

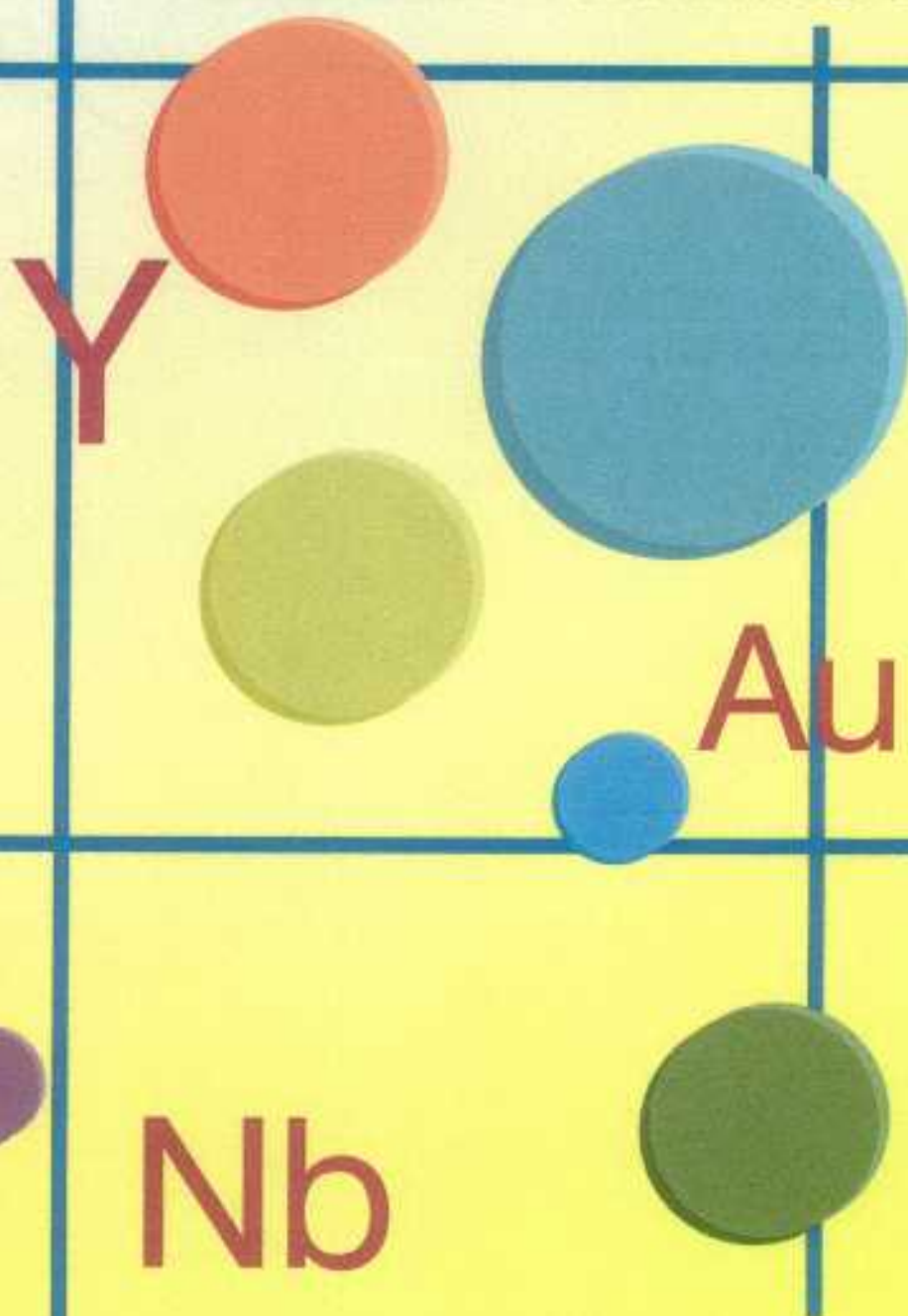
**EXPLANATORY
NOTES**



GEOCHEMICAL MAPPING OF THE STANLEY 1:250 000 SHEET

by P. A. Morris, S. A. McGuinness
A. J. Sanders, and J. Coker

1:250 000 REGOLITH GEOCHEMISTRY SERIES



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY



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Contents

Abstract	1
Introduction	1
Location and access	2
Climate	2
Vegetation	2
Geomorphology and soils	2
Topographic and remote-sensing datasets	2
Geology	2
Archaean	3
Earaheedy Group	3
Yelma Formation	3
Frere Formation	3
Chiall Formation	3
Wongawol Formation	3
Kulele Limestone	4
Mulgarra Sandstone	4
Deformed and metamorphosed Earraheedy Group	4
Bangemall Supergroup	4
Scorpion Group	4
Collier Group	4
Sunbeam Group	4
Mafic intrusive rocks	4
Paterson Formation	4
Recorded mineralization	5
Geochemical surveys in open-file company reports	5
Regolith sampling	5
Regolith-materials mapping	5
Residual-regime regolith (<i>R</i>)	5
Exposed-regime regolith (<i>X</i>) and locally derived colluvium	6
Undivided colluvium (<i>Cd</i>) and distal sheetwash (<i>W</i>)	7
Alluvial (<i>A</i>), floodplain (<i>F</i>), and lacustrine (<i>L</i>) regolith	7
Sandplain (<i>S</i>) and eolian (<i>E</i>) regolith	7
Chemical analysis	8
Quality control	8
Comparison of laboratories	9
Geological Survey of Western Australia standards	9
Discussion	9
Discussion of element-distribution maps	9
Grouping of chemical components	10
Major element oxides and loss on ignition	10
Precious metals	11
Anions	11
Base metals	11
Ferro-alloy metals	12
Fissionable metals	13
Minor metals and non-metals	13
Discussion	15
Controls on regolith by parent lithology	15
Dolerite	15
Wongawol Formation	15
Chiall, Frere, and Yelma Formations	16
Frere Formation	16
Granitoid rocks	16
Regolith type	16
Statistical treatment of regolith chemical data	16
Statistical comparison of regolith types over the Sunbeam Group and dolerites	19
Exposed-regime regolith and colluvium derived from dolerites (<i>Xmh</i> , <i>Cmh</i>)	19
Colluvium derived from dolerites (<i>Cmh</i>) and colluvium of mixed parentage (<i>Cl</i>)	19
Iron-rich sandplain (<i>Sf</i>) relative to other sandplain and eolian units	19
Iron-rich sandplain (<i>Sf</i>) and residual iron-rich regolith (<i>Rf</i>)	19
Iron-rich sandplain (<i>Sf</i>) and heterogeneous sandplain (<i>SI</i>)	24
Iron-rich sandplain (<i>Sf</i>) and eolian regolith (<i>E</i>)	24
Iron-rich sandplain (<i>Sf</i>) and sheetwash (<i>W</i>)	24
Eolian material and other sandplain types	24
Heterogeneous sandplain (<i>SI</i>) and sheetwash (<i>W</i>)	24

Lake-sediment (L_l) and lake-margin deposits (L_m)	24
Sandplain (S) over Archaean granitoid and the Paterson Formation	24
Stream sediments and sheetwash over the Wongawol Formation	28
Soil and sheetwash samples over the Wongawol Formation	28
Speciality maps	28
Mineralization potential	28
Conclusions	31
References	33

Appendices

1. Gazetteer of localities	35
2. Open-file surface geochemistry for STANLEY as at June 1999	37
3. Regolith-materials classification, regolith sampling and laboratory procedures, and quality control ..	43
4. Quality-control data (digital; disk in pocket)	

Plates (in pocket)

1. Sample locations (1:250 000)
2. Company projects with surface geochemical data in open-file reports (at June 1999)
3. Regolith-materials map (1:250 000)

Figures

1. Status of GSWA regional regolith and geochemical mapping program
2. Simplified locality plan
3. Simplified geological interpretation
4. Generalized regolith

Element-distribution and other maps

5. SiO_2
6. TiO_2
7. Al_2O_3
8. Fe_2O_3
9. MnO
10. MgO
11. CaO
12. Na_2O
13. K_2O
14. P_2O_5
15. LOI
16. Ag
17. As
18. Au
19. Ba
20. Be
21. Bi
22. Cd
23. Ce
24. Co
25. Cr
26. Cu
27. Ga
28. In
29. La
30. Li
31. Mo
32. Nb
33. Ni
34. Pb
35. Pd
36. Pt
37. Rb
38. S
39. Sb

40. Sc
41. Se
42. Sn
43. Sr
44. Ta
45. Te
46. Th
47. U
48. V
49. W
50. Y
51. Zn
52. Zr
53. Schematic cross section showing bedrock–regolith relationships for northern STANLEY
54. Contoured dolerite additive-index scores (Fe+Ti+Cr+Sc+V+In)
55. Dolerite index and total magnetic intensity
56. pH of regolith
57. Conductivity of regolith

Tables

1. Regolith-materials unit area and number of samples according to regolith type	6
2. Samples with three or more anomalous analytes	9
3. Summary statistics for regolith over outcropping dolerite (<i>Xmh</i>) and colluvium derived from dolerite (<i>Cmh</i>) over the Sunbeam Group and dolerite	17
4. Summary statistics for heterogeneous colluvium (<i>Cl</i>) and colluvium derived from dolerite (<i>Cmh</i>) over the Sunbeam Group and dolerite	18
5. Summary statistics for ferruginous duricrust (<i>Rf</i>) and iron-rich sandplain (<i>Sf</i>) over the Sunbeam Group and dolerite	20
6. Summary statistics for iron-rich sandplain (<i>Sf</i>) and heterogeneous sandplain (<i>Sl</i>) over the Sunbeam Group and dolerite	21
7. Summary statistics for eolian sandplain (<i>E</i>) and iron-rich sandplain (<i>Sf</i>) over the Sunbeam Group and dolerite	22
8. Summary statistics for sheetwash (<i>W</i>) and iron-rich sandplain (<i>Sf</i>) over the Sunbeam Group and dolerite	23
9. Summary statistics for sheetwash (<i>W</i>) and heterogeneous sandplain (<i>Sl</i>) over the Sunbeam Group and dolerite	25
10. Summary statistics for regolith in lake systems (<i>L_r</i>) and regolith marginal to lakes (<i>L_m</i>)	26
11. Summary statistics for sandplain (<i>S</i>) over Archaean granitoid and the Paterson Formation	27
12. Summary statistics for stream sediments and sheetwash samples over the Wongawol Formation	29
13. Summary statistics for soil and sheetwash samples over the Wongawol Formation	30

Digital dataset (in pocket)



STANLEY regional geochemistry data (STANCHEM.CSV)
Appendix 4 (quality-control data)

Geochemical mapping of the Stanley 1:250 000 sheet

by

P. A. Morris, S. A. McGuinness, A. J. Sanders, and J. Coker

Abstract

Regolith geochemical mapping on STANLEY at 1:250 000 scale was carried out by sampling of regolith at a nominal sampling density of one sample per 16 km². The resulting 1012 samples have been analysed for 48 components, pH, and conductivity. All of the components are shown as either spot-concentration or contour maps. Analysis of regolith on STANLEY was carried out, along with standards, blanks, and replicate samples, under an established analytical protocol. Precision and accuracy were generally good, although some interlaboratory variations exist for several analytes.

Summary data include geomorphological and botanical information, and open-file information on geochemical surveys. A regolith map compiled from Landsat and geophysical imagery, aerial photography, and regolith characteristics recorded at each sample site shows that approximately 3% of the regolith on Stanley has developed in situ, whereas a further 17% represents outcrop or subcrop. Depositional-regime regolith is dominantly sandplain (approximately 23%), with subordinate eolian material (9%), colluvium (6%), and alluvial-related deposits (19%). Sheetwash accounts for a further 23%.

Bedrock exerts a significant control on regolith chemistry on STANLEY, especially in areas of dolerite in the northeastern half of the map sheet. Iron-rich sandplain in this area, which accounts for 13% of all regolith, is largely dolerite sourced, and offers a viable sampling medium. Statistical analysis of different regolith types over the Sunbeam Group and dolerites shows that physical rather than chemical weathering is dominant, regolith types become more heterogeneous downslope, and eolian regolith can be distinguished on chemistry as well as morphology. Statistical analysis of sheetwash and stream-sediment samples, and sheetwash and soil samples over the Wongawol Formation shows no differences in chemistry according to sample type.

Three areas of potential mineralization have been identified. There are two areas of elevated MnO, base metals, and several other analytes (including Na₂O, K₂O, Ba, Be, Ce, Co, Cu, La, Li, Nb, Ni, Rb, Sn, Sr, Y, and Zn); one is in the south-central part of Stanley, whereas the other is within a 25 km radius of Earacheedy Station. The former is coincident with an area of potential stratiform mineralization, whereas the latter overlaps an area of structurally controlled mineralization. The highest values for platinum group elements (PGE) are in regolith either over or close to dolerite, especially in the northwest of Stanley. Further examination of these areas, in conjunction with gravity modelling using data acquired during regolith sampling, should provide more insight into the three-dimensional characteristics of these bodies.

KEYWORDS: Stanley, geochemistry, regolith, mineralization, regolith mapping.

Introduction

The STANLEY* 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). The program aims to collect and synthesize information about the distribution and composition of regolith, for use by the mineral exploration industry and landuse agencies. The program originally focused on the northern part of the Yilgarn

Craton, whereas more recent work has concentrated on the less extensively explored areas between the Pilbara and Yilgarn Cratons (Fig. 1), the Northampton Complex and Phanerozoic basins (Sanders and McGuinness, 2000), and part of the Albany–Fraser Orogen (Morris et al., 2000).

The term 'regolith' includes surficial rock and consolidated or unconsolidated material derived from the weathering and erosion of bedrock (Merrill, 1897). Regolith can form in situ or be transported. Depositional processes include gravity, fluvial or eolian action, and chemical precipitation. Large areas of Western Australia are covered by regolith, which can restrict direct

* Capitalized names refer to standard 1:250 000 map sheets, unless otherwise indicated.

examination of the bedrock and the contained mineralization. An understanding of the distribution and composition of regolith is both a valuable and necessary exploration tool (Smith et al., 1989). The main goal of the GSWA regolith geochemistry program is to determine the distribution of regolith types and provide information on the composition of regolith, based on the systematic collection and analysis of regolith samples. These data can identify areas of potential mineralization, as well as delineate the extent of bedrock units.

Location and access

The STANLEY 1:250 000 sheet (SG 51-6) is bounded by latitudes 25°00' and 26°00'S and longitudes 121°30' and 123°00'E (Fig. 2, Plate 1). Pastoral stations partly or wholly on STANLEY include Earahedy, Carnegie, Glenayle, and Wongawol, and the few permanent residents in the area are involved in the pastoral industry. Access to STANLEY is by a graded road from Wiluna, approximately 200 km to the southwest, which links up to the Gunbarrel Highway at Carnegie Homestead. The Canning Stock Route passes through the northwestern corner of the map sheet, and provides reasonable access except after heavy rainfall. Station tracks allow access to most of the map sheet, but during wet weather, roads and tracks can become impassable due to flooding. Most stations have airstrips suitable for light planes. A gazetteer of localities mentioned in the text is presented as Appendix 1.

Climate

The climate on STANLEY is arid, with an average rainfall of about 240 mm, an average potential evaporation of 3000 mm per year, and 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 23–38°C, and July is the coolest month, with a temperature range of 6–20°C (Commander et al., 1982).

Vegetation

STANLEY lies in the Eremaean Botanical Province of Diels (1906). Beard (1981) subdivided Western Australia into phytogeographic regions based on botanical provinces, regions, and districts or subdistricts, and STANLEY covers part of the Ashburton and Kertland Botanical Districts (Beard, 1975). The vegetation assemblages mapped by Beard (1975) correspond largely with the physiographic units.

In the Ashburton Botanical District, areas of colluvium and outcrop are covered by open mulga (*Acacia aneura*) woodland or soft spinifex (*Plectrachene melvillei*) and wattle (*Acacia* sp.). Sandplain areas are covered by spinifex (*Triodia* sp.) and scattered mallee (*Eucalyptus* sp.). Areas marginal to salt lakes support halophytes such as samphire (*Artrocneum* sp.), saltbush (*Atriplex* sp.), and bluebush (*Kochia* sp.), with *Casuarina* sp. in alluvial channels. Major watercourses are commonly lined with

tall river gums (*Eucalyptus camaldulensis*) and have an understory of *Eremophila* sp.

Part of the Kertland Botanical District is found on the northeastern boundary of STANLEY, and is characterized by a sparse vegetation cover of *Acacia* spp and *Triodia basedowii* between sandhills.

Geomorphology and soils

The land surface on STANLEY is characterized by low relief, rising from less than 450 m above sea level in the east to over 550 m in the west. Several ranges of hills stand above the general level, the most prominent being the Mudan Hills – Lee Steere Range (Plate 1). In the east of the map sheet, sedimentary rocks form flat-top ranges with steep sides, whereas younger, fluvial and glacial rocks form mesas and breakaways.

All streams and lakes are ephemeral and flow only after heavy rain. The Mudan Hills – Lee Steere Range forms a drainage divide between creeks flowing southwards into Lake Carnegie and those flowing eastwards into Lake Burnside.

Northcote et al. (1968) described duplex soils, with a red clayey subsoil, over areas close to prominent relief, though the majority of soils on STANLEY are described as coarse and of uniform texture. An area of gradational textured soils corresponds to the Windidda Formation.

The major landforms on STANLEY are:

- broad areas of sandplain, sheetwash, and claypans with low relief;
- ridges, hills, and low hills of sedimentary and igneous rocks;
- plateaus, mesas, and buttes of silcrete and ferricrete with moderate relief.

Topographic and remote-sensing datasets

The topographic information used to compile the accompanying maps was obtained from the Department of Land Administration (DOLA) and the Australian Land Information Group (AUSLIG). Landsat Thematic Mapper images were obtained from Remote Sensing Services (via DOLA). Airborne radiometric and magnetic images were generated using data from the Australian Geological Survey Organisation (AGSO; 1500 m line spacing) and World Geoscience Corporation – CRA data. Other remote-sensing datasets include colour 1:25 000-scale and black and white 1:50 000-scale aerial photographs available from DOLA.

Geology

Commander et al. (1982) summarized earlier geological investigations on STANLEY, and compiled the first 1:250 000-scale geological map and comprehensive discussion of the geology. Their lithological descriptions

and stratigraphy form the geological basis of these Explanatory Notes, although some aspects of the stratigraphy are from Bunting (1986), Myers and Hocking (1988), Pirajno et al. (1999), and Bagas et al. (1999). The following discussion of the regional geology is taken from these publications, as well as from Hall and Goode (1975), Williams (1992), Gee and Grey (1993), and Pirajno et al. (1996). Parts of STANLEY are currently being remapped at 1:100 000 scale by GSWA.

The four major tectonic units recognized on STANLEY are Archaean granitoid rocks (exposed in the Malmac Dome), Palaeoproterozoic metamorphic and sedimentary rocks of the Earaaheedy Group (deposited in the Earaaheedy Basin), Mesoproterozoic and Neoproterozoic sedimentary rocks and dolerites previously assigned to the Bangemall Basin (Scorpion and Collier Groups) and Officer Basin (Sunbeam Group and dolerites), and Palaeozoic sedimentary rocks of the Paterson Formation (deposited in the Gunbarrel Basin). The distribution of these rock types is shown on Plate 1 and Figure 3.

Archaean

Scattered outcrops of Archaean granitoid rocks of the Malmac Dome outcrop north of the Lee Steere Range. These rocks consist of metamorphosed medium- to coarse-grained, porphyritic granitic rocks (Commander et al., 1982). Felsic porphyry included with the Troy Creek beds of Commander et al. (1982) is now assigned to the Proterozoic (Pirajno, F., 2000, pers. comm.).

