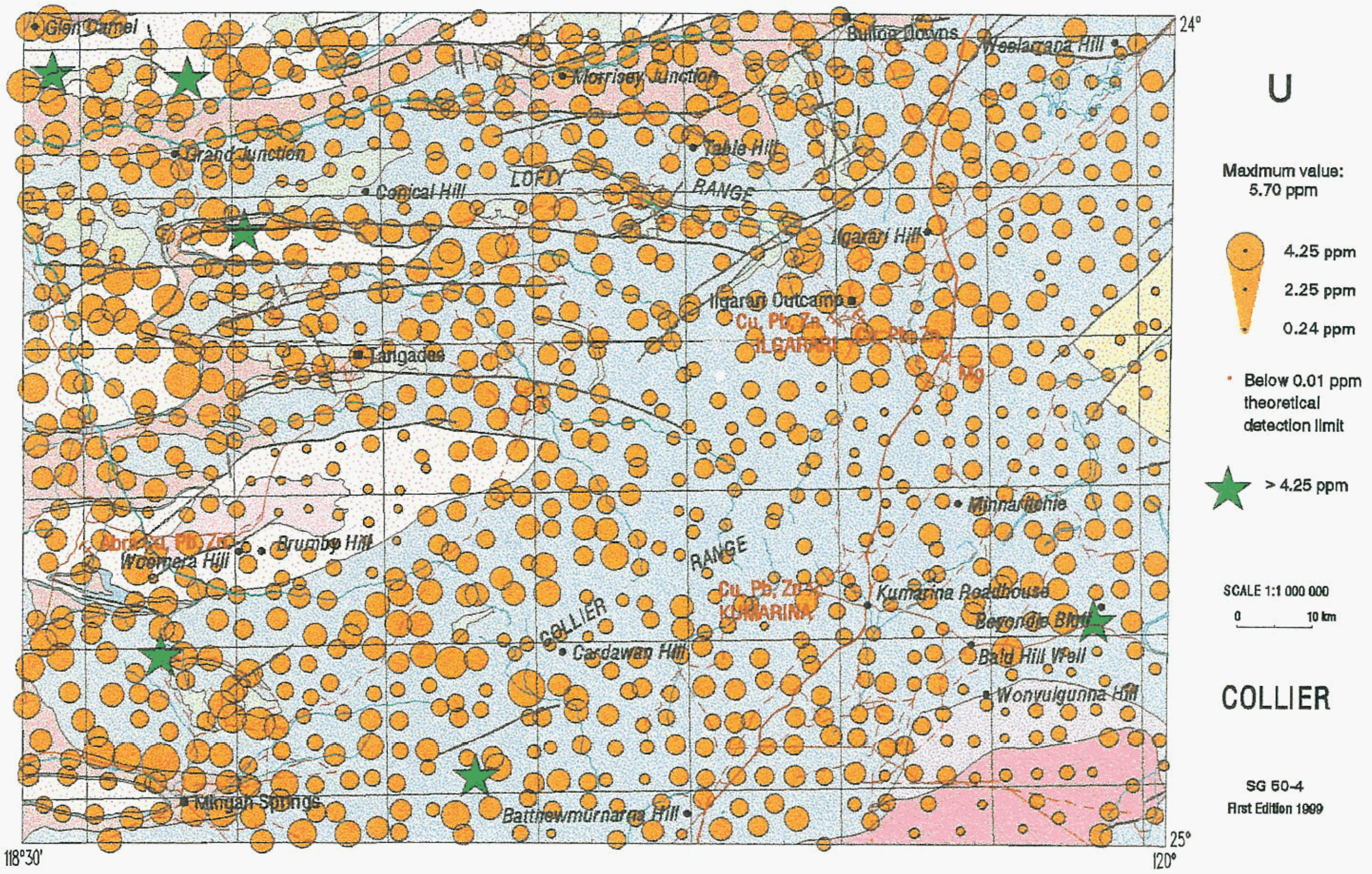


Figure 46

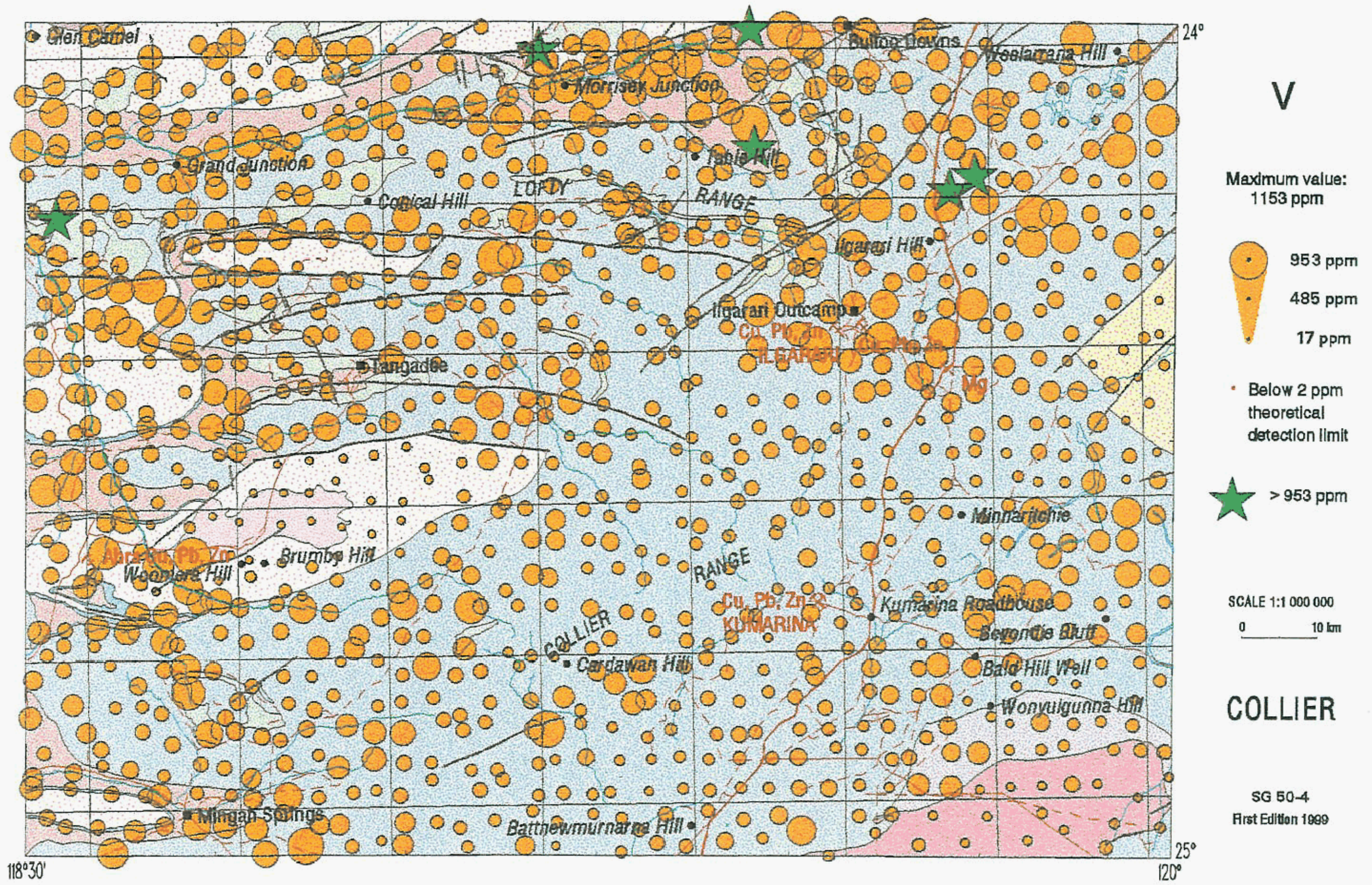


Figure 47

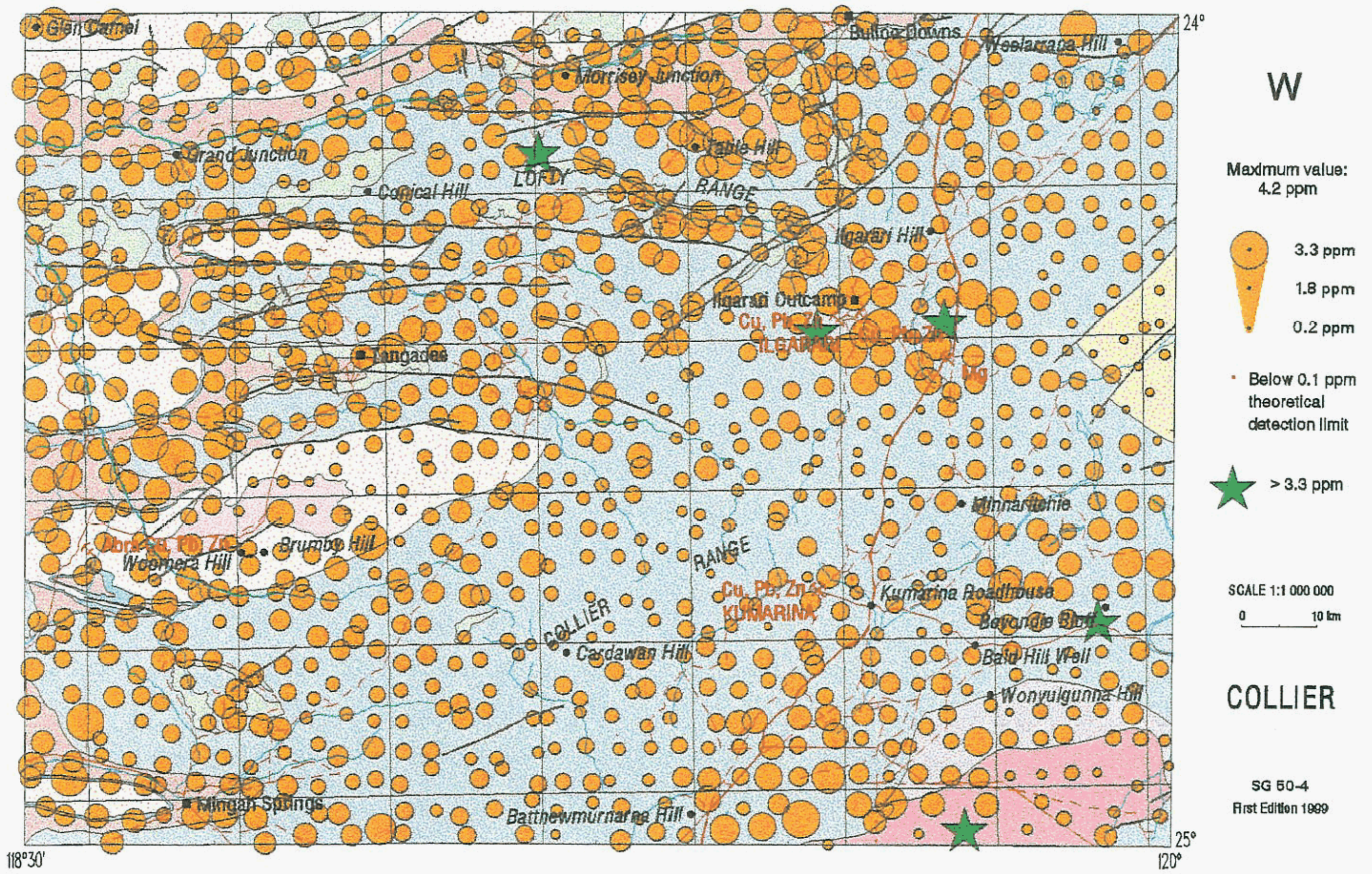


Figure 48

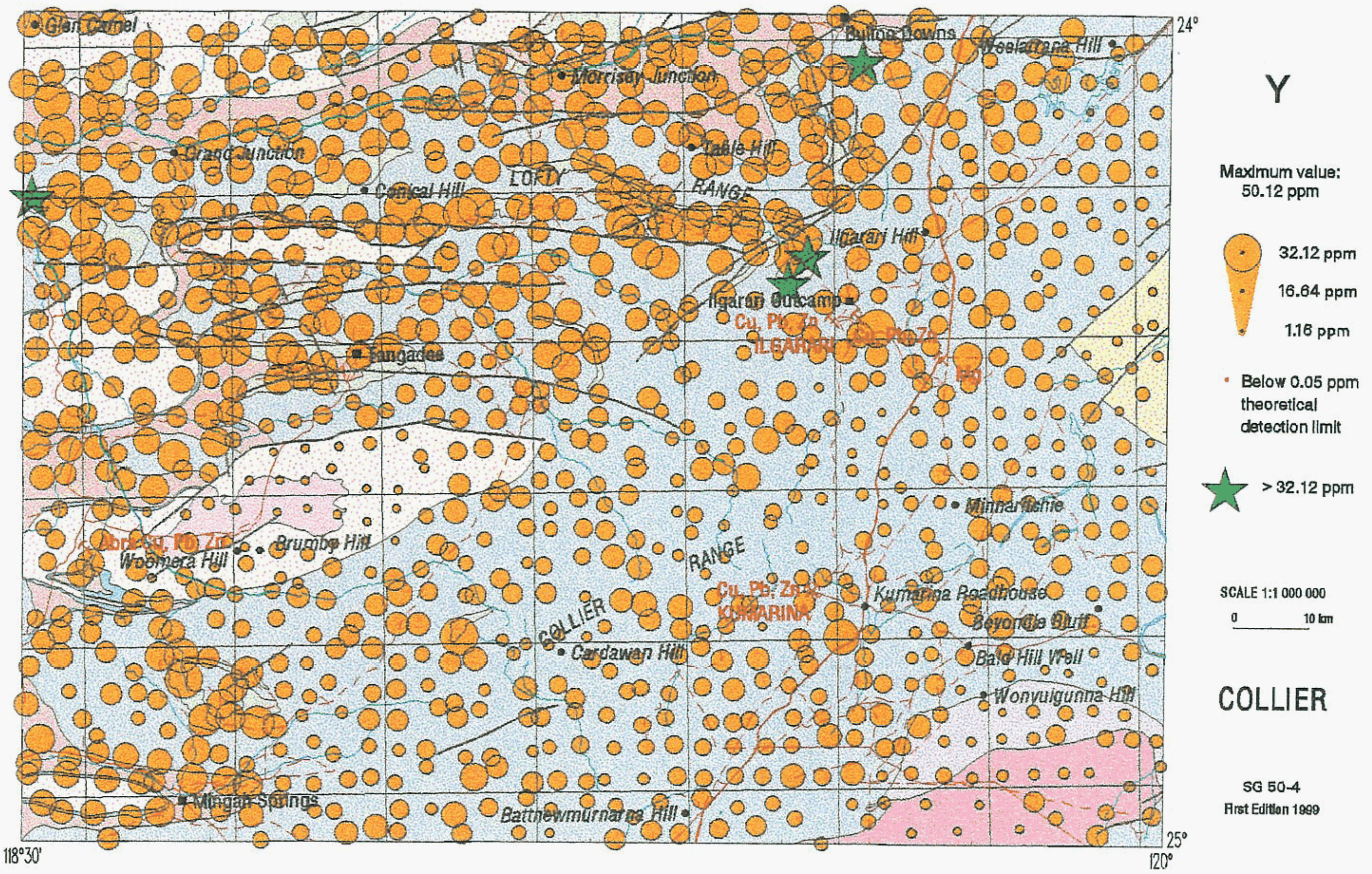


Figure 49

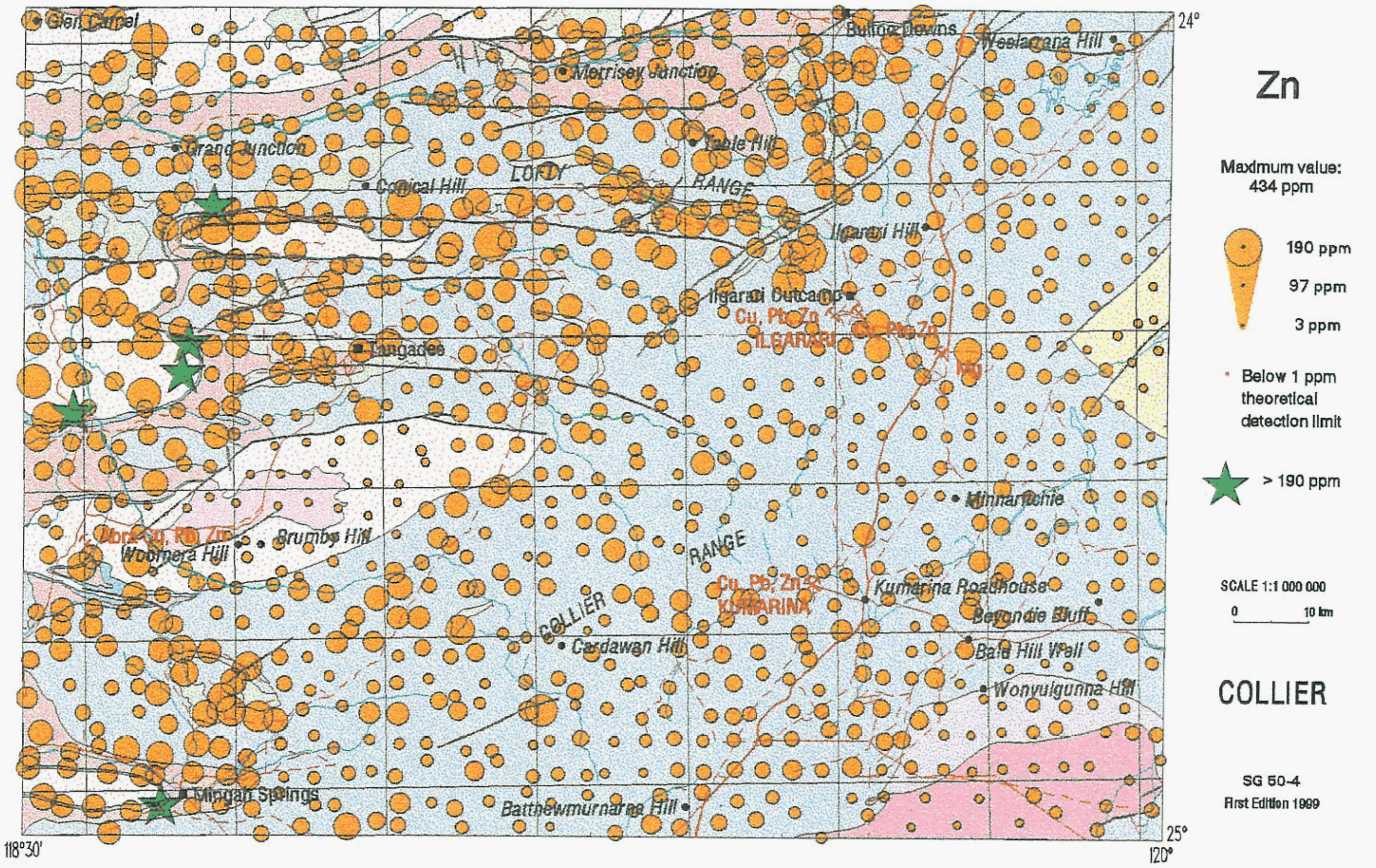
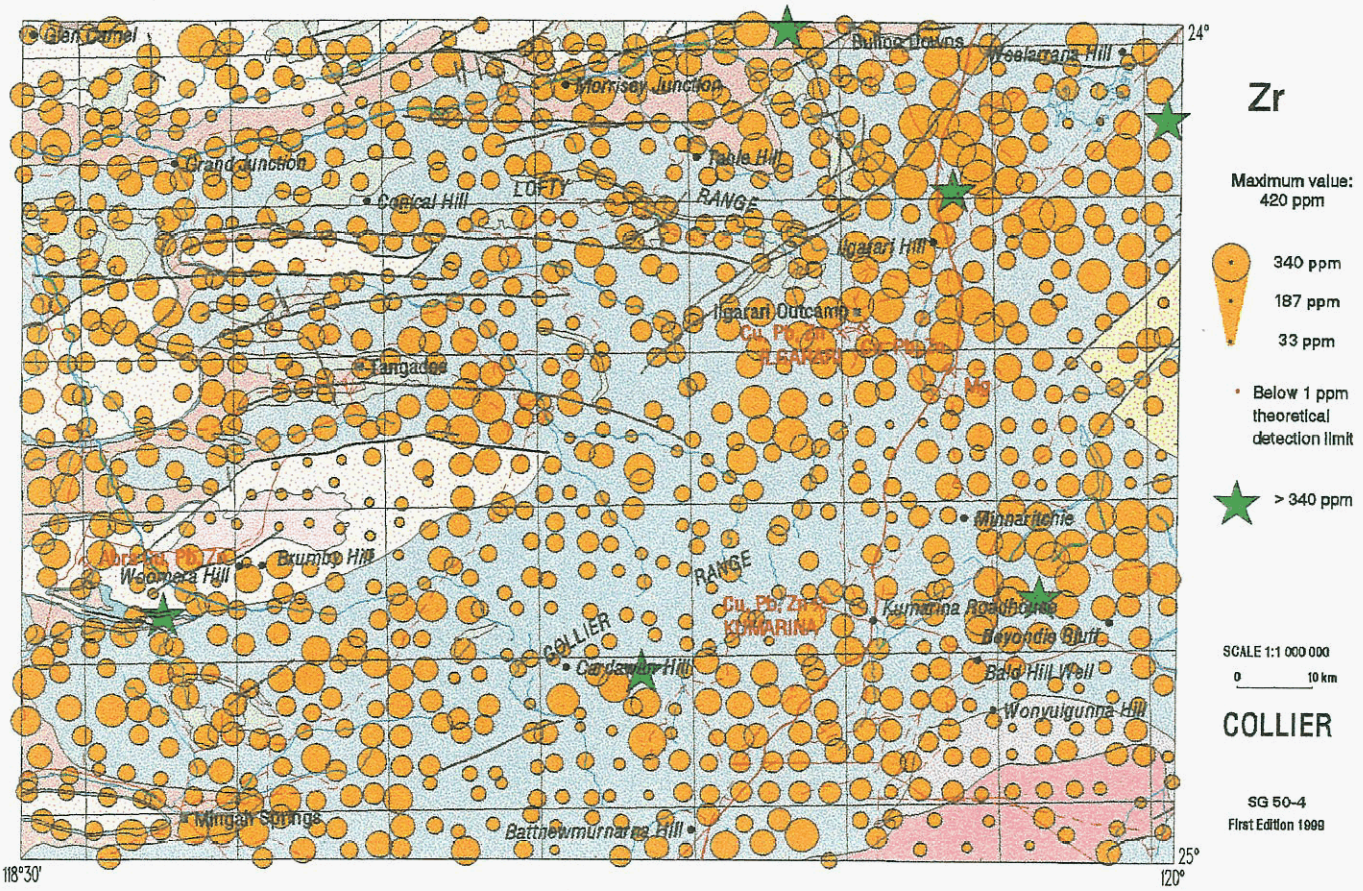
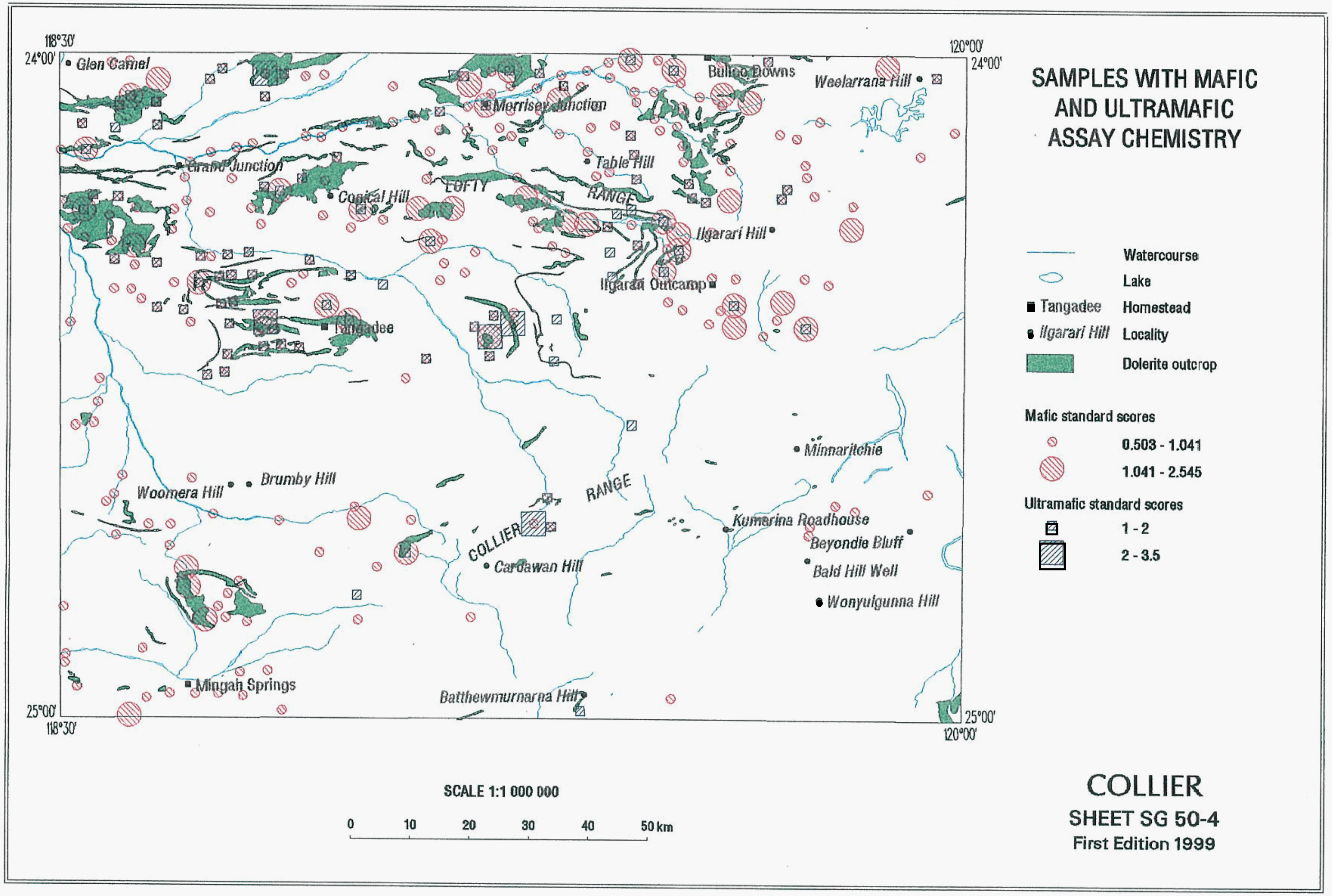


Figure 50



Glen Carnel
Morrisey Junction
Bulloo Downs
Woolanana Hill
Grand Junction
Table Hill
Conical Hill
LOFTY
RANGE
Ilgarari Hill
Ilgarari Outcamp
Cu, Pb, Zn
ILGARARI
Cu, Pb, Zn
Mg
Tangadee