Earaaheedy Group

The 5000 m-thick Earaaheedy Group is dominated by siliciclastic sedimentary rocks, predominantly sandstone and shale, with subordinate limestone and granular iron-formation. Preiss et al. (1975) recorded glauconite Rb/Sr ages of 1590 and 1710 Ma from the Yelma Formation, and Horwitz (1975) dated glauconite from the Wandiwarras Formation (now Chiall Formation) on KINGSTON by the same method at 1685 Ma. These represent minimum ages for deposition. Based on stratigraphic correlations with the Yelma Formation at Mount Leake (north of Meekatharra), the group is probably younger than the c.1800 Ma Capricorn Orogeny. The Earaaheedy Group predates the c.1600 Ma Scorpion Group, and is unconformably overlain by the c.1200 Ma Collier Group.

Yelma Formation

The Yelma Formation is the basal unit of the Earaaheedy Group and lies unconformably on Archaean granitic rocks, and is in turn conformably overlain by the Frere Formation. The Yelma Formation is generally less than 100 m thick on STANLEY, and consists of sandstone, shale, and siltstone, with an upper dolomite unit. Bunting (1986) suggested that these rocks represented deposition during a rapid, extensive marine transgression over a flat mature landscape.

Frere Formation

The Frere Formation is an approximately 1200 m-thick unit of ferruginous, chemically deposited sedimentary rocks, and fine-grained clastic rocks. This unit is conformable with the underlying Yelma Formation. The entire formation is not exposed in a single section. Several iron-formation units, between 10 and 50 m thick, form a series of parallel ridges in the Lee Steere Range area and the Mudan Hills. These units are interbedded with three major bands of purple and cream shale. Each iron-formation member consists of alternating bands of hematitic shale and granular iron-formation, with chert horizons. The formation was deposited in a shallow-marine nearshore environment in mixed low- and high-energy settings, rather than in a deep marine environment (Bunting, 1986). The ratio of iron formation to shale decreases from the west (on NABBERU) to the east (KINGSTON and STANLEY), with increasing water depth (Jones, A., and Pirajno, F., 1999, pers. comm.).

On KINGSTON, the Frere Formation is conformably overlain by the Windidda Formation, a 1200 m-thick succession of carbonate-rich rocks and shale (Hall et al., 1977). On STANLEY, the Windidda Formation cannot be easily distinguished from the lower parts of the Wandiwarras Formation (Commander et al., 1982).

Chiall Formation

Pirajno et al. (1999) included the Wandiwarras Formation and Princess Ranges Quartzite as members of the Chiall Formation on NABBERU (1:100 000), and this convention is followed on STANLEY (Fig. 3, Plate 1). The Wandiwarras Member consists of shale and fine- to coarse-grained quartz sandstone, with locally developed glauconitic units. The shale is maroon to white, and well cleaved, with fine-grained sandstone intercalations. This unit outcrops in the central western part of STANLEY, south of the Mudan Hills and Lee Steere Range. The Wandiwarras Member is interpreted to be a nearshore to marine shelf deposit, which deepened to the west.

The Wandiwarras Member is conformably overlain by the Princess Ranges Member, a white, well-sorted arenite, with siltstone interbeds. Cross-bedding, graded bedding, ripples, and clay intercalations are abundant. The unit is exposed on the southwestern part of STANLEY.

Wongawol Formation

This unit marks a gradual upwards-fining transition from the mature clastic sedimentation of the Princess Ranges Member of the Chiall Formation, to the carbonate sedimentation of the Kulele Limestone. It consists of fine arkosic sandstone and shale, grading upwards into mudstone, sandstone, and shale, with minor carbonate-rich rocks. Sedimentary structures indicate a low-energy, very shallow marine to intertidal depositional setting (Jones, A., and Hocking, R., 1999, pers. comm.).

Kulele Limestone

The Kulele Limestone, a 300 m-thick unit overlying the Wongawol Formation, consists of stromatolitic limestone, cross-bedded calcarenite, and mudstone. The unit is characterized by metre-scale shallowing-upwards cycles. The mechanism that caused the cyclicity is not known. This unit is exposed in the southern part of STANLEY.

Mulgarra Sandstone

The Mulgarra Sandstone is exposed in the southeastern part of STANLEY, as a mainly fine- to medium-grained quartz sandstone with minor carbonate bands and shale, and locally developed glauconite. The basal 20 m consist of medium-grained ferruginous quartz arenite. In the middle of the formation, there are some thin arenite beds containing shale and pink limestone layers. The formation is thought to represent shallow-marine deposition, but it is unclear whether the sequence is transgressive or regressive, as there is evidence to support both models (Bunting, 1986). The total thickness of the formation cannot be determined because of poor exposure; however, it is thought to be about 100 m thick. The Sunbeam Group and the Permian Paterson Formation unconformably overlie the Mulgarra Sandstone.

Deformed and metamorphosed Earahedy Group

Although the absolute age is unknown, the greater degree of deformation (compared to the adjacent Earahedy Group) led Bunting et al. (1986) to suggest that the Troy Creek beds of Commander et al. (1982) predates the oldest part of the Earahedy Group, the Yelma Formation. The Troy Creek beds of Commander et al. (1982) has now been mapped as a deformed and dynamically metamorphosed part of the Earahedy Group by Pirajno et al. (1999). It is found on the western part of STANLEY, and consists of shale, quartz sandstone, and minor chert.

Bangemall Supergroup

Parts of the Mesoproterozoic Bangemall Supergroup, including the Scorpion and Collier Groups, are exposed in the northern half of STANLEY.

Scorpion Group

A 10-km thick, folded sequence of sandstone, shale, conglomerate, and dolomite of the Scorpion Group is in faulted contact with deformed and metamorphosed Earahedy Group rocks along the Salvation Fault. The Scorpion Group probably correlates with the c.1640 Ma Edmund Group to the west. The Sunbeam Group of Bagas et al. (1999) overlies the Scorpion Group to the north. Some areas of the Scorpion Group have now been assigned to the Coonabildie Formation or the Collier Group.

Collier Group

Collier Group rocks, which are thought to be c.1200 Ma in age, are now only recognized south of Glenayle, where they consist of ripple-bedded and cross-bedded quartz sandstone, with minor shale and siltstone. Locally developed quartz veins and stockwork (Hocking, R., 1999, pers. comm.) have also been observed.

Sunbeam Group

Relatively undeformed sedimentary rocks on the northern part of STANLEY were initially assigned to the Bangemall Basin by Commander et al. (1982), and subsequently placed in the younger Savory Basin succession by Williams (1992). The Savory Basin is now recognized as part of the Officer Basin, and Bagas et al. (1999) have assigned older rocks of the former Savory Basin to the Sunbeam Group. R. Hocking (1999, pers. comm.) has suggested that both the former Savory Basin and Bangemall Basin rocks on the northern part of STANLEY should be assigned to the Coonabildie Formation or Brassey Range Formation, and included in the Sunbeam Group. This approach is adopted here and, although subdivisions of the Sunbeam Group (Coonabildie Formation and Brassey Range Formation) are not shown on Figure 3 or Plate 1, their constituent lithologies are discussed briefly.

The Coonabildie Formation comprises interbedded siltstone and quartz arenite overlying a basal laminated and bedded chert. It is a coarsening-upwards prodelta to delta-front sequence (Hocking, R., 1999, pers. comm.). Rocks designated by Commander et al. (1982) as Marlooyanoo Formation are now included in the Coonabildie Formation. The Brassey Range Formation conformably overlies the Coonabildie Formation on STANLEY. It is exposed as low, rocky hills jutting out of wind-blown sand on the northern third of the sheet. The majority of the unit is fine- and medium-grained, siliceous quartz arenite. Less common fine-grained sandstone and siltstone are also present (Hocking, R., 1999, pers. comm.). The unit is a delta-front to fluvial deposit.

Mafic intrusive rocks

Dolerite and gabbro sills and dykes are widespread on STANLEY, where they outcrop as concordant or slightly discordant intrusions in the Sunbeam Group. These intrusive rocks are fresh to weakly altered, and largely composed of plagioclase (locally sericitized), clinopyroxene, and titanomagnetite. Accessory amounts of apatite and pyrite are found in dolerites at Digby Hill and Faulkne Bore near Glenayle Station. Several dolerites have well-developed granophyric layers and veins at the top.

Paterson Formation

The Paterson Formation is an Early Permian, flat-lying glacial and fluvioglacial succession, which can be divided into three lithofacies — tillite (non-bedded, poorly sorted

boulder conglomerate to pebbly, clayey siltstone), cross-bedded conglomeritic sandstone of fluvio-glacial origin, and lacustrine siltstone. These rocks are deeply weathered, and in some places are completely capped by silcrete. Locally developed cross-bedding indicates a north to north-northeast transport direction. A polymictic boulder lag (originally glacial erratics and moraine) is widespread over the southern part of STANLEY, and scattered boulders resting on Earahedy Group rocks are found in some areas.

Recorded mineralization

STANLEY, which is in the Warburton Mineral Field, has been explored for various commodities, but there is no recorded mining activity. Current exploration in the area is focused on base metals, gold, and diamonds. Subeconomic bands of surface encrustations of manganese are located in the Windidda and Wongawol Formations (Commander et al, 1982), south of Mount Ooloongathoo and near Desolation Hills. Livingstone Resources (1998) have recorded several micro-diamonds from the Jewill Kimberlite in the eastern part of STANLEY, but no follow-up work has been carried out.

Geochemical surveys in open-file company reports

In order to comply with the Mining Act (1978), mineral exploration companies must lodge reports dealing with exploration activity. These are listed in the GSWA Western Australian mineral exploration (WAMEX) database, as either open-file or confidential reports. Details of open-file company reports that contain surface or near-surface (i.e. less than 4 m depth) geochemical data on STANLEY are shown in Appendix 2. Reports common to a particular exploration project have been grouped together and assigned an identification number (ID no. of Appendix 2), which is shown, along with project boundaries, on Plate 2. Most projects cover a single area, although some projects cover two or more areas. Projects with fewer than 30 samples have been omitted. Areas with significant surface geochemistry documented in open-file reports up to 1997 include northwest and north of the Lee Steere Range, the Timberley Range, the Minyan Hills, and north of Breakaway Bore.

Twelve projects, covering the period from 1979 to 1997, are tabulated in Appendix 2 in order of increasing M number (the project number assigned for the WAMEX database), and shown on Plate 2. 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 requirement for mineral-claim holders to report all of their exploration results prior to 1978.

The exploration company projects listed in Appendix 2 are grouped according to the targeted mineralization as follows:

- base metals 84%
- gold 11%
- manganese 5%

Regolith sampling

Regolith sampling on STANLEY was carried out over a two-week period during May–June 1999 by six, two-person sampling teams (each comprising a field assistant and a geologist) using two Bell Jet-Ranger helicopters. The approach to regolith sampling, and the form used to record characteristics of the regolith and surrounding geology are detailed in Appendix 3. A measurement of the earth's gravitational field was also made at each sample site, based on methodology defined by Howard and Shevchenko (2000). The distribution of the sample sites is shown on Plate 1.

Regolith-materials mapping

A regolith-materials map (Plate 3) has been produced for STANLEY using Landsat TM imagery, Landsat synthetic stereo-pairs, aerial photography, and field observations recorded at sample sites. Geological information was obtained from the 1:250 000 STANLEY geological map of Commander et al. (1982), and the EARAHEDY 1:100 000 geological map of Adamides et al. (in prep.). A simplified version of the regolith-materials map (Fig. 4) shows the distribution of residual, exposed, and depositional regolith. The regolith codes for each sample on STANLEY are listed in the accompanying digital datafile (STANLEY.CSV) and these codes are described on Plate 3. Table 1 details regolith units by area and the number of samples collected from each regolith type.

Major features of the regolith on STANLEY are:

- Exposed rock, residual sand, ferruginous duricrust, and spatially associated iron-rich sand and colluvium over Sunbeam Group sedimentary rocks and dolerites;
- Exposed rock and associated colluvium over the Earahedy Group sedimentary rocks;
- Residual regolith units, derived from heterogeneous Permian rocks, characterized by distinctive landform features such as breakaways and residual sandplain;
- Lacustrine regolith that is part of an extensive paleodrainage system in the south of STANLEY; and
- Quartz-rich eolian sand with extensive dune development in the northeast.

Residual-regime regolith (R)

Residual regolith on STANLEY, which accounts for 3% of all regolith in terms of area (19 samples), consists of locally derived material, including ferruginous and siliceous duricrust (and reworked equivalents), and residual sand. Cappings of iron-rich duricrust (*R_f*) are found throughout the northern half of the map sheet over dolerites and sedimentary rocks of the Sunbeam Group.

Table 1. Regolith-materials unit area and number of samples

Regolith code	Area (km ²)	% of total area	No. of samples	% of all samples
Residual (R)				
<i>Rf</i>	339	2.03	14	1.4
<i>Rls</i>	138	0.82	4	0.4
<i>Rq</i>	36	0.21	1	0.1
<i>Rz</i>	3	0.02	0	0.0
Total	516	3.08	19	1.9
Exposed (X)				
<i>Xfc</i>	109	0.65	1	0.1
<i>Xgp</i>	19	0.11	1	0.1
<i>Xgs</i>	1 149	6.88	55	5.4
<i>Xkc</i>	158	0.95	8	0.8
<i>Xls</i>	39	0.23	0	0.0
<i>Xmh</i>	332	1.99	13	1.3
<i>Xqs</i>	1 031	6.17	36	3.6
<i>Xzs</i>	9	0.05	0	0.0
Total	2 845	17.03	114	11.3
Colluvial (C)				
<i>Cd</i>	6	0.03	0	0.0
<i>Cf</i>	54	0.32	1	0.1
<i>Cfc</i>	9	0.05	1	0.1
<i>Cgs</i>	68	0.41	3	0.3
<i>Ckc</i>	25	0.15	0	0.0
<i>Cl</i>	343	2.05	22	2.2
<i>Cls</i>	123	0.74	9	0.8
<i>Cmh</i>	131	0.79	13	1.3
<i>Cqs</i>	234	1.40	20	2.0
<i>Czs</i>	1	0.01	0	0.0
Total	993	5.95	69	6.7
Sheetwash (W)				
<i>W</i>	3 762	22.53	250	24.7
<i>Wf</i>	167	1.00	10	1.0
Total	3 928	23.53	260	25.7
Alluvial (A), Floodplain (F)				
<i>A</i>	597	3.58	122	12.1
<i>F</i>	110	0.66	11	1.1
<i>Fk</i>	681	4.08	38	3.8
Total	1 388	8.32	171	16.9
Lacustrine (L)				
<i>L_i</i>	331	1.98	9	0.9
<i>L_m</i>	1 494	8.95	99	9.8
Total	1 825	10.93	108	10.7
Sandplain (S), Eolian (E)				
<i>S</i>	738	4.42	36	3.6
<i>Sf</i>	2 241	13.42	128	12.6
<i>Sl</i>	811	4.86	31	3.1
<i>E</i>	1 412	8.46	76	7.5
Total	5 201	31.16	271	26.8
Total	16 696	100	1 012	100

This regolith type commonly forms small cigar-shaped hills, and erosion of this duricrust (*Rf*) material produces iron-rich colluvium (*Cf*). Some iron-rich colluvium (*Cf*) is derived in part from mafic hypabyssal rocks (*Xmh*), along with input of iron-rich material from ferruginous duricrust. Weathered rock is exposed in breakaways on the face of these hills. Iron-rich sand (*Sf*) commonly overlies, and is shed from, gentle backslopes blanketed by ferruginous duricrust.

Residual-regime regolith formed by weathering in-situ of heterogeneous glaciogene and glaciolacustrine rocks of the Permian Paterson Formation (*Rls*) is found in the southwest and east of STANLEY. This unit is strongly silicified, forming flat-topped mesas bounded by steep breakaways. Locally derived colluvium (*Cls*) is found close to these breakaways. Thin layers of quartz-rich residual sand that are too small to be shown at the map scale, and are thus included with *Rls*, are often developed over these Permian rocks. Less extensive quartz-rich residual sand (*Rq*) and siliceous capping (*Rz*) have been identified over quartz-rich sedimentary rocks of the Sunbeam Group.

Exposed-regime regolith (X) and locally derived colluvium

Areas of exposed rock, subcrop, or bouldery lag (X) make up approximately 17% of regolith on STANLEY, and account for 114 (11%) of the regolith samples. Locally derived colluvium can be divided according to parent lithology, as is usually close to exposed-regime regolith. This colluvial material consists of sandy to cobbly material on hillsides, which grades rapidly downslope into heterogeneous or undivided colluvium, sheetwash, alluvium, or sandplain.

Quartzofeldspathic siliciclastic rocks (*Xgs*) outcrop throughout STANLEY. A large area of this unit makes up part of the Wongawol Formation in the south of the map sheet near Lake Carnegie, where lacustrine-regime regolith (*L_i* and *L_m*) is also well developed. In this area, highly ferruginized quartzofeldspathic rocks are often mantled by a thin veneer of lake sediment, and on aerial photographs bedding is often visible on lake floors. Derived colluvium (*Cgs*) is restricted to areas of higher relief. Other areas of exposed quartzofeldspathic rocks (*Xgs*) include arkosic lithologies of the Sunbeam Group in the northeastern part of the map sheet. Here, colluvium (*Cgs*) is more widespread than near Lake Carnegie, due to more marked relief.

Quartz-rich siliciclastic sedimentary rocks (*Xqs*) are common across the map sheet and include material derived from the Earraheedy and Sunbeam Group sandstones. This regolith unit, particularly when it is located over the resistant Princess Ranges Member of the Chiall Formation, commonly forms rugged hills and ridges with a rubbly apron of colluvium (*Cqs*) that is incised by drainage. Outcrop of a small shale and chert unit (*Xzs*) of the Sunbeam Group has been mapped northeast of the Glenayle Fault. Colluvium (*Czs*) derived from this unit is poorly developed, and is only located close to the parent rock.

The Frere Formation is exposed in the central western part of STANLEY, where it consists mainly of interbedded iron-formation (*Xfc*) and shale (*Xgs*). Less common chert and carbonate-rich rocks and associated colluvium (designated *Xkc* and *Ckc* respectively) are also present. A granular and banded iron-formation (*Xfc*) forms resistant strike ridges in the Mudan Hills and Lee Steere Range. Shale and siltstone horizons (*Xgs*) and quartz-rich

sandstones (*Xqs*) are less resistant and are commonly exposed at topographically lower levels between ridges of iron formation. Colluvium in this area is of mixed parentage (*Cl*), and contains sandstone, shale, siltstone, and iron-rich clasts. This heterogeneous colluvium is in close proximity to exposed-regime regolith, and rapidly grades into sheetwash (*W*) and sandplain (*S*) downslope.

Carbonate-rich rocks (*Xkc*) are associated with the Kulele Limestone and carbonate breccia of the Frere Formation. Deformed and metamorphosed Earacheedy Group rocks (*Xls*) outcrop in the western part of the map sheet. There are low-angle slopes covered in colluvium (*Cl*s) adjacent to this regolith type. In the north of STANLEY, sedimentary rocks of the Sunbeam Group (*Xqs* and *Xgs*) have been intruded by dolerite sills and dykes (*Xmh*). Colluvium derived from dolerites (*Cmh*) is frequently mixed with iron-rich material shed from ferruginous duricrust or colluvial material from sedimentary rocks.

Small areas of quartzofeldspathic plutonic rock (*Xgp*), which correlate with the Malmac Dome, outcrop in the centre of STANLEY. Derived colluvium has been mixed with material from nearby rock exposures, and has been mapped as heterogeneous colluvium (*Cl*).

Undivided colluvium (*Cd*) and distal sheetwash (*W*)

Colluvium is mapped as an undivided unit (*Cd*) where it is not possible to designate the dominant composition or the regolith type cannot be shown at the map scale.

Sheetwash accounts for almost 24% of the regolith on STANLEY and 260 or 26% of the samples. It is commonly composed of sand, silt, and clay with variable amounts of small clasts, locally derived ferruginous material, and transported pisoliths. This regolith type is best developed over the Earacheedy Group rocks, where it forms low-angle, extensive fans in broad valleys. It is typically poorly vegetated, with belts of vegetation confined to weakly defined alluvial channels. Sheetwash usually grades downslope into floodplain, alluvium, and lacustrine material, although in areas of low relief, sheetwash material can be found adjacent to exposed-regime regolith.

Iron-rich sheetwash (*Wf*) contains ferruginous clasts in low-gradient areas, usually on the margins of lakes. Weakly cemented iron-rich units exhibiting more relief often form next to ferruginous sheetwash deposits, and these have been mapped as ferruginous colluvium (*Cf*). These may result from precipitation of iron oxides that has been caused by changes in pH and salinity at the edges of salt lake systems. Magnetic clasts have been observed in both *Wf* and *Cf* units.

Alluvial (*A*), floodplain (*F*), and lacustrine (*L*) regolith

Depositional alluvial (*A*), floodplain (*F*), and lacustrine (*L*) regolith make up 8% of the regolith by area, and account for 171 samples.

Alluvium in stream channels (*A*) is associated with major drainage systems and their tributaries, and alluvial channels developed within lacustrine environments. Alluvial material consists of variably sorted, unconsolidated, ferruginous and altered lithic fragments, sand, and clay.

Floodplain deposits (*F*) consisting of clay, sand, and calcrete clasts sometimes flank alluvial channels. Large areas of calcrete associated with valley floors are mapped separately as *Fk*. These areas of valley calcrete are often located above active drainage channels, and may be overlain by thin alluvial or eolian deposits.

Regolith in lake systems (*L_i* and *L_m*) occupies low areas in the south and east on Stanley, forming part of an extensive paleodrainage system (van der Graff et al., 1977). The lake environment contains a mixture of claypans and playas, with fringing dunes and small sandplain areas. Calcrete or gypcrete, and gypsiferous or calcareous sand in dunes are also found in this environment (Pirajno, F., 2000, pers. comm.). Alluvial-regime regolith has also developed within the lake system. Lake Burnside (*L_i*), on the eastern margin of Stanley, has some surrounding dune and playa terrain (*L_m*), but is largely bounded by eolian sand (*E*). Deposits in present-day lakes (*L_i*) consist of silt and clay, with a halite or gypsiferous crust. Lakes are generally not vegetated, although salt-tolerant plant species (phreatophytes and halophytes) are found on the lake margins.

Sandplain (*S*) and eolian (*E*) regolith

Sandplain (*S*, *Sf*, and *Sl*) and eolian (*E*) regolith are extensively developed on STANLEY, accounting for 22% (approximately 19% of samples) and 8% of total regolith (approximately 8% of samples) respectively (Table 1).

Sandplain is characterized by a mixture of residual, eolian, and colluvial components, and has been divided into three types based on composition — iron-rich sandplain (*Sf*), heterogeneous sandplain (*Sl*), and quartz-dominated sandplain (*S*).

Iron-rich sandplain (*Sf*) is well developed in the north of STANLEY over the Sunbeam Group rocks and dolerite, where it commonly fills broad drainage areas between subdued outcrops. It contains quartz sand derived from sandstones and ferruginous material shedding from duricrust (*Rf*). Field observations indicate that small iron-rich clasts (many of which are magnetic) are abundant, and these clasts are commonly concentrated on the surface by deflation. Some iron-rich sandplain exists within areas of extensive eolian sand (*E*) of the Little Sandy Desert. This is derived from small pockets of ferruginous duricrust (*Rf*) developed over quartz-rich sedimentary rocks (*Xqs*). In the central northern part of STANLEY, iron-rich sandplain (*Sf*) becomes mixed with colluvium and sheetwash downslope, and this heterogeneous type of sandplain has been termed *Sl*. Iron-rich sandplain is also developed in the northeast of STANLEY, and may indicate development of subsurface dolerite in this area, although dolerite is not exposed.

Quartz-dominated sandplain (*S*) is found throughout STANLEY. It is dominated by residual material that has been locally reworked by wind action. In the east and southwest of the map sheet, it is developed both adjacent to and locally overlying residual regolith (*RLs*) over the Paterson Formation. This sandplain type is also located in the vicinity of granitoid rocks of the Malmac Dome, as well as near quartz-rich sedimentary rocks (*Xqs*).

Eolian sand (*E*) is well developed in the northeast of STANLEY, where it forms part of the Little Sandy Desert. This regolith type is mineralogically and texturally mature, well sorted, and is dominated by quartz. East-west oriented dune systems and net dunes are common — major dunes are shown on Plate 3. Eolian sand (*E*) and outcrops of quartz-rich siliciclastic rocks (*Xqs*) are located in the central part of STANLEY. In this area, net dunes have developed due to swirling winds between outcrops.

Chemical analysis

Quality control

One thousand and twelve regolith samples were analysed in five separate batches by Analabs, Perth. The samples comprise 368 sheetwash samples, 212 stream-sediment samples, 53 lake-sediment samples, 315 sandplain samples, and 64 soil samples. In addition, multiple analyses of three in-house GSWA standards were carried out in each batch, along with analyses of duplicates and standards. The laboratory procedures and quality-control approach are summarized in Appendix 3. In the following discussion, the quality of analysis is discussed according to technique. Appendix 4 is a digital file containing data for analyses of various standards, blanks, and replicates. A guide to this file is presented as a digital file (GUIDE.TXT) on this disk. In the following, quality control is discussed according to analytical method.

The 24 blank values were all acceptably low for Se and Te (Analabs code H109). Eighty-two samples were analysed in duplicate, and four in triplicate (i.e. unknown, replicate, and split). Values for both Se and Te were less than detection level for all samples. The standard GXR1 (recommended values of Se = 16.1 parts per million (ppm) and Te = 13.6 ppm) was analysed in all five batches. Precision, as measured by the percent relative standard deviation (RSD%), was acceptable for all analyses, apart from an RSD% of 38 for Te in batch 4. Analyses in this batch also showed poor precision in terms of the half relative difference (HRD; Shaw et al., 1998), which was 15 for Te in batch 4. This was caused by one determination of less than detection level for Te.

Two blank values of Sr = 34 ppm and Zr = 97 ppm in batch 4 were the only unacceptable values for method I104. These two values followed analysis of the standards SARM3 (Sr = 4610 ppm and Zr = 11 400 ppm). A check on the flushing out of the ICP ensured that there was no similar effect on other samples, and the two samples following this standard were reanalysed. For the analysis of standards, the recommended value of 10 ppm for Cr in SARM3 is probably too low, as eight repeated analyses

of this standard produced a mean value of 23 ppm. Poor agreement in the analysis of Cr at high levels was shown by SARM5, which produced an average value of 16 975 ppm compared to a cited value of 23 900 ppm (i.e. HRD = 17). Repeated analysis of SARM4 produced relatively poor precision for Zr, with an RSD% of 29, and Cr in SO₃ produced an RSD% of 21 (average value of 28 ppm). Despite good precision, the average value of Sr in SO₃ (229 ppm) was lower than the cited value of 340 ppm.

Eighty-two samples were analysed in replicate, and three in triplicate, for the I104 method. Generally, there was good agreement between replicates (according to HRD), with the biggest discrepancies being for Cr (HRD >10 for 12 samples), and Sr (HRD >10 for 5 samples).

Blank analyses for the precious metals Au, Pd, and Pt (analytical method F627) were acceptably low (25 samples). Eight analyses of the standard PM8 (Au = 38.5 parts per billion (ppb), Pd = 28.7 ppb, and Pt = 15.7 ppb) were analysed in each of the five batches, yielding acceptable values in terms of both precision and accuracy. Most precious metal values for unknowns are close to, or less than, detection level (Au = 1 ppb, Pt and Pd = 0.5 ppb). One duplicate Au determination gave results of less than 1 and 5 ppb, and a Pd duplicate produced values of 0.5 and 3.5 ppb. Seventy-one duplicates and four triplicates were analysed.

Sulfur analysis by Leco (method V821) relies on internal calibration of the machine, and the only quality-control data supplied were for duplicates (84 samples) and triplicates (3 samples). Seventeen of the duplicate analyses had HRD greater than 10 for values greater than ten times the detection level. All other data were acceptable.

Blank values were not provided for XRF data (method X408). For analysis of standards and duplicates, analytes at least ten times the detection level, precision, and accuracy were acceptable.

For the ICP-MS method M104, all blank values were acceptably low. For some analytes (e.g. Ag, Be, Bi, Cd, In, Sn, Ta, U, and W) values are uniformly low, which means that it is not possible to rigorously examine precision and accuracy. Several HRD values were greater than 10 for As, Ce, Cu, Ga, Li, Mo, Ni, Pb, and Rb, although many of these analyte values were close to the ten-times detection-level threshold. A threshold of ten times the detection level is used to avoid problems of analytical imprecision at low levels. The highest number of HRD values greater than 10 was recorded for Nb (18 samples). Other analyte determinations were acceptable. For the standard data, there was relatively poor precision, as shown by the RSD% for As in SARM1, SARM3, and SO₃, and Nb in SARM4. Agreement between cited values and average analyses (as measured by HRD) was relatively poor for Ce and La in SARM3, Cu in SO₂, and Y in SARM1, SARM4, SARM5, SO₂, SO₃, and SO₄. Ten consecutively numbered samples, GSWA 167482–167491, produced relatively high Nb values, ranging between 15.2 and 70.8 ppm. They were analysed immediately after the standard SARM3, which contains 991 ppm Nb. These ten

samples lie on a north-south line in the northeastern part of STANLEY, and these Nb values cannot be reconciled with either the geology, sample media, or regolith. Reanalysis of these ten samples produced notably lower Nb results (e.g. GSWA 167482, 39.8 ppm versus 3.7 ppm; GSWA 167485, 58.9 ppm versus 12.4 ppm; GSWA167489, 48.5 ppm versus 16.3 ppm), and it is concluded that the initial set of higher results are an analytical 'tail' resulting from analysis of a high Nb standard. The reanalysed values have been inserted in the database STANCHEM.CSV.

Comparison of laboratories

Splits of archive material from twelve samples with high values for one or more analytes were sent to Genalysis Laboratory Services for umpire analysis. Analytical techniques for this laboratory are summarized in Appendix 3. For the major element oxides, agreement between the two laboratories (as measured by HRD) is good, apart from SiO₂ in low silica samples, where Analabs values are low relative to those from Genalysis. Between-laboratory variations are seen in several trace elements. Arsenic values are higher in 8 of the 12 cases for Analabs, and lower in 1. HRD values greater than 10 were produced for Ba (Analabs lower in 3 cases and higher in 1), Ce (Analabs lower in 8 cases), Cr (Analabs lower in 4 cases and higher in 1), Cu (Analabs values lower in all 12 cases), La (Analabs lower in 6 cases), Nb (Analabs higher in 7 cases and lower in 3), Ni (Analabs higher in 2 cases and lower in 4), Rb (Analabs lower in 8 cases), Sr (Analabs lower in 4 cases and higher in 1), V (Analabs lower in 4 cases), W (Analabs higher in all 12 cases), Y (Analabs lower in 7 cases), Zn (Analabs lower in 5 cases and higher in 1), and Zr (Analabs lower in 10 cases).

Geological Survey of Western Australia standards

Three GSWA standards, GRMWA42 (amphibolite), GRMWA45 (gossan), and GRMWA47 (laterite) were analysed in each of the five batches of unknowns. Consensus values, used for determining the accuracy of Analabs' determinations, are from Morris (2000). Precision and accuracy were acceptable for all analytes, apart from poorer accuracy for Cr in two standards, and poorer accuracy and precision for Nb and W in one standard.

Discussion

In general, precision and accuracy are acceptable for most analytes, as measured by duplicate determinations and repeated measurement of standards, and application of simple approaches such as RSD% and HRD. Determination of acceptable levels of accuracy relies on comparison of mean values for multiple determinations with consensus analyte concentrations, which are often poorly constrained or unavailable (Kane, 1992; Morris, 2000). Relatively poorer precision and accuracy are shown by analytes such as Cr and Zr, which are usually found

Table 2. Samples with three or more anomalous analytes

GSWA no.	Sample medium	Geology	Anomalous analyte							
168230	Lake sediment	Pa	CaO	S	Sr					
167633	Sheetwash	Pd	Be	Ce	La	Rb	Y	Zn		
168307	Sheetwash	Pd	CaO	P ₂ O ₅	LOI					
167593	Stream sediment	Pd	TiO ₂	Co	Ni	Zn				
168332	Stream sediment	Pd	TiO ₂	Co	V					
168062	Sheetwash	Pecp	MnO	Cu	Li	Pb				
167646	Sheetwash	Pef	Fe ₂ O ₃	As	Bi	Pd				
168055	Sheetwash	PEo	Al ₂ O ₃	K ₂ O	Rb					
167939	Stream sediment	PEo	CaO	LOI	Y					
168026	Soil	PEo	K ₂ O	Li	Rb					
168025	Sheetwash	PEo	MnO	Be	Ce	Pb				
167949	Stream sediment	PEo	MnO	Ce	Co	La	Pb	Y		
167442	Soil	Peo	Sb	Ta	Nb					
167547	Sheetwash	Pey	Bi	Sb	Th					
167732	Sandplain	PO	Sc	Th	Zr					
167709	Sandplain	PSg	Ag	Pd	Sb					
167787	Sandplain	PSg	Ag	Sn	Zr					
167613	Sheetwash	PSg	Al ₂ O ₃	Mo	Zr					
167768	Stream sediment	PSg	Al ₂ O ₃	Sn	Th	Zr				
168210	Sheetwash	PSg	CaO	MgO	LOI	Sr				
168014	Sandplain	PSg	Cu	Mo	Sn					
167704	Sandplain	PSg	Fe ₂ O ₃	Ag	Ga	In	Mo	Pt	Zr	
167307	Sandplain	PSg	Fe ₂ O ₃	Bi	Ga	In	Pd	Sc	Ta	Th
167507	Sandplain	PSg	Fe ₂ O ₃	Bi	Sb	Th				
167614	Sandplain	PSg	Fe ₂ O ₃	Ga	In	Sc	V			
167588	Sandplain	PSg	Ga	Sn	V	Zr				
168417	Stream sediment	PSg	MgO	LOI	Sr	U				
168319	Sheetwash	PSg	P ₂ O ₅	Ce	La					
167714	Sandplain	PSg	TiO ₂	Ga	Pd	Pt				
167594	Stream sediment	PSg	TiO ₂	La	Zn					

in resistate minerals such as chromite and zircon. These are highly resistant to acid attack, and quantitative conversion into solution is rarely achieved (Morris et al., 1998).

The cause for greatest concern in the quality-control program for STANLEY is the interlaboratory comparison carried out on 12 samples. These data have highlighted consistent trends, in that some analytes return consistently lower concentrations according to laboratory. As both laboratories are employing similar analytical techniques for several analytes, these differences cannot be explained by different analytical approaches. The problem is well illustrated by the analysis of W. Of the twelve samples analysed, the Analabs/Genalysis determinations of 27/3 ppm, 13/3.5 ppm, 20/0.8 ppm, 7/2.2 ppm, 6/2.1 ppm, 15/1.7 ppm, 16/2.6 ppm, 7/1 ppm, 3/0.6 ppm, and 10/1.7 ppm highlight this problem. Although some concentrations are close to detection level, clear trends are apparent. In order to be consistent with other analytical data, the Analabs W values are used in STANCHEM.CSV.

Discussion of element-distribution maps

The concentrations of various components on STANLEY are shown as a series of spot-concentration maps (Figs 5 to 52), where the diameter of the circle corresponds to the concentration, unless the concentration is greater than 2.5 standard deviations above the mean, in which case 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 (ppm) and

ultra-trace elements (ppb) in alphabetical order, but they are discussed in terms of categories as outlined below. In the following discussion, the chemistry of the regolith is occasionally discussed according to sample medium. It should be emphasized that sample media types may not reflect the nature of the surrounding regolith as shown on the accompanying regolith map (Plate 3). For example, a sheetwash sample may be located in an area mapped as sandplain. In order to maintain legibility, there are few geographic locations shown on Figures 5 to 52, and the following discussion should be read in conjunction with Plate 1 and Appendix 1. Table 2 lists samples with three or more anomalous concentrations of analytes.

Grouping of chemical components

Morris et al. (1997, 1998) grouped chemical components into seven categories based on the scheme of Evans (1993), and this approach has been adopted for STANLEY. The categories are:

- major element oxides and loss on ignition — SiO_2 , TiO_2 , Al_2O_3 , Fe_2O_3 , MnO , MgO , CaO , Na_2O , K_2O , P_2O_5 , LOI
- precious metals — Au, Ag, Pd, Pt
- anions — S
- base metals — Cu, Pb, Zn, Sn
- ferro-alloy metals — Ni, Cr, Mo, W, V, Co
- fissionable metals — Th, U
- minor metals and non-metals — As, Ba, Be, Bi, Cd, Ce, Ga, In, La, Li, Nb, Rb, Sb, Sc, Se, Sr, Ta, Te, Y, Zr.

Major element oxides and loss on ignition

A group of five samples with anomalous SiO_2 values are found clustered in the northeastern part of STANLEY. Four of these are sandplain samples (Fig. 5). The sixth anomalous sample is another sandplain sample (GSWA 167839) from 20 km southwest of Digby Hill in the northwestern part of STANLEY. Silica is reasonably uniformly distributed over the map sheet, but areas of slightly higher SiO_2 are found in the northeast of the map sheet, and west of Minyan Hills.

All anomalous TiO_2 values in regolith (i.e. greater than 3.44%) are found on, or close to, dolerites, particularly those in the vicinity of Parker Range, and approximately 30 km to the northeast near Carooil Bluff (Fig. 6). There is a marked contrast in the concentration of TiO_2 in regolith over the Sunbeam Group and dolerites, compared with regolith over the Earraheedy Group and Archaean granitoid rocks. Values over the Scorpion Group are similar to those over the Sunbeam Group. Higher TiO_2 values over dolerites and the Sunbeam Group are found in all types of sample media. TiO_2 values are lower to the east and north of the Sunbeam Group. Titanium values are low in regolith over the Paterson Formation.

Aluminium in regolith shows a reasonably uniform distribution over STANLEY, apart from low values in

predominantly sandplain samples from the northeastern part of the map sheet (Fig. 7). Most high Al_2O_3 values are found overlying, or close to, dolerite, including the highest value of 22.28% in GSWA 167956, which came from 9 km southwest of Stony Point Bore in the eastern part of the map sheet. Three anomalous values, ranging from 18.85 to 21.29%, are from over the Sunbeam Group in the northwest of STANLEY, whereas two other anomalous values are from regolith samples over the deformed and metamorphosed Earraheedy Group rocks, 12 km north of Mount Evelyn (GSWA 167644), and over the Wongawol Formation in the vicinity of Desolation Hills (GSWA 168055).

Of the six regolith samples with anomalous Fe_2O_3 on STANLEY, four consist of sandplain samples close to dolerites in the northwestern part of the map sheet (Fig. 8), and range from 57.88% Fe_2O_3 in GSWA 167614 to the maximum value of 62.00% Fe_2O_3 in GSWA 167307. The other two anomalous samples are found near the contact of the Frere and Yelma Formations near Mount Ooloonathoo (GSWA 167646, 57.57 % Fe_2O_3) and over the Princes Ranges Member of the Chiall Formation, 4 km south of Mount Moore Well (GSWA 168134, 60.73 % Fe_2O_3). Lower Fe_2O_3 values in regolith are found in sandplain and lake-sediment samples in the northeast of STANLEY, and in regolith over the Chiall Formation, Wongawol Formation, Kulele Limestone, and Mulgarra Sandstone. However, a group of relatively high Fe_2O_3 values in regolith is found over the Wandiwarr Member of the Chiall Formation, east and west of Earraheedy Station.