Minnaritchie
Abra Cu, Pb, Zn
Brumby Hill
Woomera Hill
RANGE
Cu, Pb, Zn
KUMARINA
Kumarina Roadhouse
Beyondie Bluff
COLLIER
Cardawan Hill
Bald Hill Well
Wonyulgunna Hill
Mingah Springs
Batthewmurnarna Hill
24°
25°
118°30'
120°
Zr
Maximum value:
420 ppm
340 ppm
187 ppm
33 ppm
Below 1 ppm
theoretical
detection limit
> 340 ppm
SCALE 1:1 000 000
0
10 km
COLLIER
SG 50-4
First Edition 1999

Figure 51



SAMPLES WITH MAFIC AND ULTRAMAFIC ASSAY CHEMISTRY
118°30'
24°00'
120°00'
24°00'
25°00'
118°30'
25°00'
120°00'
Glen Camel
Morrisey Junction
Bulloo Downs
Weelarrana Hill
Grand Junction
Conical Hill
LOFTY
RANGE
Table Hill
Ilgarari Hill
Ilgarari Outcamp
Tangadee
Minnaritchie
Woomera Hill
Brumby Hill
COLLIER
RANGE
Cardawan Hill
Kumarina Roadhouse
Beyondie Bluff
Bald Hill Well
Wonyulgunna Hill
Mingah Springs
Batthewmurnarna Hill
Watercourse
Lake
Tangadee Homestead
Ilgarari Hill Locality
Dolerite outcrop
Mafic standard scores
0.503 - 1.041
1.041 - 2.545
Ultramafic standard scores
1 - 2
2 - 3.5
SCALE 1:1 000 000
0
10
20
30
40
50 km
COLLIER
SHEET SG 50-4
First Edition 1999

Figure 52.