Apart from a few scattered samples mainly in regolith over dolerites, the majority of high and anomalous MnO values are found in regolith over the Wongawol Formation, and immediately adjacent to the contact of the Wongawol Formation and the Princess Ranges Member of the Chiall Formation, near Jublejarrah Pool (Fig. 9). This area includes six anomalous MnO values reaching a maximum of 7.21 % in GSWA 168062. Maximum values are found in stream-sediment and sheetwash samples, although some high values are also found in lake-sediment samples. Manganese values are notably lower in sandplain and lake-sediment samples in the northeastern part of STANLEY, and in regolith over both Archaean granitoids and the Scorpion Group.

Apart from lake-sediment sample GSWA 167496 (4.7% MgO, 4 km northeast of Stony Point Bore), the other five samples with anomalous MgO contents are found over the Sunbeam Group (Fig. 10). Two of these (GSWA 167486 and 168417) are located along Kahrban Creek, along with other high-MgO samples. Higher than usual MgO values in regolith are found in the southeastern part of the Wongawol Formation. Most other regolith MgO contents are low and at uniform levels.

The few anomalously high CaO values in regolith are found in lake-sediment samples near Kahrban Creek in the eastern part of STANLEY, including the maximum value of 34.10% in GSWA 168230 (Fig. 11). Several high CaO values are also found in samples along the course of Kahrban Creek. Two sheetwash samples, on or near

dolerite of the Parker Range, also have anomalously high CaO contents (GSWA 168307, 16.56%; GSWA 168210, 22.76%). The remaining anomalous value is found in GSWA 167939, a stream-sediment sample over the Wongawol Formation, about 8 km south of Thurraguddy Bore. Its is associated with several other high CaO values. The remaining CaO values over the map sheet are in the region of 1 to 3%.

A line of anomalous, relatively high Na₂O values in regolith — including the highest value of 3.85% in GSWA 167499 — are found in lake-sediment samples and one stream-sediment sample from an area extending from the northeastern part of STANLEY south to Stony Point Bore (Fig. 12). Apart from a few scattered higher values close to dolerites, the only other relatively high Na₂O values are found roughly south of the Carnegie–Wongawol Road, over the Wongawol Formation. In this area, the high values are found in several sample media types.

The largest group of high K₂O values in regolith are found over the Wongawol Formation east of Desolation Hills, including the highest value of 3.72% in stream-sediment sample GSWA 168431 from near Nunerri Pool (Fig. 13). Relatively high values are located in parts of the Sunbeam Group and dolerites, including an anomalous value of 3.48% in stream-sediment sample GSWA 168456 from 5 km west of Mount Bates, and another stream-sediment sample over dolerite of the Parker Range (GSWA 168203, 3.50% K₂O). As with Na₂O, K₂O does not pick out Archaean granitoid rocks, although a belt of relatively high K₂O values is found in stream-sediment samples immediately south of the Lee Steere Range.

Over the Sunbeam Group and dolerites are a series of regolith samples that show relatively high P₂O₅ concentrations, in marked contrast to particularly low P₂O₅ values in the northeast of the map sheet and between the Minyan Hills and Parker Range (Fig. 14). High P₂O₅ values are found in samples from the western part of the Wandiwarr Member of the Chiall Formation near Earraheedy Station. This group includes one anomalous value of 0.16% P₂O₅ (stream-sediment sample GSWA 167437). The maximum P₂O₅ value found in regolith on STANLEY is in sheetwash sample GSWA 167822 (0.18%) over dolerite, approximately 15 km southeast of Glenayle Station.

Anomalous loss on ignition values in regolith are indicated over parts of the Sunbeam Group and dolerite, except for stream-sediment sample GSWA 167939 (21.19%) from over the Wongawol Formation, 8 km south of Thurraguddy Bore (Fig. 15). One anomalous sample (GSWA 168417, 15.82%) is a stream-sediment sample from Kahrban Creek. Over most of STANLEY, LOI values in regolith are variable, but most high values are found in regolith from drainages.

Precious metals

Ninety-two percent (928) of samples on STANLEY have less than detection level (1 ppb) gold concentrations, and only three samples (GSWA 167339, 5 ppb; GSWA 167422, 7 ppb; GSWA 167801, 23 ppb) have anomalous Au levels (Fig. 18). These and other samples with detectable Au

show no preference for any one particular lithological unit or sample medium.

Despite the low maximum concentration of 0.8 ppm, the distribution of Ag in regolith on STANLEY (Fig. 16) clearly emphasizes the influence of dolerite on regolith chemistry. Most of the anomalous samples (i.e. those with greater than 0.6 ppm Ag) are found close to areas of dolerite, and in the northwestern part of STANLEY, regolith samples with anomalous Ag concentrations are in close proximity to other samples with relatively high concentrations of Ag in regolith. In contrast, apart from several scattered samples near Earraheedy Station and over the Wongawol Formation, Ag values are close to, or less than, detection level (0.1 ppm).

Eight hundred and thirty-four or 82% of regolith samples on STANLEY have less than detection level (0.5 ppb) Pd (Fig. 35). The majority of values above detection level, including three anomalous samples of 3.0 ppb, are found in samples located in the northwestern part of the map sheet, close to, or overlying, dolerites. Two other anomalous values of 3.0 ppb are in regolith samples over deformed and metamorphosed rocks of the Earraheedy Group (GSWA 167663) and Yelma Formation (GSWA 167646), and the maximum value of 4.5 ppb is in a regolith sample over the Sunbeam Group, 16 km west of Carnegie Station (GSWA 168364).

In contrast to Pd, the majority (51% or 518) of regolith samples on STANLEY have Pt levels at or above the level of detection (0.5 ppb). All anomalous, high Pt values are in samples overlying the Sunbeam Group or dolerites (Fig. 36), including GSWA 167714 (7 ppb, northeast of The Hump), GSWA 167605 (6 ppb, 14 km west of Pumpkin Well), and GSWA 167817 (7 ppb, Brassey Range). The other two anomalous samples, also over the Sunbeam Group, are found in the southeast of STANLEY, over the Sunbeam Group. These samples are GSWA 168423 (8 ppb), and GSWA 168364 containing the maximum value of 9 ppb. Over the rest of the map sheet, Pt values are close to, or less than, detection level.

Anions

Three anomalous sulfur values, including the maximum value of 17.980%, are recorded from lake-sediment samples in Lake Burnside, on the eastern side of the map sheet (Fig. 38). Two other anomalous samples, GSWA 167828 (3.847%) and GSWA 167722 (8.400%), are from a drainage area about 20 km west of Glenayle Station. Another anomalous sample (GSWA 168348, 3.481%) is located on the margin of Lake Carnegie, in the southern part of STANLEY. Apart from several scattered samples, the remainder of the regolith samples have S levels close to detection level (0.005 %).

Base metals

Most of the high Cu values on STANLEY are found in regolith either overlying or close to dolerite (Fig. 26), with these anomalous values ranging from 93 ppm in GSWA 167538 (Brassey Range) to 113 ppm in GSWA 167790

(Parker Range). The highest Cu value of 127 ppm is in sheetwash sample GSWA 168062 close to Jublejarrah Pool; an adjacent sample has an anomalous value of 91 ppm Cu (GSWA 168439). Copper values over Earraheedy, Scorpion, and Collier Group rocks, and Archaean granitoids are low, apart from slightly elevated values over parts of the Wongawol Formation in the central southern part of the map sheet.

Lead values in regolith are slightly higher over the western part of the Sunbeam Group and dolerite compared with the east, probably as a result of the higher concentration of dolerite in the northwest of STANLEY (Fig. 34). One anomalous value of 95 ppm (stream-sediment sample GSWA 167743) is found over the Sunbeam Group adjacent to Archaean granitoid rocks, 20 km west-southwest of Glenayle Station. Over the remainder of the map sheet, Pb values in regolith are usually less than 30 ppm, apart from a group of samples with relatively high Pb values over Earraheedy Group rocks south and east of Lee Steere Range. These include anomalous values ranging between 80 ppm Pb (GSWA 167948) and 101 ppm Pb (GSWA 167949). Another less pronounced group of high values is located north of Earraheedy Station.

All of the anomalous Zn values, and many of the high values on STANLEY, are in samples spatially associated with dolerite (Fig. 51). The maximum value of 195 ppm Zn is in stream-sediment sample GSWA 167593 (Parker Range), and a group of three anomalous samples containing 157–181 ppm Zn are located over dolerite near Carooil Bluff. Over the remainder of the map sheet, Zn values are generally low and variable, although a series of relatively high values in various media types is evident in regolith samples over the eastern part of the Wongawol Formation.

Tin in regolith reaches a maximum value of 12.8 ppm in sandplain sample GSWA 168014, which is from over the Sunbeam Group, west of Kahrban Creek (Fig. 42). Other anomalous values, and most of the high Sn values, are found in regolith over other parts of the Sunbeam Group, often close to dolerite. Groups of relatively high Sn values are recorded over several lithological units near Earraheedy Station, including units south of Lee Steere Range, and south and east of Desolation Hills. One anomalous value of 6.4 ppm Sn has been measured from sheetwash sample GSWA 167957, which is from over the Paterson Formation at Stony Point Bore.

Ferro-alloy metals

The majority of high and anomalous Ni values on STANLEY are associated with regolith over dolerite (Fig. 33). Anomalous values range from 66 ppm (GSWA 167342, 17 km southeast of Glenayle Station) to the maximum value of 125 ppm in GSWA 167571, which is from 16 km south of Glenayle Station. An anomalous value of 76 ppm Ni is recorded in lake-sediment sample GSWA 168320 from the mouth of Kahrban Creek in Lake Burnside. There are a group of elevated Ni values in regolith samples from the eastern part of the Wongawol Formation, including one anomalous value of 76 ppm in stream-

sediment sample GSWA 168239 from near Mount Hoskin. Over the remainder of STANLEY, Ni values are generally low.

There is a marked contrast in the Cr content of regolith between the Sunbeam Group and dolerite, and regolith to the southwest, although some high Cr values are recorded in regolith in parts of the Earraheedy and Scorpion Groups north of Earraheedy Station (Fig. 25). Areas of high Cr in regolith are usually associated with dolerite, as shown by areas of the Sunbeam Group that have low Cr contents but no mapped dolerite (e.g. west of Minyan Hills). The maximum Cr content of regolith is in sheetwash sample GSWA 168443 (1170 ppm), 3 km east of Lake Augusta Well.

Molybdenum in regolith reaches a maximum of 11.1 ppm on STANLEY. This value in GSWA 168104 from west of Kahrban Creek is found over the Sunbeam Group, as are two other anomalous values of 3.9 ppm (GSWA 167613) and 3.8 ppm (GSWA 167704) in the north-western part of the map sheet (Fig. 31). Other high and anomalous Mo values have been assayed from regolith over the Wandiwarra Member of the Chiall Formation, in the vicinity of Earraheedy Station. Molybdenum values are generally low in regolith over the Wongawol Formation.

There are few high W values in the regolith from STANLEY. Most values greater than detection level (2 ppm) are in regolith over either the Sunbeam Group or dolerite, especially in the northwestern part of the map sheet. These include anomalous values ranging from 34 to 37 ppm (Fig. 49). Another series of relatively high W values, including two anomalous values of 31 ppm (sandplain sample GSWA 168228) and 33 ppm (sheetwash sample GSWA 168074) are found on the eastern side of the map sheet, over the Sunbeam Group. Scattered high W values are found over parts of the Earraheedy Group.

The distribution of V in regolith (Fig. 48) shows a strong demarcation between areas of dolerite, and Earraheedy Group rocks and Archaean granitoids. In particular, V values are relatively high in regolith in the northwestern part of STANLEY, including the highest value of 1480 ppm, which is from approximately 17 km west of Digby Hill (GSWA 167588). The association with dolerites is clearly shown by the low V values in regolith away from areas of mapped dolerite, such as in the northeastern part of the map sheet and west of Minyan Hills. Vanadium values in regolith elsewhere on STANLEY are usually less than 30 ppm.

As with V, there is a clear relationship between relatively high Co in regolith and the distribution of dolerite on STANLEY (Fig. 24). This is illustrated by three anomalous Co values of 40.6 ppm (GSWA 168261, 7 km east of Jimnyumbah Hill), 43.3 ppm (GSWA 168332, 3 km west of Marlooyanoo Hill), and 51.4 ppm (GSWA 167593, Parker Range). Other high values are in regolith over the southern part of the Wongawol Formation, including two anomalous values of 56.2 ppm (GSWA 167949, Nooloo Breakaway) and 82.0 ppm (GSWA 168358, Mobadoo Bore). In parts of the Sunbeam Group where dolerite is not well developed, Co values are generally low (especially in the northeast of the

map sheet), showing similar ranges to regolith over Archaean granitoid rocks and the Earraheedy and Collier Groups.

Fissionable metals

High Th values in regolith are found on, or close to, dolerite, and north of Earraheedy Station over several lithologies of the Earraheedy Group (Fig. 46). The latter includes one anomalous value of 58.80 ppm in sheetwash sample GSWA 167547 from north of Mudan Hills. The maximum Th value of 72.60 ppm is in GSWA 167307, a sandplain sample over dolerite from about 20 km southeast of Well Spring. An adjacent sample (GSWA 167507) contains 65.20 ppm Th. The other anomalous sample is a stream sediment containing 57.90 ppm Th and located adjacent to the Collier Group, west of Glenayle Station. Over the remainder of the map sheet, Th values are usually less than 20 ppm, especially in the northeast of STANLEY and west of Minyan Hills.

Uranium values are broadly similar on STANLEY (Fig. 47), with a maximum value of only 5.80 ppm, which was found in sample GSWA 167894, a stream-sediment sample on Kahrban Creek. Downstream, another stream-sediment sample (GSWA 168417) returned an anomalous U value of 4.90 ppm. Two other anomalous U values have been assayed from sheetwash samples GSWA 167680 (4.95 ppm) and GSWA 168348 (5.15 ppm) over the Wongawol Formation. One stream-sediment sample containing 5.30 ppm U is located 5 km northwest of Karinga Hill, in the southeast of STANLEY. Several lake-sediment samples have relatively high U values.

Minor metals and non-metals

The majority of elevated arsenic values in regolith are located over dolerite or the Sunbeam Group, although anomalous values are recorded from regolith on or near to the Frere Formation, with values ranging from 43 to 45 ppm (Fig. 17). Arsenic values are slightly higher than normal in regolith over the western part of the Wandiwarras Member of the Chiall Formation, near Earraheedy Station. A group of three anomalous samples, including the highest As value of 49 ppm in GSWA 168313, is found over dolerite in the vicinity of Kaljahr Pinnacle. In contrast, As values are low over the Princess Ranges Member of the Chiall Formation, the Wongawol Formation, Paterson Formation, and Sunbeam Group in the northeast of the map sheet.

Barium in regolith reaches a maximum value of 7870 ppm in sheetwash sample GSWA 167956, approximately 9 km west of Stony Point Bore (Fig. 19). A nearby sample (GSWA 168152) has 5260 ppm Ba. The remaining high and anomalous Ba values are largely confined to the Wongawol Formation, regardless of media type. These include values up to 5570 ppm Ba for sheetwash sample GSWA 167361, located approximately 11 km south of Royal Bore. In marked contrast, Ba values are relatively low in regolith over the Sunbeam Group and dolerite.

Samples with elevated beryllium in regolith on STANLEY are unevenly spread (Fig. 20). Four of the five

anomalous values, ranging from 3.0 ppm (GSWA 167720 and 167822) to the maximum value of 3.6 ppm (GSWA 167321), are in regolith over dolerite. The Be values are typically higher over dolerite than over sedimentary rocks of the Sunbeam Group. The fifth anomalous value of 2.9 ppm (sheetwash sample GSWA 168205, 10 km east southeast of Mingol Camp) is found with a group of samples with relatively high Be, which are located over the Wongawol Formation and Kulele Limestone in the south-central part of the map sheet.

Anomalous bismuth values in regolith (i.e. greater than 1.7 ppm) are located in samples either in the northwestern part of STANLEY, close to or over the Yelma Formation in the central western part of the map sheet, or over the Wandiwarras Member of the Chiall Formation (GSWA 167453) about 20 km east of Earraheedy Station (Fig. 21). In this central western part of the map sheet are a series of relatively high Bi values that span various lithological units. Bismuth values in regolith elsewhere on STANLEY are relatively low, especially in the northeastern part of the map sheet and over the Sunbeam Group.

Only seven regolith samples returned more than detection level concentrations of Cd (i.e. greater than 0.1 ppm), and the highest value is only 0.7 ppm in stream-sediment sample GSWA 167667, east of Earraheedy Station (Fig. 22). There appears to be no relationship between the distribution of Cd and lithology.

The highest concentration of elevated Ce values is located in the southern central part of STANLEY, in regolith over the Wongawol Formation. These include anomalous values of 97.10 ppm (GSWA 168240) and 109.00 ppm (GSWA 168025 and 167949). The highest value of 195.00 ppm is in soil sample GSWA 167779 from 10 km west of Jackies Well No. 1, and located over the Wandiwarras Member of the Chiall Formation (Fig. 23). Other high Ce values are found in regolith close to, or overlying, dolerite and include anomalous values of 151.00 ppm (GSWA 167633, 7 km west of Yarra Bore) and 180.50 ppm (GSWA 168319, 4 km northwest of Carooil Bluff). Cerium values are lower than usual over Archaean granitoid rocks and deformed and metamorphosed Earraheedy Group rocks.

Gallium in regolith (Fig. 27) is highest in sandplain sample GSWA 167307 (63.9 ppm), 18 km northwest of The Hump in the northwestern part of STANLEY. There are a group of high and anomalous values in this area that appear to be spatially related to dolerite. This association is apparent throughout the Sunbeam Group, with lower Ga values in regolith in the northeast of STANLEY and west of Minyan Hills where dolerite has not been mapped. Apart from a few high Ga values north of Earraheedy Station, which encompass several lithologies, Ga values are low in regolith over other lithological units.

Although indium levels in regolith are low (maximum of 0.41 ppm), elevated In values are strongly tied to areas of dolerite (Fig. 28), which is particularly evident in the northwestern part of STANLEY. Areas with notably low In contents in regolith include the Sunbeam Group in the northeast of the map sheet, and west of Minyan Hills, where dolerite has not been mapped by Commander

et al.(1982). Indium values are slightly higher in regolith overlying the Wandiwara Member of the Chiall Formation in the vicinity of Earraheedy Station than in regolith over the Wongawol Formation and Kulele Limestone.

The largest number of samples with relatively high La values is located over the central southern part of the map sheet (Wongawol Formation) and includes three anomalous values ranging from 46.10 to 51.50 ppm (Fig. 29). Three other anomalous values (47.00 to a maximum 81.80 ppm) are close to, or overlie, dolerite; La values are generally higher closer to areas of dolerite. Areas of notably low La in regolith include the northeastern part of STANLEY and west of Minyan Hills.

Lithium in regolith is generally low over most of STANLEY, apart from elevated values on or near to the southern part of the Wongawol Formation (Fig. 30). These include six anomalous values ranging from 43.4 to 54.6 ppm Li, with these high values not restricted to any one media type.

The maximum Nb value of 131.0 ppm is recorded in soil sample GSWA 167442, 15 km east of Breakaway Bore in the southwestern part of the map sheet (Fig. 32). Most high Nb values are found in regolith overlying, or close to, dolerite, although a group of high values are also found between Thurruguddy Bore and Nooloo Breakaway over the Wongawol Group. One anomalous sample (GSWA 167470, 49.5 ppm) is located over the Yelma Formation in the Lee Steere Range, and another anomalous Nb value of 48.4 ppm is found in sandplain sample GSWA 168416, immediately east of Kahrban Creek.

The largest concentration of high Rb values in regolith is in the eastern part of the Wongawol Formation (Fig. 37), and includes five anomalous values up to the maximum concentration of 170.00 ppm (sheetwash sample GSWA 168055, Desolation Hills). Over the Sunbeam Group and dolerite, Rb values are generally low apart from several high values on, or near, dolerite units, including one anomalous value of 159.50 ppm from a sheetwash sample at Mount St Gerard. Variable Rb contents, usually less than 60 ppm, are found over Earraheedy Group rocks south of Lee Steere Range.

Most high Sb values, including the maximum value of 9.0 ppm in sandplain sample GSWA 167609, are found in regolith over, or close to, dolerite, or over parts of the Sunbeam Group (Fig. 39). A group of higher Sb values, including one anomalous value of 4.8 ppm (GSWA 167547), is located north and northeast of Earraheedy Station over several different lithologies of the Earraheedy Group. Several other high values are in regolith from elsewhere in the Earraheedy Group, including one anomalous value of 5.5 ppm from 15 km east of Breakaway Bore (GSWA 167442).

A strong association between Sc in regolith and dolerite is apparent in Figure 40. Five of the six anomalous Sc values are found in regolith samples from on, or close to, dolerite, with the sixth sample (GSWA 167732, 34 ppm) from over the Scorpion Group, about 46 km west of Glenayle Station. Areas of lower Sc in regolith, such as in the northeast of STANLEY and west of Minyan

Hills, are those where dolerite has not been mapped (Commander et al., 1982).

Seventy-eight percent or 790 of the 1012 samples on STANLEY have less than detection level (0.5 ppm) Se (Fig. 41). A group of relatively high Se values, including two anomalous values of 4.3 ppm (GSWA 167648 and 167660) are located in the vicinity of Earraheedy Station, whereas the other anomalous sample is in regolith over dolerite near Kaljahr Pinnacle (GSWA 167392, 3.8 ppm). Elsewhere, Se values are close to detection level.

Most of the highest Sr values in regolith are in lake-sediment samples, including the highest value of 6600 ppm in GSWA 168230, at the mouth of Kahrban Creek (Fig. 43). A series of samples with relatively high Sr contents are found along the trace of this creek, and there are also high values from samples in Lake Burnside. Two samples from drainages about 17 km west of Glenayle Station have high Sr contents, including one anomalous assay of 426 ppm (GSWA 167828). Several high-Sr regolith samples are scattered over the Wongawol Formation, east of Nureri Pool.

Most regolith samples high in Ta have been collected over the Sunbeam Group, and several of the higher values intersect areas of dolerite (Fig. 44). One anomalous value of 3.3 ppm Ta (GSWA 167347) is found in regolith over the Scorpion Group, and another anomalous value (5.5 ppm) is in a sandplain sample (GSWA 167470) in the Lee Steere Range, over the Yelma Formation. A group of relatively high Ta values, including one anomalous value of 5.7 ppm (stream-sediment sample GSWA 167937, about 7 km southwest of Mobadoo Bore), are found over part of the Wongawol Formation. Elsewhere, Ta values are close to, or less than, detection level (0.1 ppm).

Ninety-four percent, or 953 out of the 1012 samples from STANLEY, have less than detection level (0.5 ppm) Te (Fig. 45), and most of the samples with detectable Te have only 1.1 ppm. These samples are found in one of two areas — either over the central western part of the Sunbeam Group and dolerite, or over the western part of the Earraheedy Group. The highest value of 2.3 ppm Te is in regolith over dolerite, north of Mount Sir Gerard (GSWA 167533).

Many high Y values show a strong coincidence with dolerite (Fig. 50), including the maximum value of 37.40 ppm in sheetwash sample GSWA 167633, at Mount Sir Gerard. The only other high Y values are in regolith samples scattered across the Sunbeam Group, most of which are found close to areas of dolerite. A group of high Y values are also found over the Wongawol Formation and Kulele Limestone in the southern part of STANLEY, including two anomalous values of 35.60 ppm (GSWA 167939, 8 km southeast of Thurruguddy Bore) and 27.70 ppm (GSWA 167949, close to Nooloo Breakaway).

All but one of the anomalous values for Zr in regolith on STANLEY are in samples from areas of dolerite, in the northwest of the map sheet (Fig. 52). In this area, anomalous values range from 398 ppm in sandplain sample GSWA 167704 (14 km west of Pumpkin Well) to the maximum value of 481 ppm in stream-sediment sample GSWA 167768 near Stanley Bluff. Zirconium

values are low in samples over the Sunbeam Group in the northeast of the map sheet, and west of Minyan Hills. One anomalous Zr value is recorded in sample GSWA 167732, over the Scorpion Group (399 ppm).

Discussion

The chemistry of regolith is largely controlled by the composition of the parent lithology, and the nature and extent to which the parent lithology is weathered. Factors contributing to weathering include climate, vegetation, and the distance and mechanism (water, wind, gravity, and ice) of regolith transport. On the sampling scale of GSWA's regional regolith-geochemistry program (one sample per 16 km²), the major control on regolith chemistry is the underlying lithology (Morris et al., 1997, 2000). However, in some cases such as on AJANA (Sanders and McGuinness, 2000), regolith chemistry has been influenced by the introduction of exotic (wind-blown) material, whereas in others (such as lacustrine environments), the chemistry of regolith reflects a particular environment.

Regolith associated with saline lake systems is usually independent of bedrock, and is commonly characterized by elevated CaO, Na₂O, LOI, and occasionally Ba, Sr, MgO, U, and S, indicative of the carbonate- and sulphate-dominated mineralogy of this material. Another example is eolian sandplain, which is largely composed of well-sorted, quartz-rich sand. The morphology of these sandplain deposits, which are characterized by well-developed dune systems, reflects the dominance of wind transport and deposition.

Controls on regolith by parent lithology

Dolerite

The clearest example of parent lithology controlling the chemistry of regolith is provided by dolerite. Most regolith samples with elevated concentrations of TiO₂, Al₂O₃, Fe₂O₃, Cu, Pb, Zn, Ni, Cr, Mo, and Ga north of the Glenayle Fault are found either overlying or close to areas of dolerite. Even analytes at low concentrations — such as In, Ta, and Te — are indicative of dolerite-related regolith. Other analytes in relatively high concentrations in these samples include Bi, Be, Sb, Y, and Zr, whereas CaO, Ce, La, Nb, and Rb are higher in some samples spatially associated with dolerites. Higher concentrations of Rb could indicate some clay development. In parts of STANLEY, weathering of dolerite has produced clay-rich saprock overlain by ferruginous duricrust. Patchy development of calcrete over some dolerites is consistent with locally elevated CaO values. The concentration of resistate phases during the formation of regolith could explain higher Nb (rutile), La, Ce, Y (apatite, monazite), and Zr (zircon) values. Higher Sb values are consistent with local development of sulphides in dolerites, such as in the vicinity of Digby Hill and Faulkne Bore (Plate 1).

Sandplain is a common regolith type in the northern part of STANLEY (Plate 3). On other map sheets such as NABBERU (Morris et al., 1997), most regolith samples from

areas of sandplain are dominated by quartz, with a resulting SiO₂-dominated chemistry that reflects eolian transport and deposition. If other locally derived components are present, they are effectively diluted by this quartz-rich wind-blown component. This type of sandplain is found over the Sunbeam Group in the northeast of the map sheet, and west of Minyan Hills (Plate 3).

In contrast, sandplain in the northwestern part of STANLEY is iron-rich (*Sf* on Plate 3), and often contains ferruginous granules and nodules (some of which are magnetic), and ferruginized lithic fragments. The composition of this material provides evidence for local derivation, and suggests that the sand cover is probably thin. On an idealized cross section (Fig. 53), this iron-rich sandplain is developed on the shallow backslope, and shows an intimate relationship with underlying ferruginous duricrust.

The distinctive chemistry of regolith sourced from dolerite on STANLEY can be used to examine the extent of dolerites relative to that shown on Plate 1 and Figure 3. An additive-index approach has been used, employing analytes typical of a mafic igneous rock association, termed here a dolerite index (Fe₂O₃ + Ti + Cr + Sc + V + In; modified from Hawkes and Webb, 1962). This additive approach (Smith et al., 1989) has been used elsewhere to examine the likelihood of chalcophile associations, and pegmatite, base metal and black shale-hosted mineralization (Morris et al., 1998). The approach does not involve the direct addition of analyte concentrations, but requires some data transformation to ensure that an element showing anomalous concentrations, even at low abundances, is given equal importance to an element showing anomalous concentrations at a higher level of concentration. This means that higher concentration elements do not negate the importance of other elements that may be found at lower concentrations. The transformation involves addition of a constant to each analyte value to remove zero data, followed by calculating the logarithmic value, which reduces the effects of extremely high or low values. These values are then expressed as standard deviations relative to the overall distribution (standard normal deviates), which allows direct comparison of analytes regardless of absolute concentration. These values are then summed to calculate the standard score.

A contoured dolerite additive-index map (Fig. 54) includes the mapped extent of dolerite on STANLEY based on Figure 3 and Plate 1. The additive-score approach shows a much greater extent of dolerite on STANLEY than originally mapped, as well as clear demarcation between dolerite-dominated areas to the northeast of the Glenayle Fault, and those to the southwest. On Figure 55, dolerite additive-index values are shown as a series of circles relative to total magnetic intensity. Relatively high index scores correspond well with areas interpreted to be underlain by dolerite.

Wongawol Formation

Regolith over, or near to, the central and eastern parts of the Wongawol Formation on STANLEY has high and

occasionally anomalous concentrations of several analytes (Table 2). Six anomalous MnO values in this area range up to 7.21 %, which is significantly higher than the maximum MnO values on the adjacent map sheets of NABBERU (0.60 %; Morris et al., 1997) and KINGSTON (2.69 %; Pye et al., 2000). Other analytes in relatively high concentrations include Na₂O, K₂O, Ba, Be, Ce, Co, Cu, La, Li, Nb, Ni, Rb, Sn, Sr, Y, and Zn. At some sample sites, regolith consists of well-sorted, clay-rich sand with no lithic fragments or granules (e.g. GSWA 168125), but at other sites, angular Mn-coated lithic fragments are accompanied by silcrete and vein quartz (GSWA 168358). A similar clast population at site GSWA 168439 (3.55 % MnO) is accompanied by a black (MnO-rich?) sandy regolith. Some of these analytes found at relatively high levels in regolith over the Wongawol Formation are also found in regolith over adjacent units (e.g. Y over the Kulele Limestone) close to the boundary with the Wongawol Formation.

Chiall, Frere, and Yelma Formations

Over parts of the Princess Ranges and Wandiwara Members of the Chiall Formation, and the Frere and Yelma Formations, within a radius of about 25 km of Earacheedy Station, are regolith samples with relatively high concentrations of Fe₂O₃, P₂O₅, Ag, Sn, Cr, Mo, As, Bi, Ga, Sb, Se, and Te. In this case, structure rather than lithology appears to control regolith composition. It has been shown that this area has been intensely deformed, resulting in regional-scale shearing and quartz veining as a consequence of the same deformational event responsible for the production of deformed and metamorphosed Earacheedy Group rocks (Pirajno, F., 2000, pers. comm.).

Frere Formation

Unlike NABBERU (Morris et al., 1997), there is no clear demarcation of the Frere Formation on STANLEY in terms of its regolith chemistry. On NABBERU, the ferruginous nature of the Frere Formation is shown by a high concentration of such analytes as Fe₂O₃ and V in regolith. The more subdued chemical response in regolith on STANLEY may be due to the combination of the smaller outcrop area on STANLEY, and the higher shale to iron-formation ratio in this deeper, eastern part of the basin, compared to the western part on NABBERU (Pirajno, F., 1999, pers. comm.).

Granitoid rocks

In marked contrast to the clear control of dolerite on regolith chemistry to the north of the Glenayle Fault, is the apparent lack of bedrock control of regolith by Archaean granitoid rocks north of Mudan Hills and Lee Steere Range. On NABBERU, Morris et al. (1997) showed that regolith chemistry could be used to identify different granitoid types either side of the Celia Fault. In the Fraser Range region, chemical zonation of Archaean granitic rocks was apparent from differences in K₂O and Na₂O contents of regolith (Morris et al., 2000). Analytes such as Na₂O, K₂O, Sr, Rb, and Ba, which are usually associated with granitoid rocks, are not notably higher in regolith over

granitoid rocks on STANLEY. This may be due to the intense weathering, which has destroyed the granitoid signature, or to the limited exposure of these rocks.

Regolith type

The clearest example of regolith type controlling the chemistry of regolith is in the drainage systems. As is typical of many areas in Western Australia, saline lake sediments are characterized by relatively high values for CaO, MgO, and LOI (e.g. SIR SAMUEL, Kojan et al., 1996; NABBERU, Morris et al., 1997), and this is well illustrated by lake-sediment samples collected in Lake Burnside on STANLEY. In the Lake Burnside area, a series of stream-sediment samples collected along Kahrban Creek, which debouches into Lake Burnside, also show the influence of regolith on chemistry in terms of elevated LOI (e.g. GSWA 168417, 15.82%) and CaO. Sample GSWA 167894 is a stream sediment from Kahrban Creek and contains the maximum value of U (5.80 ppm) found on STANLEY. At this site, white calcareous mottling is observed in sample pits, and calcrete fragments are found in regolith. Another sample from downstream (GSWA 168417) returned an anomalous U value of 4.90 ppm. These results are consistent with the established relationship of U and calcrete discussed by Butt et al. (1977). The anomalous analyte associations of samples GSWA 168230, 168307, 167939, 168210, and 168417 in Table 2 are typical of those attributed to regolith in drainage areas.

Sheetwash samples GSWA 167956 and 168152 have anomalous Ba concentrations of 7870 and 5260 ppm respectively. At both sample sites, Fe-rich regolith has been recorded, including ferruginous duricrust at GSWA 167956. This sample also has relatively high Fe₂O₃ (16.73 %) and Al₂O₃ (22.28 %). It is possible that the high Ba in both samples reflects scavenging by Fe-rich solutions (Hawkes and Webb, 1962).

Statistical treatment of regolith chemical data

Although spot-concentration maps (Figs 5 to 52) allow a rapid comparison of regolith chemistry relative to bedrock geology, statistical analysis means that differences in the chemistry of regolith populations according to such criteria as sample media, bedrock unit, or regolith unit can be quantitatively examined. Problems of comparing datasets of unequal size, where the data are usually positively skewed and follow a non-normal distribution, have been discussed by several authors (Koch and Link, 1970; Swan and Sandilands, 1995), and have been specifically addressed within the GSWA regolith program by Morris et al. (1998). In order to produce a dataset that more closely resembles a normal distribution, and avoid the problem of zero values, data can be log transformed after addition of a constant (Rock, 1988). Following this, geometric mean values can be calculated, and standard statistical tests can be carried out for comparison of mean values for two (Student's t-test) or more than two (Tukey's HSD) sample populations. The application of this

Table 3. Summary statistics for regolith over outcropping dolerite (*Xmh*) and colluvium derived from dolerite (*Cmh*) over the Sunbeam Group and dolerite

		Xmh (n=13)				Cmh (n=13)			
	DL ^a	Mean	SD ^b	Median	Skewness	Mean	SD	Median	Skewness
Percent									
SiO ₂	0.05	58.63	13.38	57.39	0.34	61.91	9.73	61.62	-0.87
TiO ₂	0.01	1.59	0.82	1.59	0.47	2.45	1.91	1.80	1.30
Al ₂ O ₃	0.05	11.44	2.74	11.31	-1.08	10.95	1.89	10.60	-0.11
Fe ₂ O ₃	0.01	19.88	10.92	16.23	0.89	15.97	9.16	14.33	1.42
MnO	0.01	0.09	0.05	0.08	0.93	0.12	0.05	0.11	0.66
MgO	0.01	0.33	0.28	0.19	1.19	0.51	0.27	0.48	0.25
CaO	0.01	0.33	0.51	0.15	2.66	0.63	0.49	0.65	0.83
Na ₂ O	0.05	0.32	0.42	0.10	1.45	0.51	0.41	0.58	-0.05
K ₂ O	0.01	1.18	0.98	0.63	0.51	1.51	0.72	1.65	0.52
P ₂ O ₅	0.01	0.08	0.02	0.07	0.93	0.08	0.04	0.07	1.62
LOI	0.01	5.81	1.87	6.14	-0.43	4.92	1.31	5.22	-0.48
Parts per million ^c									
Ag	0.1	—	—	—	×	—	—	—	×
As	1	12	11	9	3	10	11	7	3
Au (ppb)	1	—	1	—	×	—	—	—	×
Ba	2	404	240	391	1	364	129	375	0
Be	0.1	1	1	1	2	1	1	1	2
Bi	0.1	—	—	—	×	—	—	—	×
Cd	0.1	—	—	—	×	—	—	—	×
Ce	0.05	49	34	38	2	54	17	59	0
Co	0.2	17	8	20	0	25	13	28	1
Cr	10	127	83	96	1	115	139	66	3
Cu	2	48	15	47	0	43	13	42	0
Ga	0.5	23	7	22	-1	20	6	20	0
In	0.05	—	—	—	×	—	—	—	×
La	0.05	21	11	18	1	24	7	22	1
Li	0.1	12	4	11	1	13	3	13	0
Mo	0.1	1	1	1	0	1	1	1	0
Nb	0.2	15	8	14	1	15	6	17	0
Ni	2	31	10	33	0	38	17	41	0
Pb	1	27	10	27	0	26	10	24	0
Pd (ppb)	0.5	—	—	1	×	—	1	—	×
Pt (ppb)	0.5	1	1	1	1	1	1	1	1
Rb	0.05	61	46	35	1	70	33	58	1
S (%)	0.005	—	—	—	×	—	—	—	×
Sb	0.1	1	1	1	1	1	1	1	2
Sc	2	18	7	18	0	16	4	17	1
Se	0.5	—	—	—	×	—	—	—	×
Sn	0.5	2	1	3	0	2	1	3	0
Sr	1	54	41	47	1	70	33	74	0
Ta	0.1	1	1	1	1	1	1	1	2
Te	0.5	—	1	—	×	—	—	—	×
Th	0.05	17	8	19	0	16	8	15	1
U	0.05	2	1	2	1	2	1	2	1
V	2	351	258	326	2	370	235	306	1
W	2	7	9	4	3	5	3	4	0
Y	0.05	16	9	15	1	17	4	17	0
Zn	5	57	28	51	1	90	53	72	1
Zr	5	185	73	189	0	194	57	192	0

NOTES: n number of samples
 ppb parts per billion
 a detection level
 b standard deviation
 c unless otherwise shown
 — less than detection level
 × insufficient data for calculation of skewness

Table 4. Summary statistics for heterogeneous colluvium (Cl) and colluvium derived from dolerite (Cmh) over the Sunbeam Group and dolerite

		Cl (n=11)				Cmh (n=13)			
	DL ^a	Mean	SD ^b	Median	Skewness	Mean	SD	Median	Skewness
Percent									
SiO ₂	0.05	65.59	10.62	68.80	-0.79	61.91	9.73	61.62	-0.87
TiO ₂	0.01	1.11	0.30	1.07	0.19	2.45	1.91	1.80	1.30
Al ₂ O ₃	0.05	10.60	2.35	10.88	-0.20	10.95	1.89	10.60	-0.11
Fe ₂ O ₃	0.01	14.83	8.24	11.22	1.00	15.97	9.16	14.33	1.42
MnO	0.01	0.11	0.08	0.09	1.21	0.12	0.05	0.11	0.66
MgO	0.01	0.29	0.21	0.22	0.76	0.51	0.27	0.48	0.25
CaO	0.01	0.31	0.41	0.21	2.13	0.63	0.49	0.65	0.83
Na ₂ O	0.05	0.30	0.36	0.14	1.68	0.51	0.41	0.58	-0.05
K ₂ O	0.01	1.21	0.60	1.23	-0.12	1.51	0.72	1.65	0.52
P ₂ O ₅	0.01	0.07	0.03	0.07	0.34	0.08	0.04	0.07	1.62
LOI	0.01	5.00	1.73	5.74	-0.59	4.92	1.31	5.22	-0.48
Parts per million ^c									
Ag	0.1	—	—	—	×	—	—	—	×
As	1	13	4	11	0	10	11	7	3
Au (ppb)	1	—	—	—	×	—	—	—	×
Ba	2	422	176	501	0	364	129	375	0
Be	0.1	1	1	1	2	1	1	1	2
Bi	0.1	—	—	—	×	—	—	—	×
Cd	0.1	—	—	—	×	—	—	—	×
Ce	0.05	49	19	50	0	54	17	59	0
Co	0.2	17	8	15	1	25	13	28	1
Cr	10	142	60	160	0	115	139	66	3
Cu	2	37	17	27	1	43	13	42	0
Ga	0.5	19	6	19	1	20	6	20	0
In	0.05	—	—	—	×	—	—	—	×
La	0.05	22	6	22	0	24	7	22	1
Li	0.1	14	6	12	1	13	3	13	0
Mo	0.1	1	1	1	0	1	1	1	0
Nb	0.2	18	5	16	0	15	6	17	0
Ni	2	32	12	27	1	38	17	41	0
Pb	1	27	11	23	2	26	10	24	0
Pd (ppb)	0.5	—	—	—	×	—	1	—	×
Pt (ppb)	0.5	1	1	1	1	1	1	1	1
Rb	0.05	62	32	56	1	70	33	58	1
S (%)	0.005	—	—	—	×	—	—	—	×
Sb	0.1	1	—	1	1	1	1	1	2
Sc	2	14	6	12	1	16	4	17	1
Se	0.5	—	1	—	×	—	—	—	×
Sn	0.5	3	1	3	1	2	1	3	0
Sr	1	52	34	47	2	70	33	74	0
Ta	0.1	1	—	1	-1	1	1	1	2
Te	0.5	—	—	—	×	—	—	—	×
Th	0.05	16	7	12	1	16	8	15	1
U	0.05	2	1	2	1	2	1	2	1
V	2	264	133	262	2	370	235	306	1
W	2	5	3	6	-1	5	3	4	0
Y	0.05	16	6	15	1	17	4	17	0
Zn	5	57	30	46	1	90	53	72	1
Zr	5	162	27	155	1	194	57	192	0

NOTES: n number of samples
 ppb parts per billion
 a detection level
 b standard deviation
 c unless otherwise shown
 — less than detection level
 × insufficient data for calculation of skewness

approach within the GSWA program has been discussed by Morris et al. (1997, 1998). One major assumption of this approach is that addition of a constant and log normalization produces a sufficiently normally distributed dataset for the application of such parametric tests as Student's t-test and Tukey's HSD. When datasets are small or not normally distributed, non-parametric tests may be more appropriate. Amongst these is the non-parametric equivalent of the Student's t-test for independent samples, known as either the Mann-Whitney U test or the Wilcoxon rank-sum test (Swan and Sandilands, 1995). Whereas Student's t-test tests the hypothesis of equality of population means, the Mann-Whitney U test tests for the equality of medians (i.e. the middle value in a set of ranked data).