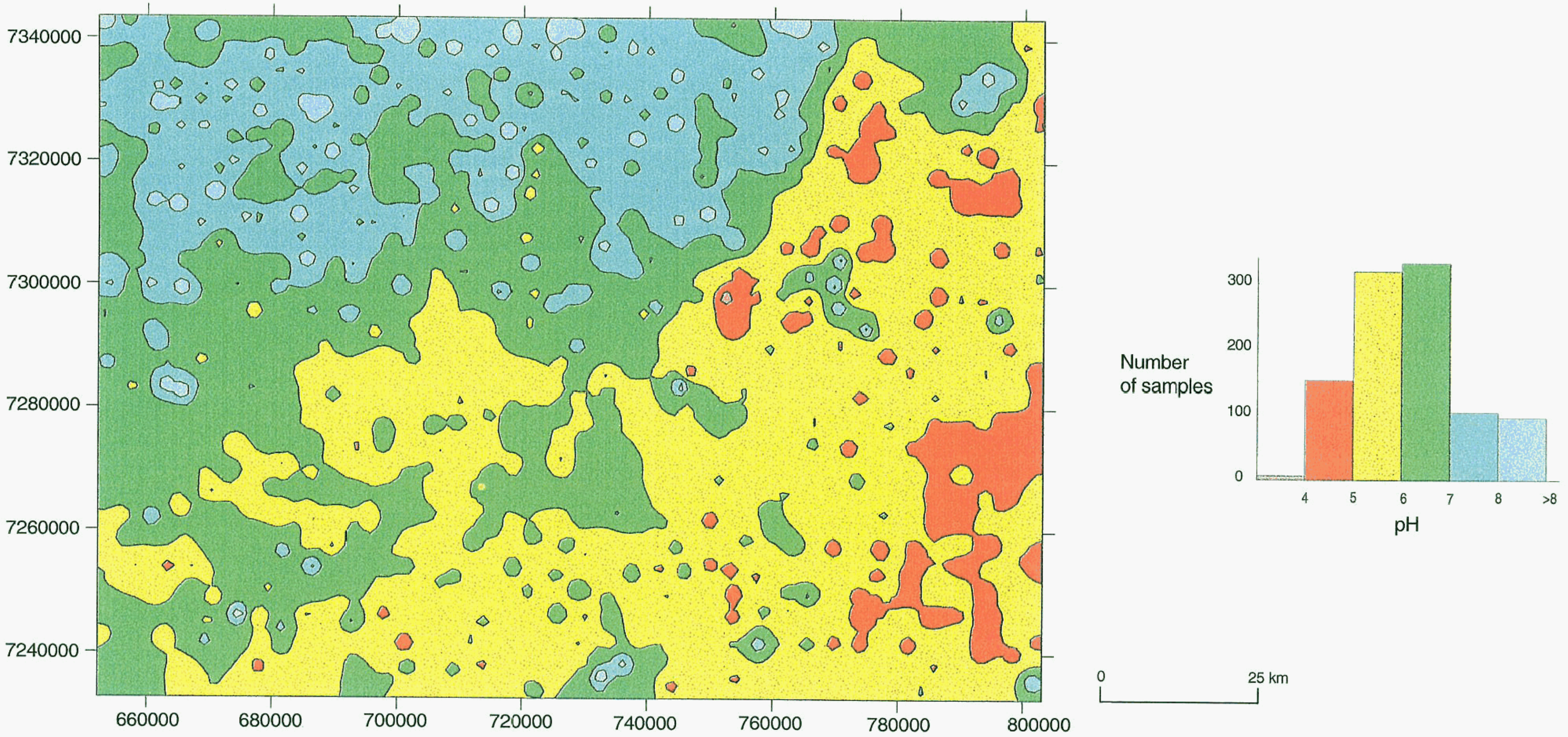


Figure 53. Contoured pH for regolith on COLLIER

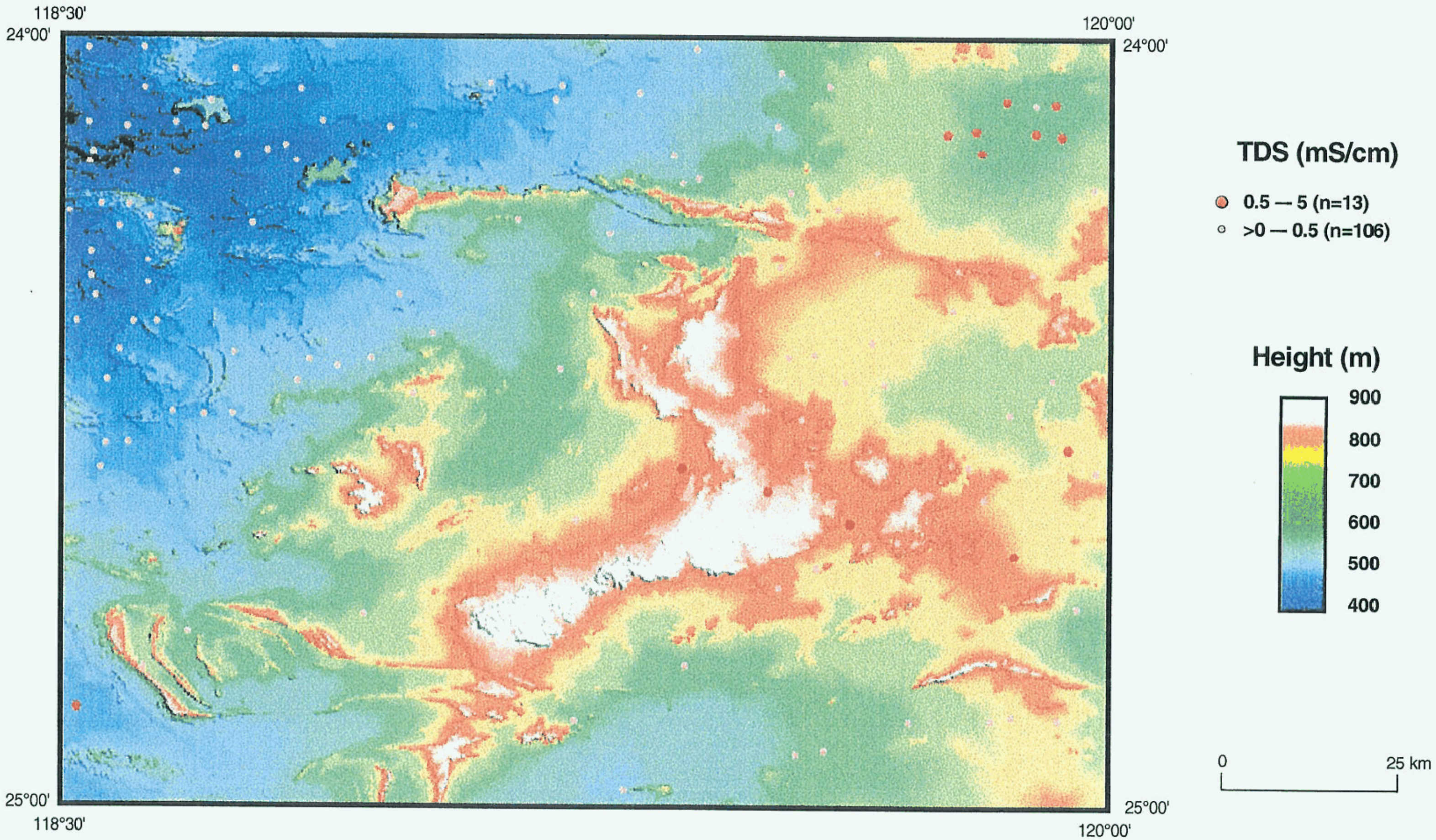


Figure 54. TDS and digital terrain model of COLLIER

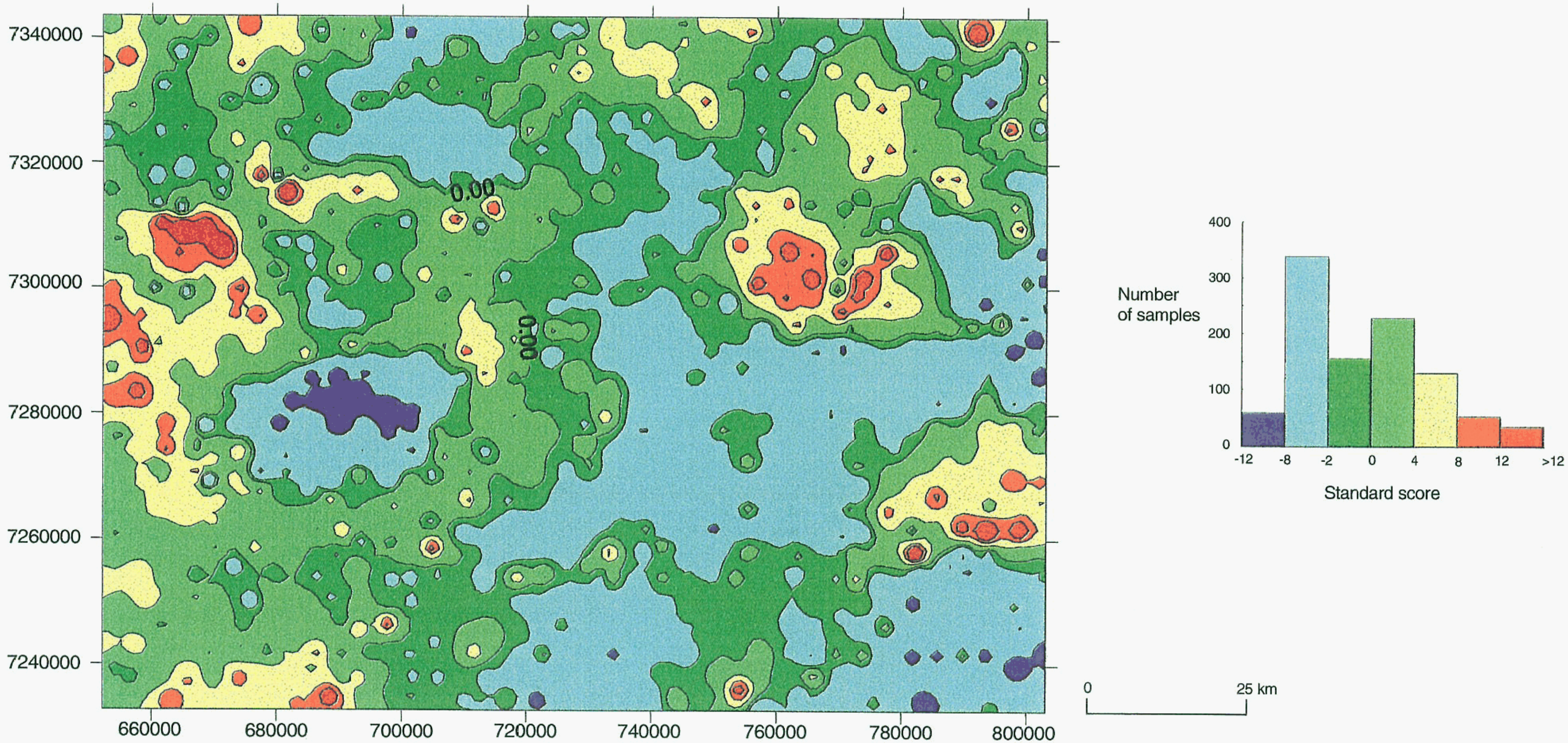


Figure 55. Contoured chalcophile index for regolith on COLLIER

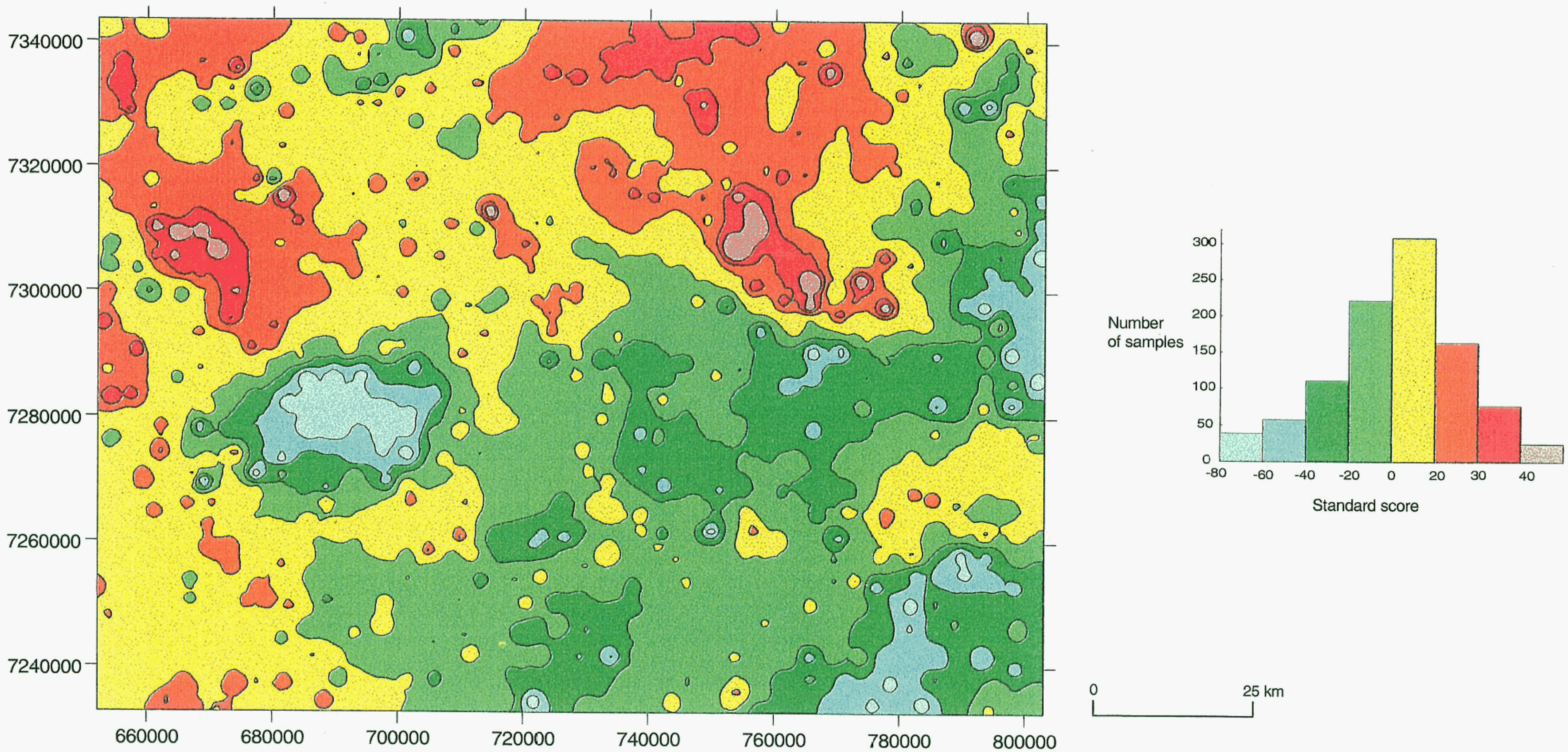


Figure 56. Contoured summed standard scores index for regolith on COLLIER

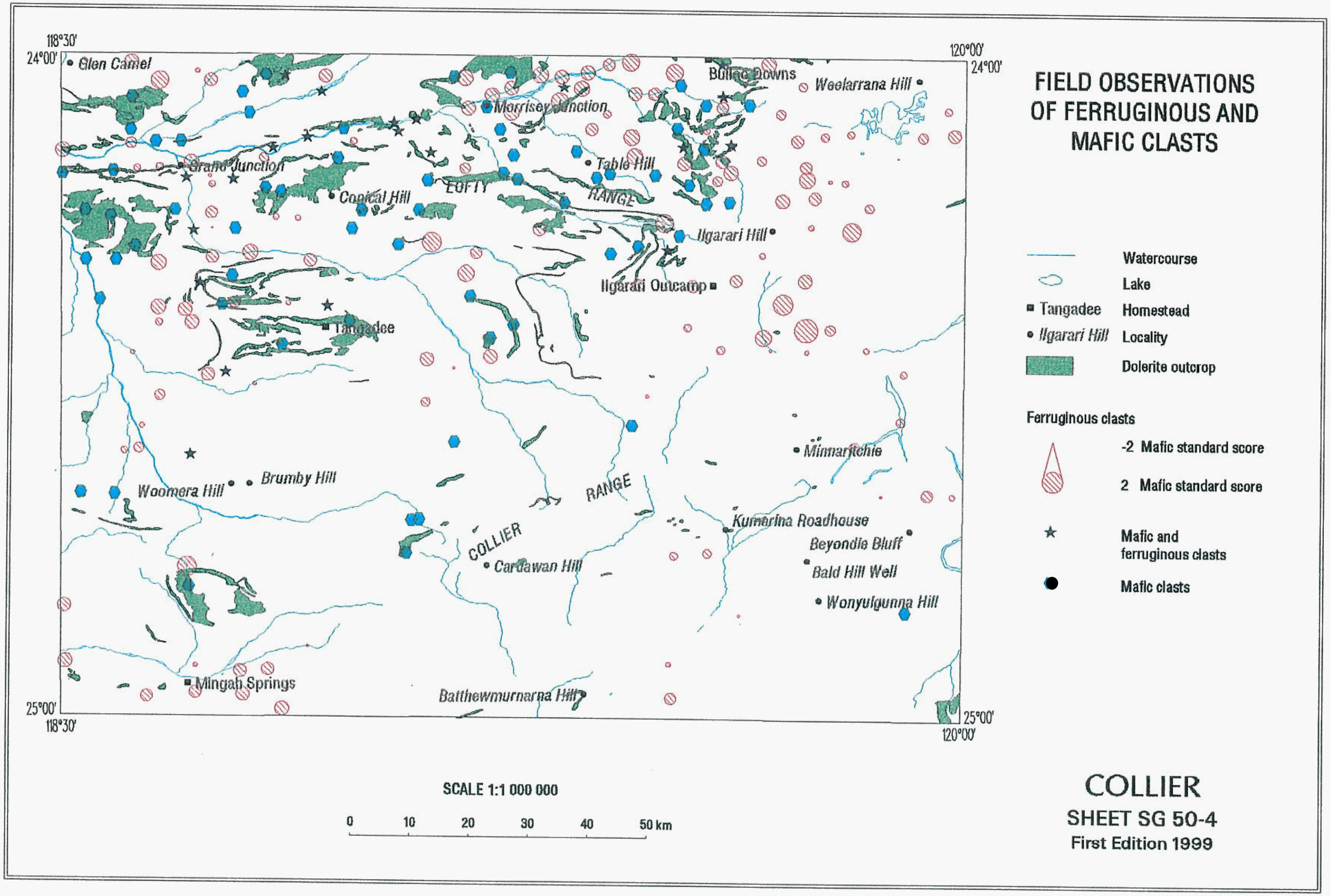
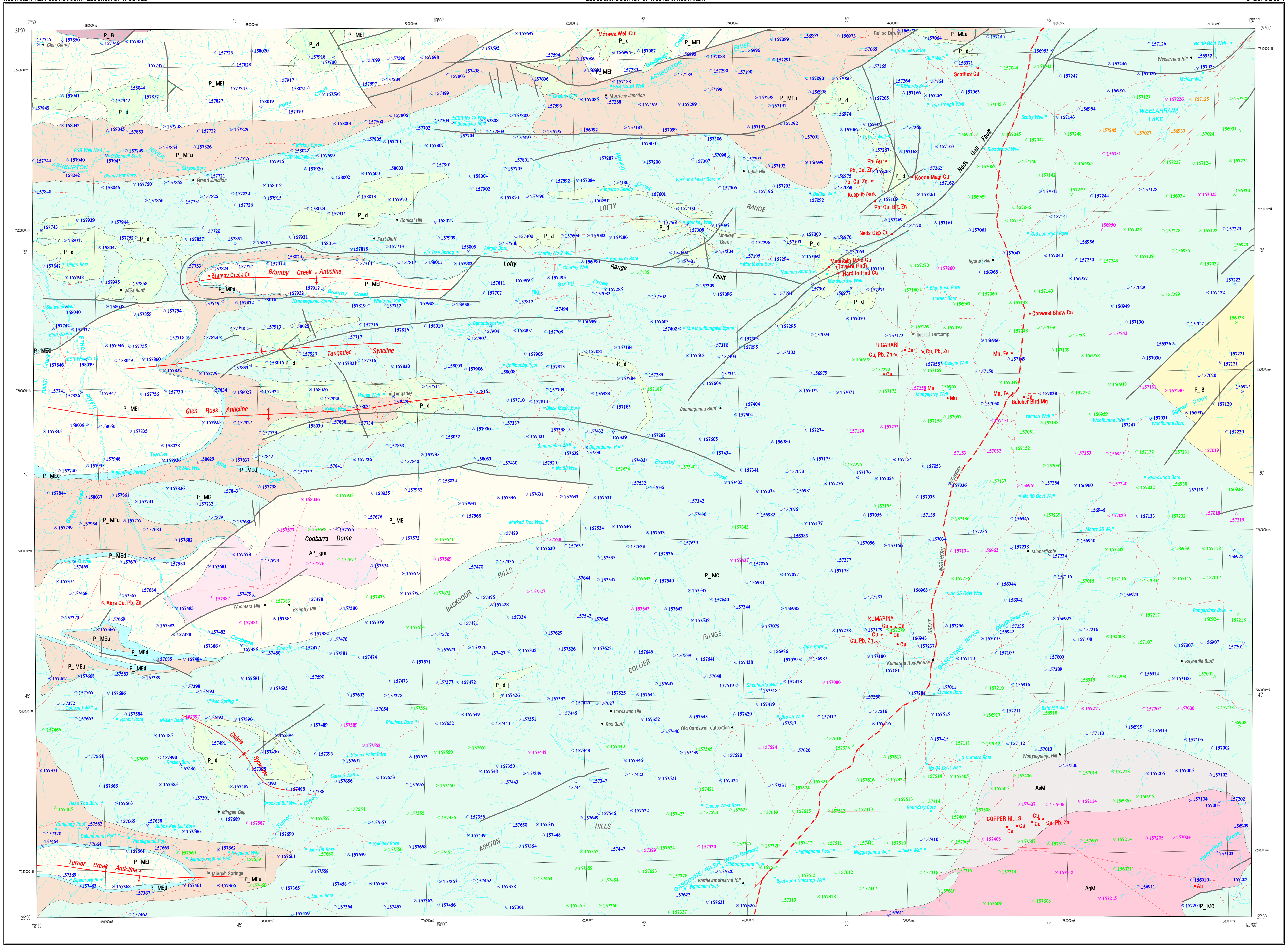

FIELD OBSERVATIONS OF FERRUGINOUS AND MAFIC CLASTS
118°30'
24°00'
120°00'
25°00'
Glen Camel
Bulloo Downs
Weelarrana Hill
Morrisey Junction
Grand Junction
Table Hill
Conical Hill
LOFTY
RANGE
Ilgarari Hill
Ilgarari Outcamp
Tangadee
Minnaritchie
Woomera Hill
Brumby Hill
RANGE
COLLIER
Cardawan Hill
Kumarina Roadhouse
Beyondie Bluff
Bald Hill Well
Wonyulgunna Hill
Mingah Springs
Batthewmurnarna Hill
Watercourse
Lake
Tangadee
Homestead
Ilgarari Hill
Locality
Dolerite outcrop
Ferruginous clasts
-2 Mafic standard score
2 Mafic standard score
Mafic and ferruginous clasts
Mafic clasts