For many geochemical datasets, particularly those containing large amounts of zero or near-zero data, use of such tests as the Mann-Whitney U test (where data are ranked before being statistically compared) must take into account the problems introduced by having a significant number of data of the same value, which is usually zero in the case of regolith geochemistry. In this situation, the Mann-Whitney approach may unrealistically highlight the importance of the few non-zero data. This must be borne in mind, although it is accepted that the Mann-Whitney U test is more appropriate for testing geochemistry, as most such datasets are positively skewed. Tests of median equality have been carried out at the 99% probability level for data from STANLEY. In order to avoid the influence of poorer precision and accuracy at low concentrations, only median values that are greater than ten times the detection level are discussed. It is unrealistic to report median values of trace elements to the level of precision presented in STANLEY.CSV, and these median values are reported as integers in the relevant tables. In order to indicate if data are non-normally distributed, both mean and skewness values are included with median values in summary statistics tables. The standard deviation gives an idea of the spread of the data.

Statistical comparison of regolith types over the Sunbeam Group and dolerites

In order to examine the chemistry of different regolith types, it is necessary to test populations for which other variables, such as bedrock composition, are held constant. Approximately 50% of STANLEY is composed of sedimentary rocks of the Sunbeam Group and dolerite intrusions. This association offers some scope in examining the controls on the chemistry of various regolith types, particularly sand-dominated units, which are well developed in the northern part of the map sheet (Plate 3).

Exposed-regime regolith and colluvium derived from dolerites (*Xmh*, *Cmh*)

Summary statistics for exposed-regime regolith and colluvium derived from dolerites (*Xmh* and *Cmh*) are shown in Table 3. A comparison of median values at the 99% level using the Mann-Whitney U test shows that there are no significant differences between the two populations for any analyte, although both sample populations are small

(13 samples). Pye et al. (2000) examined exposed regime – colluvium relationships over the Frere Formation and Archaean granitoid on KINGSTON, and also found no statistical differences between sample populations, which is consistent with physical rather than chemical weathering. Their study also extended to the colluvium – sheetwash relations over the Frere Formation, for which there were also no statistical differences between population medians for any analyte, indicating that even for more distal regolith, physical weathering is of importance.

Colluvium derived from dolerites (*Cmh*) and colluvium of mixed parentage (*Cl*)

Statistically comparing colluvium derived from dolerite (*Cmh*) and colluvium of mixed parentage (*Cl*, which includes dolerite as well as metasedimentary rocks of the Sunbeam Group) should indicate the influence of dolerite on heterogeneous colluvium. Summary statistics for both sample populations are shown in Table 4. A statistical test of median values shows no differences for any analytes between the two sample populations. Spot-concentration maps for such analytes as TiO_2 and Sc, and the additive-index approach (Fig. 54) indicate a much greater extent of dolerite than previously mapped, and the similarity of *Cmh* and *Cl* indicates that dolerite is a major contributor to heterogeneous colluvium (*Cl*) over the Sunbeam Group.

Iron-rich sandplain (*Sf*) relative to other sandplain and eolian units

Iron-rich sandplain (*Sf*) accounts for 13 % of regolith on STANLEY, and is extensively developed north of the Glenayle Fault, over rocks of the Sunbeam Group and dolerites (Plate 3). Its chemistry and spatial relations indicate a genetic link with dolerite, and statistical tests have been carried out to determine more about its parentage and its relationship to other regolith types.

Iron-rich sandplain (*Sf*) and residual iron-rich regolith (*Rf*)

At several sample sites, iron-rich sandplain contains fragments of ferruginous duricrust. A statistical comparison of median values (Table 5) for iron-rich sandplain (*Sf*) and residual iron-rich material (*Rf*) shows that Ce is higher and Cr lower in ferruginous duricrust (*Rf*) compared to iron-rich sandplain (*Sf*). The overall similarity of population medians could be due to two factors. Either iron-rich sandplain is a locally sourced product derived from the breakdown of ferruginous duricrust, or iron-rich sandplain results from the weathering in situ of dolerite. As iron-rich sandplain contains some quartz sand, as well as ferruginized lithic fragments, and iron-rich nodules and granules, it is more likely that local reworking of ferruginized duricrust is the dominant process. This is supported by the spatial relationships of regolith units, shown on an idealized cross section (Fig. 53), where iron-rich sandplain, which is largely confined to more gentle back-slopes over dolerites, overlies, or is adjacent to, ferruginous duricrust developed over dolerite. The overall

Table 5. Summary statistics for ferruginous duricrust (Rf) and iron-rich sandplain (Sf) over the Sunbeam Group and dolerite

		Rf (n=13)				Sf (n=105)			
	DL ^a	Mean	SD ^b	Median	Skewness	Mean	SD	Median	Skewness
Percent									
SiO ₂	0.05	53.13	12.38	56.70	-0.34	48.02	18.01	46.50	0.41
TiO ₂	0.01	1.41	0.67	1.40	1.04	1.58	0.81	1.65	0.10
Al ₂ O ₃	0.05	12.68	3.02	12.13	0.69	11.75	3.52	12.11	-0.23
Fe ₂ O ₃	0.01	25.53	9.01	25.19	0.24	32.51	14.00	32.30	-0.00
MnO	0.01	0.05	0.02	0.04	-0.20	0.04	0.02	0.04	1.09
MgO	0.01	0.06	0.03	0.06	1.08	0.04	0.05	0.04	4.29
CaO	0.01	0.04	0.03	0.02	1.12	0.02	0.03	0.02	3.51
Na ₂ O	0.05	0.00	0.00	0.00	x	0.00	0.00	0.00	x
K ₂ O	0.01	0.22	0.10	0.21	0.66	0.17	0.10	0.14	1.89
P ₂ O ₅	0.01	0.07	0.02	0.07	0.14	0.07	0.02	0.07	-0.18
LOI	0.01	6.38	1.48	6.40	0.08	5.34	1.57	5.44	-0.20
Parts per million ^c									
Ag	0.1	—	—	—	x	—	—	—	x
As	1	20	8	18	0	21	8	20	0
Au (ppb)	1	—	—	—	x	—	2	—	x
Ba	2	109	85	91	3	84	109	63	6
Be	0.1	1	—	1	x	1	—	1	x
Bi	0.1	—	—	—	x	1	—	1	2
Cd	0.1	—	—	—	x	—	—	—	x
Ce	0.05	32	14	28	1	21	9	20	2
Co	0.2	7	3	7	0	8	3	7	1
Cr	10	250	119	225	0	380	191	350	1
Cu	2	28	14	24	1	34	19	31	1
Ga	0.5	26	9	24	2	32	13	31	0
In	0.05	—	—	—	x	—	—	—	x
La	0.05	12	4	12	1	11	4	10	1
Li	0.1	13	5	11	1	10	4	10	2
Mo	0.1	1	1	1	0	2	1	2	0
Nb	0.2	19	10	18	1	19	9	18	1
Ni	2	19	6	19	-2	23	9	22	1
Pb	1	30	11	32	0	31	12	31	2
Pd (ppb)	0.5	1	1	1	0	—	1	—	x
Pt (ppb)	0.5	2	2	2	2	2	2	2	1
Rb	0.05	17	7	17	0	14	8	12	2
S (%)	0.005	—	—	—	x	—	—	—	x
Sb	0.1	1	1	1	2	2	1	2	2
Sc	2	18	6	18	0	19	8	20	0
Se	0.5	1	1	—	3	—	—	—	x
Sn	0.5	3	1	3	2	3	1	3	1
Sr	1	15	6	13	1	11	5	9	1
Ta	0.1	1	1	1	1	1	1	1	1
Te	0.5	—	—	—	x	—	—	—	x
Th	0.05	26	13	20	1	29	12	28	1
U	0.05	2	1	2	1	2	1	2	0
V	2	433	173	361	1	623	303	643	0
W	2	8	4	7	2	8	7	7	2
Y	0.05	7	2	7	0	6	2	6	1
Zn	5	24	6	25	-1	23	10	22	1
Zr	5	226	94	190	2	237	88	233	0

NOTES: n number of samples
 ppb parts per billion
 a detection level
 b standard deviation
 c unless otherwise shown
 — less than detection level
 x insufficient data for calculation of skewness

Table 6. Summary statistics for iron-rich sandplain (Sf) and heterogeneous sandplain (Sl) over the Sunbeam Group and dolerite

		Sl (n=22)				Sf (n=105)			
	DL ^a	Mean	SD ^b	Median	Skewness	Mean	SD	Median	Skewness
Percent									
SiO ₂	0.05	55.99	17.04	55.55	0.12	48.02	18.01	46.50	0.41
TiO ₂	0.01	1.28	0.66	1.20	0.92	1.58	0.81	1.65	0.10
Al ₂ O ₃	0.05	10.00	3.23	11.11	-0.46	11.75	3.52	12.11	-0.23
Fe ₂ O ₃	0.01	24.83	11.59	23.90	0.23	32.51	14.00	32.30	-0.00
MnO	0.01	0.04	0.02	0.04	1.10	0.04	0.02	0.04	1.09
MgO	0.01	0.29	1.05	0.06	4.67	0.04	0.05	0.04	4.29
CaO	0.01	1.07	4.84	0.03	4.69	0.02	0.03	0.02	3.51
Na ₂ O	0.05	0.01	0.04	—	4.13	0.00	0.00	—	×
K ₂ O	0.01	0.27	0.13	0.25	1.15	0.17	0.10	0.14	1.89
P ₂ O ₅	0.01	0.07	0.03	0.07	0.54	0.07	0.02	0.07	-0.18
LOI	0.01	5.76	4.45	5.67	3.89	5.34	1.57	5.44	-0.20
Parts per million ^c									
Ag	0.1	—	—	—	×	—	—	—	×
As	1	15	7	14	0	21	8	20	0
Au (ppb)	1	—	—	—	×	—	2	—	×
Ba	2	113	55	94	1	84	109	63	6
Be	0.1	1	—	1	0	1	—	1	×
Bi	0.1	—	—	1	0	1	—	1	2
Cd	0.1	—	—	—	×	—	—	—	×
Ce	0.05	23	8	23	0	21	9	20	2
Co	0.2	8	3	8	0	8	3	7	1
Cr	10	328	229	265	2	380	191	350	1
Cu	2	30	13	27	0	34	19	31	1
Ga	0.5	23	10	22	0	32	13	31	0
In	0.05	—	—	—	×	—	—	—	×
La	0.05	13	4	13	0	11	4	10	1
Li	0.1	10	3	10	0	10	4	10	2
Mo	0.1	1	1	1	1	2	1	2	0
Nb	0.2	15	10	13	2	19	9	18	1
Ni	2	22	8	21	0	23	9	22	1
Pb	1	25	8	25	0	31	12	31	2
Pd (ppb)	0.5	—	—	—	×	—	1	—	×
Pt (ppb)	0.5	1	1	1	2	2	2	2	1
Rb	0.05	19	8	17	1	14	8	12	2
S (%)	0.005	—	—	—	×	—	—	—	×
Sb	0.1	1	1	1	0	2	1	2	2
Sc	2	17	7	17	0	19	8	20	0
Se	0.5	—	1	—	×	—	—	—	×
Sn	0.5	3	1	3	0	3	1	3	1
Sr	1	37	104	15	5	11	5	9	1
Ta	0.1	1	1	1	2	1	1	1	1
Te	0.5	—	—	—	×	—	—	—	×
Th	0.05	23	10	25	0	29	12	28	1
U	0.05	2	1	2	0	2	1	2	0
V	2	480	260	464	1	623	303	643	0
W	2	5	4	6	0	8	7	7	2
Y	0.05	8	3	7	1	6	2	6	1
Zn	5	28	12	30	0	23	10	22	1
Zr	5	192	69	185	0	237	88	233	0

NOTES: n number of samples
 ppb parts per billion
 a detection level
 b standard deviation
 c unless otherwise shown
 — less than detection level
 × insufficient data for calculation of skewness

Table 7. Summary statistics for eolian sandplain (*E*) and iron-rich sandplain (*Sf*) over the Sunbeam Group and dolerite

		E (n=51)				Sf (n=105)			
	DL ^a	Mean	SD ^b	Median	Skewness	Mean	SD	Median	Skewness
Percent									
SiO ₂	0.05	87.88	10.24	91.58	-1.95	48.02	18.01	46.50	0.41
TiO ₂	0.01	0.30	0.22	0.22	1.93	1.58	0.81	1.65	0.10
Al ₂ O ₃	0.05	3.98	3.03	2.98	2.10	11.75	3.52	12.11	-0.23
Fe ₂ O ₃	0.01	5.42	5.95	3.21	2.51	32.51	14.00	32.30	-0.00
MnO	0.01	0.00	0.01	0.00	2.27	0.04	0.02	0.04	1.09
MgO	0.01	0.05	0.13	0.02	5.31	0.04	0.05	0.04	4.29
CaO	0.01	0.03	0.06	0.01	3.86	0.02	0.03	0.02	3.51
Na ₂ O	0.05	0.06	0.40	0.00	7.14	0.00	0.00	0.00	×
K ₂ O	0.01	0.13	0.18	0.06	3.52	0.17	0.10	0.14	1.89
P ₂ O ₅	0.01	0.01	0.01	0.01	1.45	0.07	0.02	0.07	-0.18
LOI	0.01	1.99	1.45	1.50	1.38	5.34	1.57	5.44	-0.20
Parts per million ^c									
Ag	0.1	—	—	—	×	—	—	—	×
As	1	6	6	4	2	21	8	20	0
Au (ppb)	1	—	1	—	×	—	2	—	×
Ba	2	62	55	42	2	84	109	63	6
Be	0.1	—	—	—	×	1	—	1	0
Bi	0.1	—	—	—	×	1	—	1	2
Cd	0.1	—	—	—	×	—	—	—	×
Ce	0.05	9	7	8	2	21	9	20	2
Co	0.2	3	2	2	2	8	3	7	1
Cr	10	64	62	46	2	380	191	350	1
Cu	2	13	14	10	5	34	19	31	1
Ga	0.5	7	6	5	2	32	13	31	0
In	0.05	—	—	—	×	—	—	—	×
La	0.05	5	3	4	2	11	4	10	1
Li	0.1	6	3	5	1	10	4	10	2
Mo	0.1	1	2	1	6	2	1	2	0
Nb	0.2	6	5	4	3	19	9	18	1
Ni	2	11	11	7	2	23	9	22	1
Pb	1	11	7	9	3	31	12	31	2
Pd (ppb)	0.5	—	—	—	×	—	1	—	×
Pt (ppb)	0.5	—	—	—	×	2	2	2	1
Rb	0.05	10	10	6	3	14	8	12	2
S (%)	0.005	—	—	—	×	—	—	—	×
Sb	0.1	1	1	—	2	2	1	2	2
Sc	2	4	3	3	1	19	8	20	0
Se	0.5	—	—	—	×	—	—	—	×
Sn	0.5	1	2	1	6	3	1	3	1
Sr	1	9	7	6	2	11	5	9	1
Ta	0.1	—	—	—	×	1	1	1	1
Te	0.5	—	—	—	×	—	—	—	×
Th	0.05	6	6	4	3	29	12	28	1
U	0.05	1	—	1	1	2	1	2	0
V	2	95	117	55	3	623	303	643	0
W	2	3	4	2	1	8	7	7	2
Y	0.05	3	2	3	1	6	2	6	1
Zn	5	8	7	7	1	23	10	22	1
Zr	5	70	45	57	2	237	88	233	0

NOTES: n number of samples
 ppb parts per billion
 a detection level
 b standard deviation
 c unless otherwise shown
 — less than detection level
 x insufficient data for calculation of skewness

Table 8. Summary statistics for sheetwash (W) and iron-rich sandplain (Sf) over the Sunbeam Group and dolerite

		W (n=122)				Sf (n=105)			
	DL ^a	Mean	SD ^b	Median	Skewness	Mean	SD	Median	Skewness
Percent									
SiO ₂	0.05	58.55	11.36	58.31	-0.25	48.02	18.01	46.50	0.41
TiO ₂	0.01	1.28	0.58	1.14	1.60	1.58	0.81	1.65	0.1
Al ₂ O ₃	0.05	11.60	2.04	11.58	-0.21	11.75	3.52	12.11	-0.23
Fe ₂ O ₃	0.01	21.11	9.67	20.19	0.55	32.51	14.00	32.30	0
MnO	0.01	0.07	0.05	0.06	1.33	0.04	0.02	0.04	1.09
MgO	0.01	0.22	0.35	0.13	6.11	0.04	0.05	0.04	4.29
CaO	0.01	0.11	0.22	0.05	5.03	0.02	0.03	0.02	3.51
Na ₂ O	0.05	0.08	0.20	—	3.54	—	0.00	—	×
K ₂ O	0.01	0.62	0.43	0.52	2.18	0.17	0.10	0.14	1.89
P ₂ O ₅	0.01	0.08	0.02	0.08	0.52	0.07	0.02	0.07	-0.18
LOI	0.01	5.88	1.28	5.76	0.10	5.34	1.57	5.44	-0.2
Parts per million ^c									
Ag	0.1	—	—	—	×	—	—	—	×
As	1	15	8	14	1	21	8	20	0
Au (ppb)	1	—	1	—	5	—	2	—	×
Ba	2	355	557	222	7	84	109	63	6
Be	0.1	1	—	1	×	1	—	1	0
Bi	0.1	—	—	—	×	1	—	1	2
Cd	0.1	—	—	—	×	—	—	—	×
Ce	0.05	35	12	32	1	21	9	20	2
Co	0.2	12	7	10	2	8	3	7	1
Cr	10	264	191	220	2	380	191	350	1
Cu	2	38	16	34	1	34	19	31	1
Ga	0.5	23	7	23	1	32	13	31	0
In	0.05	—	—	—	×	—	—	—	×
La	0.05	17	6	17	1	11	4	10	1
Li	0.1	13	4	12	1	10	4	10	2
Mo	0.1	1	1	1	1	2	1	2	0
Nb	0.2	16	6	15	2	19	9	18	1
Ni	2	27	10	25	1	23	9	22	1
Pb	1	27	8	25	1	31	12	31	2
Pd (ppb)	0.5	—	1	—	×	—	1	—	×
Pt (ppb)	0.5	1	1	1	3	2	2	2	1
Rb	0.05	39	20	37	2	14	8	12	2
S (%)	0.005	—	—	—	×	—	—	—	×
Sb	0.1	1	1	1	1	2	1	2	2
Sc	2	18	5	18	0	19	8	20	0
Se	0.5	—	1	—	×	—	—	—	×
Sn	0.5	3	1	3	0	3	1	3	1
Sr	1	30	22	23	3	11	5	9	1
Ta	0.1	1	—	1	1	1	1	1	1
Te	0.5	—	—	—	×	—	—	—	×
Th	0.05	20	8	19	1	29	12	28	1
U	0.05	2	1	2	0	2	1	2	0
V	2	394	202	372	1	623	303	643	0
W	2	7	5	5	2	8	7	7	2
Y	0.05	12	4	11	1	6	2	6	1
Zn	5	44	19	40	1	23	10	22	1
Zr	5	182	53	176	1	237	88	233	0

NOTES: n number of samples
 ppb parts per billion
 a detection level
 b standard deviation
 c unless otherwise shown
 — less than detection level
 × insufficient data for calculation of skewness

compositional similarity of iron-rich regolith and iron-rich sandplain means that iron-rich sandplain is a viable sampling medium in these areas of dolerite.

Iron-rich sandplain (*Sf*) and heterogeneous sandplain (*Sl*)

Sandplain derived from various sources (*Sl*), which largely represents mixed sand and sheetwash, accounts for 5% of regolith on STANLEY. Summary statistics for this unit and iron-rich sandplain (*Sf*) are shown in Table 6. A statistical comparison of medians for the two sample populations shows that there is a greater than 99% probability that iron-rich sandplain has high Fe₂O₃, As, Ga, Pb, and Zr, and lower SiO₂, Ba, and Rb compared to the heterogeneous unit *Sl*. This comparison shows the importance of dolerite in the formation of iron-rich sandplain (i.e. higher Fe₂O₃, As, Ga, and Pb median values), and the dilution of the dolerite component downslope by mixing with siliciclastic-sourced material. This scenario is consistent with the relative positions of these regolith types as shown in Figure 53.

Iron-rich sandplain (*Sf*) and eolian regolith (*E*)

Regolith indicative of eolian transport and deposition (*E*), which is in the form of well-developed dune systems, is largely found in the northeastern part of STANLEY. It accounts for about 8% of regolith, and 76 samples. A statistical comparison of population medians between this type of regolith and iron-rich sandplain (Table 7) shows that there is a greater than 99% probability that the iron-rich sandplain unit (*Sf*) has higher median values for TiO₂, Al₂O₃, Fe₂O₃, LOI, Ce, Cr, Li, Nb, Rb, Th, U, V, Y, and Zr and a lower median value for SiO₂ than eolian material (*E*). Although many of the analytes that have higher median values in the iron-rich sandplain unit are indicative of dolerite input (e.g. TiO₂, Fe₂O₃, Cr, and V), others (e.g. Ce, La, Nb, Y, and Zr) are consistent with a higher content of resistate phases, such as rutile, zircon, and monazite. This indicates a higher residual component in iron-rich sandplain compared to eolian regolith. Higher SiO₂ in the eolian unit is typical of high contents of wind-blown quartz sand.

Iron-rich sandplain (*Sf*) and sheetwash (*W*)

Both sheetwash (*W*) and iron-rich sandplain (*Sf*) are found close to dolerite on STANLEY (Plate 3). Summary statistics for sheetwash and iron-rich sandplain are shown in Table 8, and there are strong contrasts in terms of median values according to the Mann-Whitney U test. Sheetwash has higher median values for SiO₂, K₂O, LOI, Ba, Ce, Co, La, Li, Nb, Ni, Rb, Y, and Zn, and lower median values for TiO₂, Fe₂O₃, As, Cr, Ga, Pb, Th, V, and Zr compared to iron-rich sandplain. The analytes which are higher in the iron-rich sandplain are consistent with significant dolerite input and derivation from the ferruginous duricrust (*Rf*) unit (i.e. Fe₂O₃, Cr, Ga, and V), whereas higher SiO₂, K₂O, LOI, Ce, La, Li, and Y in the sheetwash indicate some input from siliciclastic sedimentary rocks. This is consistent with the relative position of sheetwash (*W*) and iron-rich sandplain (*Sf*) in areas of dolerite (Fig. 53), with sheetwash usually found on

the breakaway side of dolerite outcrops (where more siliciclastic rocks are exposed) and iron-rich sandplain more common on the gentle backslope.

Eolian material and other sandplain types

Heterogeneous sandplain (*Sl*) and sheetwash (*W*)

Heterogeneous sandplain (*Sl*) and sheetwash (*W*) are usually found as interfingering deposits lower down in the landform profile (Fig. 53). Sheetwash (*W*) is usually found in greater abundance on the breakaway side of dolerite outcrops. A statistical test of these two sample populations (Table 9) shows that the sheetwash unit (*W*) has a greater than 99% probability of having higher median values for K₂O, Ba, Ce, Co, La, Rb, and Sr than the heterogeneous sandplain unit (*Sl*). The higher K₂O, Ba, Rb, and Sr are consistent with input from siliciclastic rocks and the relatively unweathered nature of this material. Material comprising heterogeneous sandplain (*Sl*) is more mature. These observations are consistent with the mutual position of these regolith types in outcrop (Fig. 53).

Lake-sediment (*L_l*) and lake-margin (*L_m*) deposits

Summary statistics for lacustrine regolith (*L_l*) and regolith marginal to lake systems (*L_m*) are shown in Table 10. The relatively high concentrations of SiO₂, Al₂O₃, Fe₂O₃, MgO, CaO, and LOI in both sample populations are indicative of clay- and carbonate-rich material. There are no statistical differences in any analytes apart from higher median MgO and LOI values in lake regolith, and higher Ba in the regolith marginal to lakes. The former is consistent with a higher carbonate content, whereas the high Ba in the marginal material may indicate a higher barite content.

Sandplain (*S*) over Archaean granitoid and the Paterson Formation

Sandplain regolith (*S*) is developed over parts of the Paterson Formation (e.g. southwest of STANLEY), and over Archaean granitoid rocks of the Malmac Dome. A statistical comparison of this regolith type can offer some insight into the contribution of parent lithology to regolith, in that the Paterson Formation is composed of much more lithologically diverse material than Archaean granitoid. Summary statistics are shown in Table 11. The median values are statistically similar, apart from Ba and Li, which have a 99% probability of being higher in sandplain over the Paterson Formation than sandplain over Archaean granitoid. On KINGSTON, Pye et al. (2000) compared sandplain (*S*) developed over the same two lithologic units, and found a greater than 99% probability that TiO₂, As, Li, Mo, Nb, Th, and Zr were lower in sandplain regolith over Archaean granitoid than the same regolith type developed over the Paterson Formation. They attributed these

Table 9. Summary statistics for sheetwash (W) and heterogeneous sandplain (SI) over the Sunbeam Group and dolerite

		SI (n=22)				W (n=122)			
	DL ^a	Mean	SD ^b	Median	Skewness	Mean	SD	Median	Skewness
Percent									
SiO ₂	0.05	55.99	17.04	55.55	0.12	58.55	11.36	58.31	-0.25
TiO ₂	0.01	1.28	0.66	1.20	0.92	1.28	0.58	1.14	1.60
Al ₂ O ₃	0.05	10.00	3.23	11.11	-0.46	11.60	2.04	11.58	-0.21
Fe ₂ O ₃	0.01	24.83	11.59	23.90	0.23	21.11	9.67	20.19	0.55
MnO	0.01	0.04	0.02	0.04	1.10	0.07	0.05	0.06	1.33
MgO	0.01	0.29	1.05	0.06	4.67	0.22	0.35	0.13	6.11
CaO	0.01	1.07	4.84	0.03	4.69	0.11	0.22	0.05	5.03
Na ₂ O	0.05	0.01	0.04	—	4.13	0.08	0.20	—	3.54
K ₂ O	0.01	0.27	0.13	0.25	1.15	0.62	0.43	0.52	2.18
P ₂ O ₅	0.01	0.07	0.03	0.07	0.54	0.08	0.02	0.08	0.52
LOI	0.01	5.76	4.45	5.67	3.89	5.88	1.28	5.76	0.10
Parts per million ^c									
Ag	0.1	—	—	—	×	—	—	—	×
As	1	15	7	14	0	15	8	14	1
Au (ppb)	1	—	—	—	×	—	1	—	×
Ba	2	113	55	94	1	355	557	222	7
Be	0.1	1	—	1	0	1	—	1	0
Bi	0.1	—	—	1	×	—	—	—	×
Cd	0.1	—	—	—	×	—	—	—	×
Ce	0.05	23	8	23	0	35	12	32	1
Co	0.2	8	3	8	0	12	7	10	2
Cr	10	328	229	265	2	264	191	220	2
Cu	2	30	13	27	0	38	16	34	1
Ga	0.5	23	10	22	0	23	7	23	1
In	0.05	—	—	—	×	—	—	—	×
La	0.05	13	4	13	0	17	6	17	1
Li	0.1	10	3	10	0	13	4	12	1
Mo	0.1	1	1	1	1	1	1	1	1
Nb	0.2	15	10	13	2	16	6	15	2
Ni	2	22	8	21	0	27	10	25	1
Pb	1	25	8	25	0	27	8	25	1
Pd (ppb)	0.5	—	—	—	×	—	1	—	×
Pt (ppb)	0.5	1	1	1	2	1	1	1	3
Rb	0.05	19	8	17	1	39	20	37	2
S (%)	0.005	—	—	—	×	—	—	—	×
Sb	0.1	1	1	1	0	1	1	1	1
Sc	2	17	7	17	0	18	5	18	0
Se	0.5	—	1	—	×	—	1	—	×
Sn	0.5	3	1	3	0	3	1	3	0
Sr	1	37	104	15	5	30	22	23	3
Ta	0.1	1	1	1	2	1	—	1	1
Te	0.5	—	—	—	×	—	—	—	×
Th	0.05	23	10	25	0	20	8	19	1
U	0.05	2	1	2	0	2	1	2	0
V	2	480	260	464	1	394	202	372	1
W	2	5	4	6	0	7	5	5	2
Y	0.05	8	3	7	1	12	4	11	1
Zn	5	28	12	30	0	44	19	40	1
Zr	5	192	69	185	0	182	53	176	1

NOTES: n number of samples
 ppb parts per billion
 a detection level
 b standard deviation
 c unless otherwise shown
 — less than detection level
 x insufficient data for calculation of skewness

Table 10. Summary statistics for regolith in lake systems (L_l) and regolith marginal to lakes (L_m)

		L_l ($n=9$)				L_m ($n=99$)			
	DL^a	Mean	SD^b	Median	Skewness	Mean	SD	Median	Skewness
Percent									
SiO ₂	0.05	58.87	28.80	69.10	-0.80	78.19	9.48	78.74	-0.47
TiO ₂	0.01	0.45	0.25	0.41	0.28	0.37	0.16	0.36	1.56
Al ₂ O ₃	0.05	5.90	4.11	4.71	0.89	6.64	3.80	6.02	0.87
Fe ₂ O ₃	0.01	8.53	8.36	5.49	1.27	8.54	5.53	6.85	2.01
MnO	0.01	0.03	0.03	0.03	0.74	0.18	0.80	0.05	7.90
MgO	0.01	2.48	3.90	1.15	2.45	0.56	0.53	0.39	1.43
CaO	0.01	6.87	11.50	0.28	2.04	0.32	1.23	0.04	6.29
Na ₂ O	0.05	0.80	1.23	0.35	2.31	0.18	0.19	0.11	1.08
K ₂ O	0.01	0.80	0.91	0.43	1.56	0.88	0.70	0.67	1.79
P ₂ O ₅	0.01	0.04	0.01	0.03	0.42	0.04	0.02	0.04	0.52
LOI	0.01	7.43	4.36	6.78	0.78	3.62	1.81	3.58	0.42
Parts per million ^c									
Ag	0.1	—	—	—	×	—	—	—	×
As	1	8	7	7	1	6	4	6	1
Au (ppb)	1	—	—	—	×	—	1	—	×
Ba	2	572	465	627	1	1611	939	1535	1
Be	0.1	1	1	—	1	1	—	1	1
Bi	0.1	—	—	—	×	—	—	—	×
Cd	0.1	—	—	—	×	—	—	—	×
Ce	0.05	26	25	18	2	34	17	31	1
Co	0.2	6	4	4	1	9	5	8	1
Cr	10	80	52	58	1	73	59	59	5
Cu	2	16	6	14	1	23	15	20	5
Ga	0.5	11	8	10	0	11	5	10	1
In	0.05	—	—	—	×	—	—	—	×
La	0.05	14	13	11	2	17	8	15	1
Li	0.1	13	8	13	1	16	10	14	1
Mo	0.1	1	1	1	1	1	1	1	7
Nb	0.2	9	7	6	2	8	5	7	2
Ni	2	19	23	14	2	18	11	15	2
Pb	1	17	10	15	0	23	13	21	3
Pd (ppb)	0.5	—	—	—	×	—	—	—	×
Pt (ppb)	0.5	—	1	—	×	—	—	—	×
Rb	0.05	38	46	14	2	45	32	39	2
S (%)	0.005	3	6	—	2	—	1	—	×
Sb	0.1	1	1	1	1	1	—	1	1
Sc	2	8	5	7	0	7	4	7	1
Se	0.5	—	—	—	×	—	1	—	×
Sn	0.5	1	1	1	0	2	1	2	1
Sr	1	961	2134	90	3	97	75	72	2
Ta	0.1	1	1	—	2	—	—	—	×
Te	0.5	—	—	—	×	—	—	—	×
Th	0.05	11	8	10	1	10	5	9	1
U	0.05	2	1	2	2	2	1	2	2
V	2	170	184	76	1	101	75	80	3
W	2	6	4	6	1	3	3	3	1
Y	0.05	8	6	6	1	9	4	9	1
Zn	5	24	19	17	1	35	17	32	1
Zr	5	90	48	81	0	89	37	85	1

NOTES: n number of samples
 ppb parts per billion
 a detection level
 b standard deviation
 c unless otherwise shown
 — less than detection level
 × insufficient data for calculation of skewness

Table 11. Summary statistics for sandplain (S) over Archaean granitoid and the Paterson Formation

		Ag (n=9)				Pa (n=8)			
	DL ^a	Mean	SD ^b	Median	Skewness	Mean	SD	Median	Skewness
Percent									
SiO ₂	0.05	87.33	7.19	91.57	-0.75	85.05	9.37	86.24	-1.22
TiO ₂	0.01	0.23	0.15	0.15	1.85	0.36	0.14	0.34	-0.03
Al ₂ O ₃	0.05	3.89	1.73	2.91	0.74	5.39	3.29	4.65	1.69
Fe ₂ O ₃	0.01	6.24	4.32	4.24	0.81	6.04	4.88	4.37	0.97
MnO	0.01	0.00	0.01	0.00	3.00	0.01	0.01	0.00	1.96
MgO	0.01	0.03	0.02	0.03	-0.21	0.08	0.08	0.04	1.77
CaO	0.01	0.01	0.02	0.00	2.22	0.02	0.02	0.03	-0.29
Na ₂ O	0.05	0.00	0.00	—	x	0.01	0.04	—	2.83
K ₂ O	0.01	0.23	0.16	0.14	0.90	0.28	0.26	0.19	1.20
P ₂ O ₅	0.01	0.01	0.02	0.01	1.45	0.02	0.02	0.03	0.17
LOI	0.01	1.86	1.03	1.22	1.10	2.57	1.64	1.98	2.13
Parts per million ^c									
Ag	0.1	—	—	—	x	—	—	—	x
As	1	6	6	5	2	5	5	5	1
Au (ppb)	1	—	1	—	x	—	—	—	x
Ba	2	55	31	49	0	212	171	154	2
Be	0.1	—	—	—	x	—	—	—	x
Bi	0.1	—	1	—	x	—	—	—	x
Cd	0.1	—	—	—	x	—	—	—	x
Ce	0.05	8	4	8	2	14	8	11	2
Co	0.2	2	1	2	2	3	1	3	1
Cr	10	74	51	61	1	83	50	79	0
Cu	2	9	3	8	1	11	5	11	0
Ga	0.5	7	4	5	1	9	5	8	1
In	0.05	—	—	—	x	—	—	—	x
La	0.05	5	2	4	2	8	4	6	1
Li	0.1	4	1	3	1	9	4	6	1
Mo	0.1	1	1	1	1	1	1	1	0
Nb	0.2	5	5	4	2	6	2	6	0
Ni	2	7	3	7	1	13	10	10	2
Pb	1	14	9	11	2	12	6	12	1
Pd (ppb)	0.5	—	—	—	x	—	—	—	x
Pt (ppb)	0.5	—	—	—	x	1	1	—	2
Rb	0.05	14	8	10	1	18	13	11	1
S (%)	0.005	—	—	—	x	—	—	—	x
Sb	0.1	—	—	—	x	—	—	—	x
Sc	2	4	3	3	1	5	4	4	1
Se	0.5	—	—	—	x	—	1	—	x
Sn	0.5	1	—	1	3	1	—	2	-1
Sr	1	8	3	9	-1	17	12	15	1
Ta	0.1	—	—	—	x	—	—	—	x
Te	0.5	—	—	—	x	—	1	—	x
Th	0.05	8	3	6	1	8	6	7	1
U	0.05	1	—	1	1	1	—	1	1
V	2	78	54	53	1	98	83	71	1
W	2	3	2	3	2	4	3	4	0
Y	0.05	3	1	3	2	5	2	4	1
Zn	5	7	4	6	1	11	7	9	2
Zr	5	67	20	61	1	81	34	69	1

NOTES: n number of samples
 ppb parts per billion
 a detection level
 b standard deviation
 c unless otherwise shown
 — less than detection level
 x insufficient data for calculation of skewness

differences to the combined effects of a more varied source lithology for Paterson Formation regolith, and the less intense weathering of this material to produce the overlying regolith. The overall similarity of the two regolith populations on STANLEY is perplexing. Both populations are dominated by SiO_2 , which is indicative of intense chemical weathering that may have obliterated many characteristics of the parent lithology.

Stream sediments and sheetwash over the Wongawol Formation

Most regional geochemical surveys involve the sampling and subsequent analysis of only one type of sample medium, in order to avoid any bias introduced by different media types (Hawkes and Webb, 1962). Any such bias can be examined by a statistical comparison of regolith over one lithological unit, according to sample media. The Wongawol Formation has been chosen for this exercise as it affords sufficiently large sample populations for each media type. Summary statistics for 68 sheetwash and 47 stream-sediment samples over the Wongawol Formation are presented in Table 12. A statistical comparison of median values shows there is no difference in median values between the two populations. Thus, regolith chemistry is representative of this unit regardless of the media type. This is not surprising, as streams on STANLEY are ephemeral, short, and of low gradient, and thus the bedload is of local derivation.