SCALE 1:1 000 000
0
10
20
30
40
50 km
COLLIER
SHEET SG 50-4
First Edition 1999

Figure 57.

COLLIER

AUSTRALIA 1:250 000 REGOLITH GEOCHEMISTRY SERIES — GEOLOGICAL SURVEY OF WESTERN AUSTRALIA — SHEET SG 50-4



SAMPLE LOCATIONS

Sample point references

- 157128 — Stream sample
- 156934 — Sheetwash sample
- 157023 — Soil sample
- 157245 — Lake sample

- Major road
- Minor road
- Track
- Watercourse
- Lake
- Tangadee — Homestead
- Ilgarari Hill — Locality
- ILGARARI — Mining locality
- Mine
- Prospect
- Mineral occurrence
  - Brt — Barite
  - Cu — Copper
  - Au — Gold
  - Fe — Iron
  - Pb — Lead
  - Mg — Magnesium
  - Mn — Manganese
  - Ag — Silver
  - Zn — Zinc

GEOLOGICAL INTERPRETATION

PROTEROZOIC

- P_d — Dolerite, gabbro, and basalt; sills and dykes

Savory Group

- P_S — Sandstone with conglomerate lenses; minor siltstone

Bangemall Group

Collier Subgroup

- P_MC — Siltstone, mudstone, sandstone, conglomerate, dolomite, and subordinate chert

Edmund Subgroup

- P_MEu — Sandstone, siltstone, mudstone, dolomite, and subordinate chert
- P_MEd — DISCOVERY CHERT: massive or laminated chert, mudstone, and siltstone
- P_MEl — Mudstone, siltstone, chert, dolomite, sandstone (locally dolomitic), felsic volcanic rock, and subordinate conglomerate

Bresnahan Group

- P_B — Conglomerate, pebbly sandstone, sandstone, siltstone, and mudstone

Gascoyne Complex

- AP_gm — Biotite-muscovite monzogranite

ARCHAEAN

Marymia Inlier

- AgMl — Metamorphosed granite and minor sedimentary rock
- AsMl — Metasedimentary rock

- Geological boundary
- Fault
- Syncline
- Anticline

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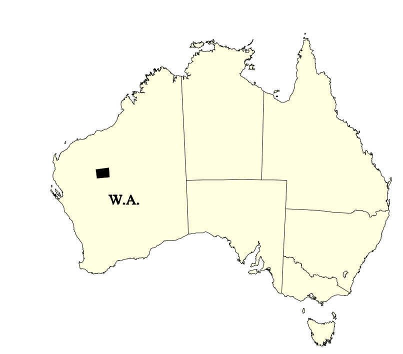
TUREE CREEK SF 50-15	NEWMAN SF 50-16	ROBERTSON SF 51-13
MOUNT EGERTON SG 50-3	COLLIER SG 50-4	BULLEN SG 51-1
ROBINSON RANGE SG 50-7	PEAK HILL SG 50-8	NABBERU SG 51-5



SAMPLE LOCATIONS

REGOLITH GEOCHEMISTRY SERIES

COLLIER

SHEET SG 50-4

FIRST EDITION 1999

Edited by G. Loan and N. Tetlaw

Cartography by G. Jose

Topography from Australian Surveying and Land Information Group and Department of Land Administration Sheet SG 50-4 and modified from geological field survey (1998)

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DEPARTMENT OF MINERALS AND ENERGY
L. C. RANFORD, DIRECTOR GENERAL

GOVERNMENT OF WESTERN AUSTRALIA
HON. NORMAN MOORE, M.L.C.
MINISTER FOR MINES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
DAVID BLIGHT, DIRECTOR

SCALE 1:250 000

5000 METRES — 0 — 5 — 10 — 15 — 20 — 25 — 30 KILOMETRES

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: AUSTRALIAN GEODETIC DATUM 1984
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM
Grid lines indicate 20 000 metre interval of the Australian Map Grid Zone 50

Sampling 1998 by J. Coker, R. Iasky, K. Pye, and S. Shevchenko (from GSWA), and S. Baesjou, J. Bradley, A.Lee, S. McGuinness, and B. White

Total sample sites: 1008; 758 stream sediments, 192 sheetwash, 54 soil, and 4 lake sediments

Analyst: Genalysis Laboratories; Minimum sample size: 1.5 kg
Fraction of sample analysed: >0.45 mm < 2mm

Geological interpretation by J. Coker after Brakel et al. (1974) and Cooper et al. (1998)

The recommended reference for this map is:
COKER, J., 1999, Sample locations, Collier, W.A. Sheet SG 50-4, *in* Geochemical mapping of the Collier 1:250 000 sheet *by* J. COKER and J. A. FAULKNER: Western Australia Geological Survey, 1:250 000 Regolith Geochemistry Series Explanatory Notes, Plate 1

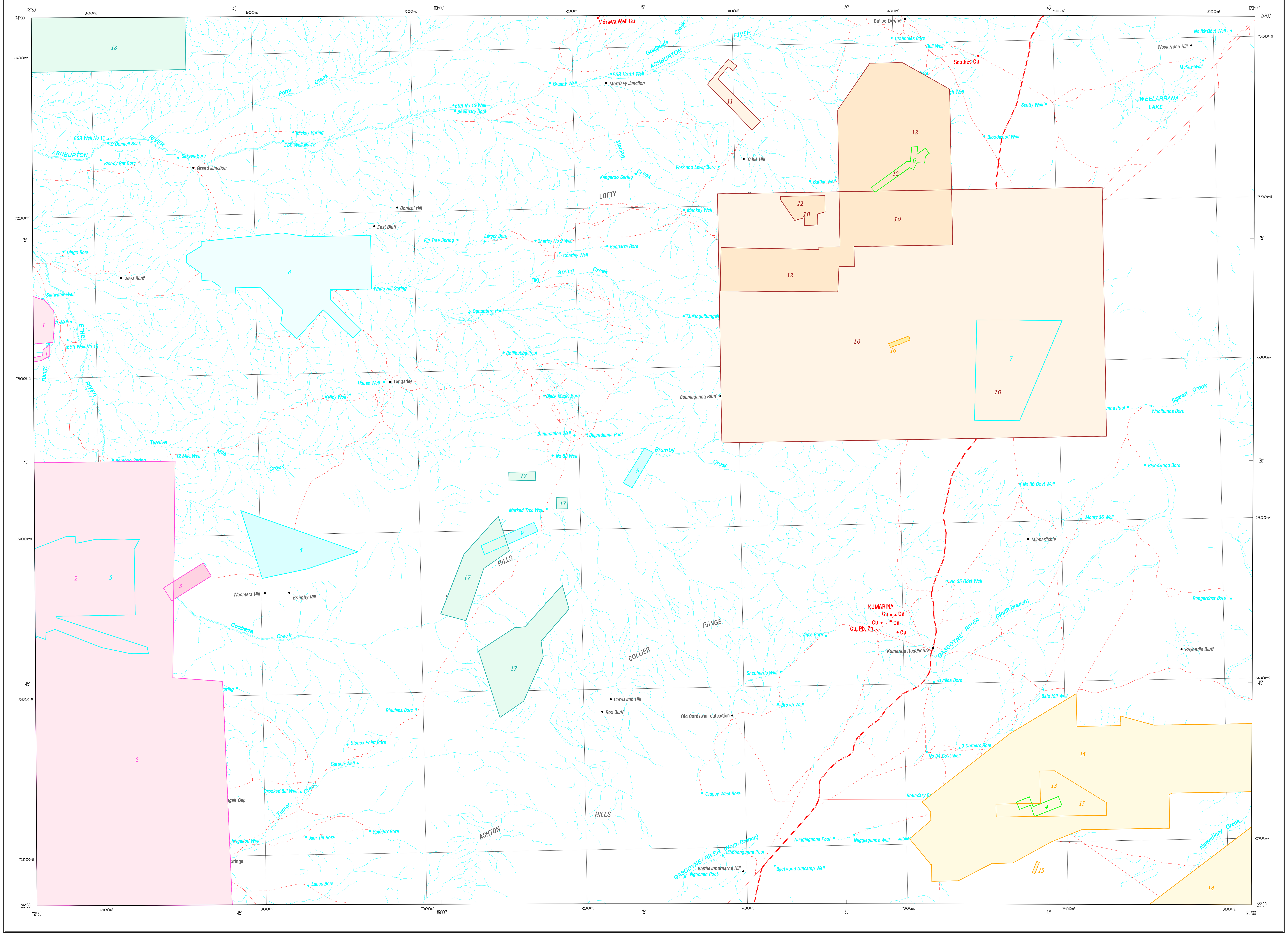
WARNING: Inks are water soluble and will fade with prolonged exposure to light

COLLIER

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

AUSTRALIA 1:250 000 REGOLITH GEOCHEMISTRY SERIES

SHEET SG 50-4



COMPANY PROJECTS WITH SURFACE GEOCHEMISTRY DATA IN OPEN-FILE REPORTS (at March 1998)

AREAS OF EXPLORATION REPORTED BETWEEN 1965 AND 1996

Project period reported within

(Various colour shades used for ease of project identification)

- 1965 - 1970
- 1971 - 1975
- 1976 - 1980
- 1981 - 1985
- 1986 - 1990
- 1991 - 1996

Number within project area is a database ID number (see Appendix 2)

- Major road
- Minor road
- Track
- Watercourse
- Lake
- Tangadee — Homestead
- Ilgarari Hill — Locality
- ILGARARI — Mining locality
- Mine
- Prospect
- Mineral occurrence
- Brt — Barite
- Cu — Copper
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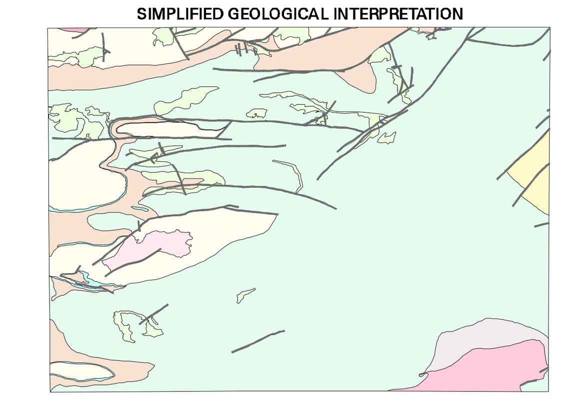
- Pb — Lead
- Mg — Magnesium
- Mn — Manganese
- Ag — Silver
- Zn — Zinc

SIMPLIFIED GEOLOGICAL INTERPRETATION



Geological interpretation by J. Coker after Brakel et al. (1974) and Cooper et al. (1998)

PROTEROZOIC

- Dolerite, gabbro, and basalt; sills and dykes

Savory Group

- Sandstone with conglomerate lenses; minor siltstone

Bangemall Group

Collier Subgroup

- Siltstone, mudstone, sandstone, conglomerate, dolomite, and subordinate chert

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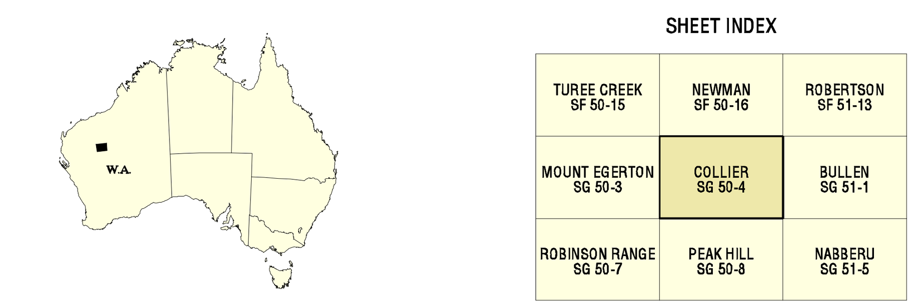

COMPANY PROJECTS WITH SURFACE GEOCHEMISTRY DATA IN OPEN-FILE REPORTS (at March 1998)

AREAS OF EXPLORATION REPORTED BETWEEN 1965 AND 1996

REGOLITH GEOCHEMISTRY SERIES

COLLIER

SG 50-4

FIRST EDITION 1999

Western Australia 1999

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Cartography by G. Jose and T. Lenane

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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
DAVID BLIGHT, DIRECTOR

SCALE 1:250 000

5000 0 5 10 15 20 25 30
METRES KILOMETRES

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: AUSTRALIAN GEODETIC DATUM 1984
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM
Grid lines indicate 20 000 metre interval of the Australian Map Grid Zone 50

Compiled by J. A. Faulkner, 1998

Compiled from the Geological Survey of Western Australia's SPINDEX database and open-file mineral exploration reports

The recommended reference for this map is:
FAULKNER, J. A., 1999, Company projects with surface geochemistry data in open-file reports (at March 1998), areas of exploration reported between 1965 and 1996, Collier, W.A. Sheet SG 50-4, *in* Geochemical mapping of the Collier 1:250 000 sheet *by* J. COKER and J. A. FAULKNER: Western Australia Geological Survey, 1:250 000 Regolith Geochemistry Series Explanatory Notes, Plate 3

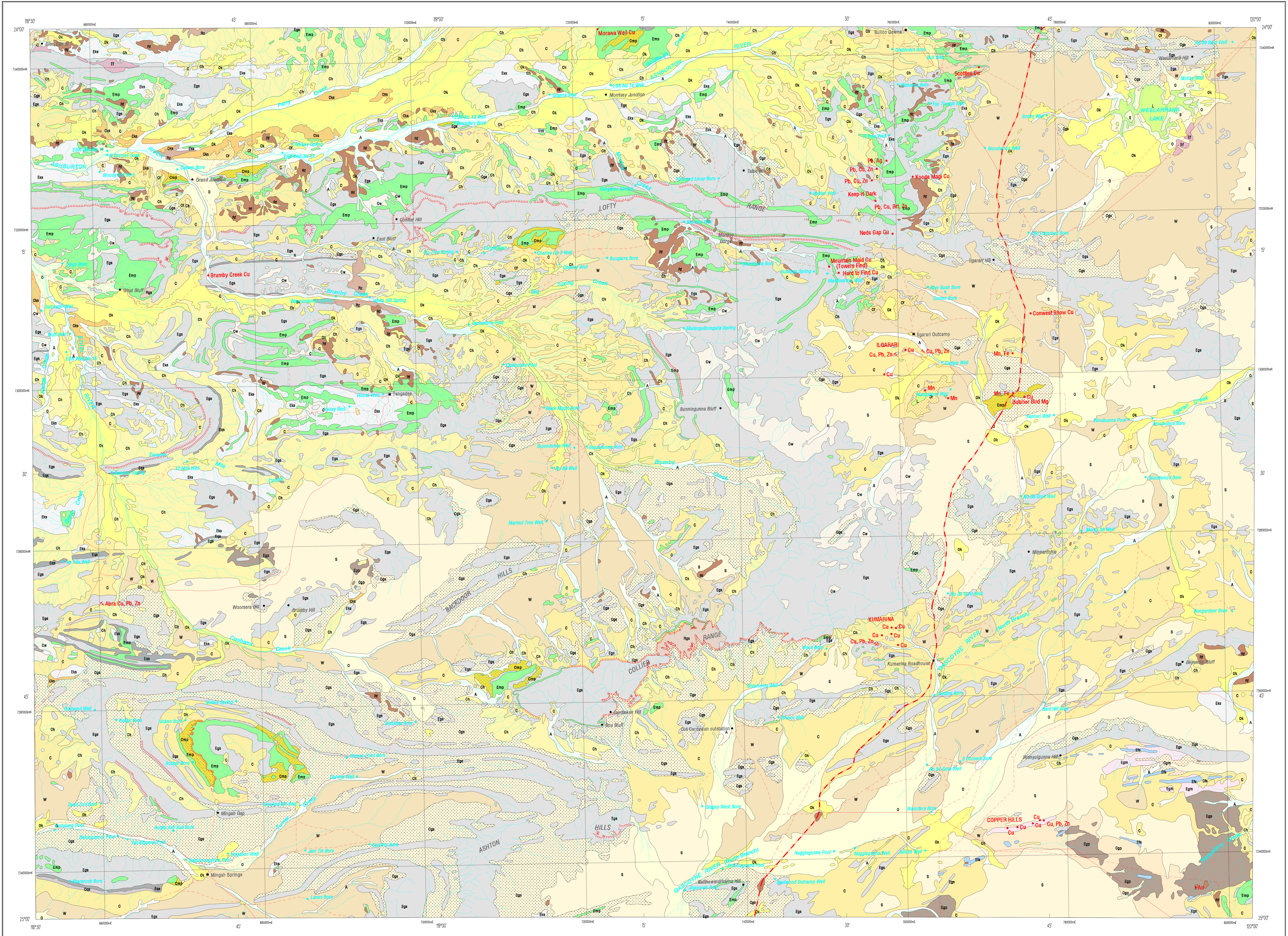
WARNING: Inks are water soluble and will fade with prolonged exposure to light

COLLIER

AUSTRALIA 1:250 000 REGOLITH GEOCHEMISTRY SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET SG 50-4



REFERENCE

RELICT REGIME

- Rz Silcrete, sometimes weakly ferruginized, forming remnant land surfaces (May include chalcedonic capping on calcrete)
- Rf Iron-rich duricrust forming remnant land surfaces
- Rgs Silicified capping on sandstone, usually horizontally bedded; forms mesas

EROSIONAL REGIME

- Ef Outcrop of saprock, bedrock, and subcrop with locally derived sand and sandy clays. Coarse bouldery lag may be present adjacent to prominent ranges: derived from ferruginized rock
- Efs As for 'Ef': derived mainly from ferruginous sedimentary rock
- Egs As for 'Ef': derived mainly from quartzofeldspathic sedimentary rock
- Egm As for 'Ef': derived mainly from quartzofeldspathic metamorphic rock
- Egp As for 'Ef': derived mainly from quartzofeldspathic plutonic rock
- Egv As for 'Ef': derived mainly from quartzofeldspathic volcanic rock
- Eks As for 'Ef': derived mainly from carbonate-rich sedimentary rock
- Emp As for 'Ef': derived mainly from coarse-grained ferromagnesian rock
- Eqs As for 'Ef': derived mainly from quartz-rich sedimentary rock

DEPOSITIONAL REGIME

DOMINANTLY COLLUVIAL

- C Unconsolidated and semi-consolidated sand, silt, gravel, and rubble. (derived from various sources)
- Cf As for 'C': derived mainly from strongly ferruginized rock
- Cfs As for 'C': derived from strongly ferruginous rock
- Cgs As for 'C': derived mainly from quartzofeldspathic sedimentary rock
- Cgm As for 'C': derived mainly from quartzofeldspathic metamorphic rock
- Cgp As for 'C': derived mainly from quartzofeldspathic plutonic rock commonly deeply incised; may include areas of hardpan
- Cks As for 'C': derived mainly from carbonate-rich sedimentary rock
- Cmp As for 'C': derived mainly from coarse-grained ferromagnesian rock
- Cqs As for 'C': derived mainly from quartz-rich sedimentary rock
- Cw Consolidated to semi-consolidated sand, silt, gravel, and rubble
- Ch Consolidated to semi-consolidated sand, silt, gravel, and rubble; commonly deeply incised; may include areas of hardpan

DOMINANTLY ALLUVIAL

- W Sand and clay dominated colluvium or sheetwash; merges into alluvial plains; may be scattered with small lakes
- O Overbank deposits, sand- or clay-rich alluvium and colluvium on floodplains; includes calcrete fragments and non-saline claypans
- Ok Valley calcrete, silicified in places
- A Gravelly sand and sandy clay in active alluvial channels with mixtures of ferruginous and variably altered lithic fragments
- L Saline or highly gypsiferous playa-lake sediments

DOMINANTLY EOLIAN

- S Eolian and residual sand

SYMBOLS

- Regolith boundary
- Minor road
- Track
- Breakaway
- Watercourse
- Lake
- Tangadee — Homestead
- Ilgarari Hill — Locality
- ILGARARI — Mining locality
- Mine
- Prospect
- Mineral occurrence
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- Cu — Copper
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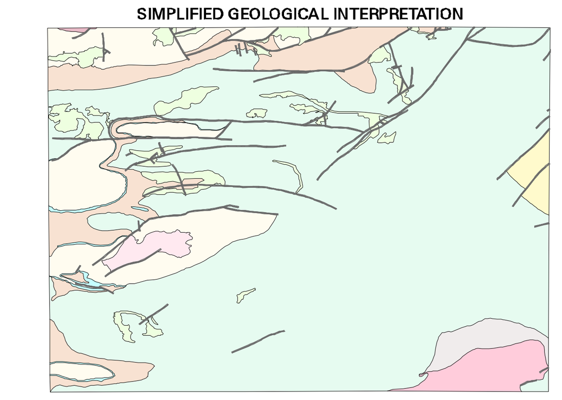

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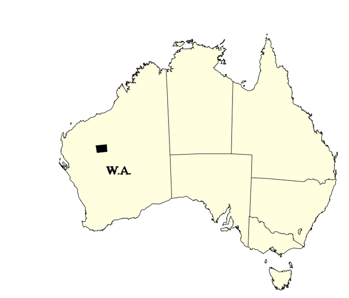

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REGOLITH MATERIALS

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Compiled by J. Coker, 1998

Field observations 1998 by J. Coker, R. Iasky, K. Pye, and S. Shevchenko (from GSWA), S. Baesjou, J. Bradley, A. Lee, S. McGuinness, and B. White

Compiled using Landsat TM images (1993 data), 1963 black and white aerial photography, published Geological Survey of Western Australia Geological Series map, Collier 1974, and field observations 1997

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REGOLITH GEOCHEMISTRY SERIES

COLLIER

SG 50-4

FIRST EDITION 1999

Western Australia 1999

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