Soil and sheetwash samples over the Wongawol Formation

Twenty-five soil and 68 sheetwash samples have been recorded as sample media types on STANLEY, with the higher proportion of the latter indicative of the poor profile development of most soils on STANLEY (Northcote et al., 1968). In order to determine if there is any compositional difference between soil and sheetwash, a statistical comparison of samples over the Wongawol Formation (Table 13) has been carried out. By restricting the populations to one geological unit, the effects of variable lithology on one or both populations are diminished. The results of the statistical analysis show that there is no likelihood of differences in the medians of any analytes above the 99% level, which is consistent with observations that soil development is particularly weak on STANLEY.

Speciality maps

The pH of regolith samples on STANLEY is shown relative to drainage in Figure 56. Eighty-five percent of regolith samples are acidic (i.e. $\text{pH} < 7$), with the few high pH samples found in drainage systems, especially on the eastern side of STANLEY. The positive correlation of high pH and drainage is particularly well illustrated in Kahrban Creek and channels draining south into Lake Carnegie in the southern part of the map sheet.

The conductivity of regolith (expressed in mS/cm) can be used as a guide to the amount of total dissolved solids,

and is an indicator of salinity (Fig. 57). Nine hundred and ninety-eight samples (99%) have values of less than 5, and of the remaining samples, seven have values of 5 – 10 mS/cm, six samples range between 10 and 15 mS/cm, and 1 sample has a value of 16.3 mS/cm (GSWA 168215). The highest values are reported from samples in the vicinity of Lake Burnside, and in the southern central part of STANLEY near Lake Carnegie.

Mineralization potential

Mineral exploration employing surface geochemistry (Plate 2) has been conducted over areas southwest of the Glenayle Fault on STANLEY. Eighty-four percent of projects tabulated in Appendix 2 have focused on base metal-related exploration, although several of these have also carried out mineralogical assays related to diamond exploration. The GSWA regional regolith-geochemistry program carried out on STANLEY has highlighted several areas worthy of further investigation in terms of potential mineralization. These are as follows:

- Some regolith samples on, or near to, the Wongawol Formation in the southern central part of STANLEY have high concentrations of MnO, reaching 7.21 % near Jublejarrah Pool (Fig. 9). Some samples also have anomalous or relatively high concentrations of other analytes, including Na_2O , K_2O , Ba, Be, Ce, Co, Cu, La, Li, Nb, Ni, Rb, Sn, Sr, Y, and Zn. Site observations include black, possibly manganiferous sand, manganese encrustations on lithic clasts, and some quartz veining. Adamides and Pirajno (in prep.) have discussed the chemistry of three iron- and manganese-rich rock samples from southwest of Thurraguddy Bore in this area. These rocks contain up to 1.21% MnO and 10.14% Fe_2O_3 , as well as high concentrations of Ba (up to 7800 ppm), Bi (10.4 ppm), Cu (320 ppm), Pb (520 ppm), and Zn (114 ppm). Adamides and Pirajno (in prep.) have drawn comparisons between these rocks and stratiform manganiferous deposits elsewhere (Schissel and Aro, 1992), arguing for the deposition of Mn-rich sediments landward of an anoxic basin in which black shales were deposited.
- A series of regolith samples over parts of the Chiall, Yelma, and Frere Formations, roughly within a 25 km radius of Earahedy Station in the western part of STANLEY, contain relatively high concentrations of Fe_2O_3 , P_2O_5 , Ag, Sn, Cr, Mo, As, Bi, Ga, Sb, Se, and Te. This area is characterized by local- and regional-scale deformation, including quartz veining, which is also responsible for the deformation of Earahedy Group rocks (Pirajno, F., 1999, pers. comm.). Adamides and Pirajno (in prep.) have discussed the chemistry of three rock samples from part of the Chiall Formation in this area. These rocks have high MnO (up to 5.03%), Fe_2O_3 (up to 22.38%), Ba (5400 ppm), Co (620 ppm), Cu (1400 ppm), Pb (580 ppm), and Zn (760 ppm) contents. In contrast to the stratiform style of mineralization further to the southeast, they have argued for structurally controlled hydrothermal vein mineralization.

Table 12. Summary statistics for stream sediments and sheetwash samples over the Wongawol Formation

		Stream sediments (n=47)				Sheetwash (n=68)			
	DL ^a	Mean	SD ^b	Median	Skewness	Mean	SD	Median	Skewness
Percent									
SiO ₂	0.05	72.31	10.89	72.95	-0.54	74.74	73.84	8.85	0.22
TiO ₂	0.01	0.42	0.16	0.42	1.67	0.42	0.42	0.13	-0.15
Al ₂ O ₃	0.05	8.66	3.58	8.43	-0.15	8.60	8.03	4.06	0.39
Fe ₂ O ₃	0.01	8.32	4.35	6.79	1.05	8.36	7.03	3.92	1.08
MnO	0.01	0.16	0.15	0.10	2.01	0.18	0.09	0.43	7.21
MgO	0.01	0.89	0.61	0.84	1.46	0.73	0.57	0.56	0.78
CaO	0.01	1.90	4.39	0.29	3.86	0.51	0.08	1.61	4.85
Na ₂ O	0.05	0.52	0.44	0.42	0.80	0.30	0.24	0.29	1.33
K ₂ O	0.01	1.68	0.94	1.48	0.35	1.34	1.04	0.90	0.95
P ₂ O ₅	0.01	0.05	0.02	0.05	0.33	0.05	0.05	0.02	0.93
LOI	0.01	4.73	3.64	3.64	2.82	4.29	4.24	1.81	0.47
Parts per million ^c									
Ag	0.1	—	—	—	×	—	—	—	×
As	1	8	4	9	0	7	7	4	0
Au (ppb)	1	—	1	—	×	—	—	1	×
Ba	2	1217	876	822	2	1296	944	969	2
Be	0.1	2	1	2	0	1	1	1	0
Bi	0.1	—	—	—	×	—	—	—	×
Cd	0.1	—	—	—	×	—	—	—	×
Ce	0.05	56	22	57	0	47	41	21	1
Co	0.2	16	13	14	4	13	12	7	1
Cr	10	61	29	54	2	70	57	43	3
Cu	2	27	9	25	1	27	25	13	2
Ga	0.5	12	4	12	0	12	12	5	0
In	0.05	—	—	—	×	—	—	—	×
La	0.05	27	10	27	0	23	20	10	1
Li	0.1	19	8	19	1	20	18	11	1
Mo	0.1	1	—	1	0	1	1	—	1
Nb	0.2	13	7	11	0	11	9	7	2
Ni	2	25	14	21	2	21	19	11	1
Pb	1	32	17	28	2	29	26	15	2
Pd (ppb)	0.5	—	—	—	×	—	—	—	×
Pt (ppb)	0.5	—	1	—	×	—	—	—	×
Rb	0.05	82	42	77	0	69	62	41	1
S (%)	0.005	—	—	—	×	—	—	—	×
Sb	0.1	1	1	1	2	1	1	—	0
Sc	2	8	3	8	1	8	8	3	0
Se	0.5	—	—	—	×	—	—	1	×
Sn	0.5	2	1	2	0	2	2	1	0
Sr	1	75	54	54	2	72	56	44	1
Ta	0.1	1	1	1	5	1	1	—	2
Te	0.5	—	—	—	×	—	—	—	×
Th	0.05	11	3	11	0	11	11	3	0
U	0.05	2	1	2	1	2	2	1	2
V	2	85	48	66	2	94	80	47	1
W	2	5	4	5	1	4	4	3	1
Y	0.05	15	6	15	1	13	12	5	0
Zn	5	49	17	49	0	48	49	19	0
Zr	5	120	38	120	0	108	106	37	0

NOTES: n number of samples
 ppb parts per billion
 a detection level
 b standard deviation
 c unless otherwise shown
 — less than detection level
 x insufficient data for calculation of skewness

Table 13. Summary statistics for soil and sheetwash samples over the Wongawol Formation

		Soil (n=25)				Sheetwash (n=68)			
	DL ^a	Mean	SD ^b	Median	Skewness	Mean	SD	Median	Skewness
Percent									
SiO ₂	0.05	73.68	9.07	72.94	0.24	74.74	73.84	8.85	0.22
TiO ₂	0.01	0.43	0.14	0.45	-0.27	0.42	0.42	0.13	-0.15
Al ₂ O ₃	0.05	9.72	4.21	10.34	-0.26	8.60	8.03	4.06	0.39
Fe ₂ O ₃	0.01	7.46	3.37	6.64	0.86	8.36	7.03	3.92	1.08
MnO	0.01	0.10	0.07	0.09	0.85	0.18	0.09	0.43	7.21
MgO	0.01	0.87	0.68	0.75	0.81	0.73	0.57	0.56	0.78
CaO	0.01	0.74	1.34	0.10	2.37	0.51	0.08	1.61	4.85
Na ₂ O	0.05	0.29	0.37	0.14	2.59	0.30	0.24	0.29	1.33
K ₂ O	0.01	1.61	1.03	1.26	0.49	1.34	1.04	0.90	0.95
P ₂ O ₅	0.01	0.05	0.02	0.04	2.15	0.05	0.05	0.02	0.93
LOI	0.01	4.78	1.83	4.66	0.02	4.29	4.24	1.81	0.47
Parts per million ^c									
Ag	0.1	—	—	—	×	—	—	—	×
As	1	8	5	8	2	7	7	4	0
Au (ppb)	1	—	1	—	×	—	—	1	×
Ba	2	1134	917	879	2	1296	944	969	2
Be	0.1	2	1	2	0	1	1	1	0
Bi	0.1	—	—	—	×	—	—	—	×
Cd	0.1	—	—	—	×	—	—	—	×
Ce	0.05	50	22	51	0	47	41	21	1
Co	0.2	11	5	12	0	13	12	7	1
Cr	10	64	35	55	2	70	57	43	3
Cu	2	24	8	22	1	27	25	13	2
Ga	0.5	13	5	13	0	12	12	5	0
In	0.05	—	—	—	×	—	—	—	×
La	0.05	26	12	27	0	23	20	10	1
Li	0.1	22	12	20	1	20	18	11	1
Mo	0.1	1	1	1	0	1	1	—	1
Nb	0.2	18	25	12	4	11	9	7	2
Ni	2	18	8	17	1	21	19	11	1
Pb	1	26	8	24	1	29	26	15	2
Pd (ppb)	0.5	—	—	—	×	—	—	—	×
Pt (ppb)	0.5	—	—	—	×	—	—	—	×
Rb	0.05	81	48	68	0	69	62	41	1
S (%)	0.005	—	—	—	×	—	—	—	×
Sb	0.1	1	1	1	3	1	1	—	0
Sc	2	9	4	9	0	8	8	3	0
Se	0.5	—	—	—	×	—	—	1	×
Sn	0.5	2	1	2	0	2	2	1	0
Sr	1	73	66	50	3	72	56	44	1
Ta	0.1	1	2	1	5	1	1	—	2
Te	0.5	—	—	—	×	—	—	—	×
Th	0.05	12	4	12	0	11	11	3	0
U	0.05	2	1	2	0	2	2	1	2
V	2	83	35	75	1	94	80	47	1
W	2	6	6	4	1	4	4	3	1
Y	0.05	13	5	12	0	13	12	5	0
Zn	5	48	22	47	0	48	49	19	0
Zr	5	117	43	113	1	108	106	37	0

NOTES: n number of samples
 ppb parts per billion
 a detection level
 b standard deviation
 c unless otherwise shown
 — less than detection level
 x insufficient data for calculation of skewness

- Spot-concentration maps, an additive-index approach, and aeromagnetic data have shown that dolerite is more extensively developed on STANLEY than previously thought. In the northwestern part of STANLEY, regolith samples (predominantly from dolerite-sourced iron-rich sandplain) contain several anomalous Pd values of 3.0 ppb, and Pt values up to 7.0 ppb. The maximum values of both these platinum group elements (PGEs) is found over the Sunbeam Group in the southeast of STANLEY, where little dolerite has been mapped. Sulfide minerals are accessory phases in dolerites at Digby Hill and Faulkne Bore, near Glenayle Station. The distribution and nature of the dolerite deserves further examination, particularly in conjunction with newly acquired gravity data that could be used to model the thickness of these intrusive bodies. On MOUNT EGERTON, Morris et al. (1998) recorded values of up to 19 ppb Pd, 31 ppb Pt, and 7 ppb Au in areas of dolerite, and showed that dolerite formed a significant part of the clast population in the majority of samples with elevated precious-metal abundances in this area. The relationship of PGE abundances and dolerite on STANLEY provides further evidence of dolerite-related mineralization potential.
- The discovery of several microdiamonds at the Jewell Kimberlite prospect in the eastern part of STANLEY indicates that this area has potential for further discoveries of precious gemstones.

Conclusions

Regional regolith and geochemical mapping of STANLEY has involved the collection and subsequent analysis of 1012 samples at a nominal density of one per 16 km², comprising roughly equal numbers of sheetwash (368) and sandplain (315), in addition to stream sediments (212), lake sediments (53), and soil samples (64). Multi-element analysis of regolith samples has been carried out under prescribed analytical protocols. Precision and accuracy are generally good, and a sufficient number of standards and replicate samples were analysed to track any deviations from prescribed conditions of precision and accuracy. Analysis of 12 samples by a second laboratory showed some analytical bias, especially for Ce, Cu, Nb, Rb, W, Y, and Zr. All analyses of standards and replicates are provided in a digital form, in order to allow any further evaluation of data quality.

The STANLEY project has confirmed the results of previous programs that throughout much of Western Australia bedrock is the major control on the chemistry of regolith. In the case of STANLEY, an understanding of the relationships between regolith chemistry and bedrock geology has been enhanced by new results from more detailed bedrock mapping at 1:100 000 scale, which is currently in progress within GSWA. In particular, regolith chemistry shows that the newly defined Sunbeam Group and intrusive dolerites northeast of the Glenayle Fault form a coherent group in terms of regolith chemistry, compared to the Earraheedy Group southwest of the fault.

Residual regolith accounts for only 3% by area on STANLEY. Its is confined to areas of dolerite and parts of the Permian Paterson Formation. Exposed-regime regolith, which largely encompasses areas of outcropping bedrock and subcrop, occupies 17% by area on STANLEY, and has been subdivided according to bedrock composition. Colluvium (6%), sheetwash (24%), and alluvial-related deposits (alluvium in stream channels, floodplain deposits, and lacustrine regolith; 8% in total) are subordinate to three types of sandplain, which together account for 31% of all regolith. Sandplain of demonstrably eolian origin, as shown by well-developed dune forms and a quartz-dominated mineralogy, accounts for 8% of regolith by area.

Spot-concentration maps largely highlight the control on chemistry by bedrock, especially that exerted by dolerite intruding the Sunbeam Group, north of the Glenayle Fault. Areas of dolerite can be identified not only by relatively high concentrations of components such as TiO₂, Sc, and V, but also by analytes at low concentrations, such as In, Ta, and Te. A greater extent of dolerite than previously mapped is shown by several analytes, and by a contoured additive-index approach combining several analytes associated with mafic igneous rocks. The proposed distribution is consistent with that shown by recently acquired airborne magnetics. Large parts of the Sunbeam Group are covered by an iron-rich sandplain unit (Sf). Statistical comparison of population medians for these data compared to other regolith types, combined with the mutual relations of regolith types derived from satellite imagery and aerial photography, show that this material has significant input from underlying dolerite and ferruginous duricrust derived from weathering in situ of dolerite. Other examples of bedrock control include Mn-rich regolith over parts of the Wongawol Formation in the southern central part of STANLEY and within a 25 km radius of Earraheedy Station. The former equates to areas of stratiform Mn mineralization, whereas the latter corresponds to an area of localized deformation related to tectonic reworking of parts of the Earraheedy Group (Adamides and Pirajno, in prep.; Pirajno, F., 1999, pers. comm.).

In parts of STANLEY, the effects of bedrock control on regolith chemistry have been replaced by control exerted by regolith-forming processes. Examples include lake sediments whose carbonate- and sulfate-rich nature is shown by elevated CaO, MgO, LOI, Sr, U, and S values, and eolian material in the northeast of STANLEY, which is delineated by well-developed dune morphology and a quartz-dominated mineralogy.

In order to examine variations in chemistry according to regolith type, most statistical comparisons have been carried out over a limited range of bedrock types, principally northeast of the Glenayle Fault over the Sunbeam Group and dolerites. As for KINGSTON (Pye et al., 2000), downslope variations in regolith are largely controlled by physical rather than chemical weathering, as shown in a comparison of exposed-regime regolith (*Xmh*) and colluvium (*Cmh*) derived from dolerites. Even further downslope, where regolith becomes more heterogeneous in terms of content, dolerite exerts a strong

influence on chemistry, as shown by statistical analysis of dolerite-sourced colluvium (*Cmh*) and heterogeneous colluvium (*Cl*). The strong influence of dolerite on iron-rich sandplain (*Sf*) has been demonstrated by comparing population medians for this regolith type with heterogeneous sandplain (*Sl*), eolian regolith (*E*), and sheetwash (*W*). Two statistical tests have examined differences in chemistry according to sample media over the Wongawol Formation. In both cases (stream sediments compared to sheetwash and soil compared to sheetwash) there are no differences in population medians above the 99% level.

Several potential styles of mineralization have been identified. These include stratabound Mn-related mineralization in parts of the Wongawol Formation in the southern central part of STANLEY, structurally controlled Mn–Ba and base metal mineralization over parts of the Earahedy Group near Earahedy Station, PGE mineralization in dolerites in the northwest and southeast of the map sheet, and diamondiferous kimberlites.

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Appendix 1

Gazetteer of localities

GDA coordinate			GDA coordinate		
Locality	Easting	Northing	Locality	Easting	Northing
Aqua Spring	439938	7158547	Mount Agnes	494310	7134513
Aurora Bore	376994	7162620	Mount Bates (Malanga)	491099	7157022
Birthday Bore	364897	7156672	Mount Bunday	420151	7230822
Bloodwood Well	440833	7160621	Mount Cecil Clifton	493698	7134044
Bottom Jungarra Bore	485240	7182553	Mount Evelyn	374435	7178769
Breakaway Bore	356661	7126298	Mount Hooley	492660	7135783
Bruce Bore	353961	7149930	Mount Hoskin	453054	7130863
Bunbandanoo Hill	455156	7169562	Mount Moore (Coondoo Noodoo)	448166	7165550
Carnegie	497453	7147049	Mount Moore Well	447046	7159262
Carool Bluff	459616	7198686	Mount Normanhurst	444290	7225301
Christmas Bore	362921	7169545	Mount Onslow (Beeahrgoo)	494712	7149573
Cooba Cooba Pool	458788	7177606	Mount Ooloongathoo	355350	7183025
Coomboorangoon Pool	464371	7165965	Mount Orme	472990	7180279
Coonabildie Bluff	468819	7150314	Mount Pritchard	498570	7161513
Coorarinee Hill	480264	7162482	Mount Royal	374883	7177211
Coringabba Hill	496917	7169806	Mount Sir Gerard	441227	7206006
Crow Bore	411337	7188014	Needoo Hill	461736	7165228
Deep Well	479282	7134382	Neekoodanoo Hill	495247	7128499
Defiance Bore	369507	7160960	Niminga Well	468427	7148174
Devils Bore	374795	7175706	Nineteen Mile Bore	471042	7131983
Digby Hill	389057	7213539	No 8 Bore	419404	7189638
Earaheedy	357998	7168640	No 10 Bore	363014	7178076
Faulkne Bore	409890	7201499	No 14 Bore	375398	7171097
Gabby Bore	360293	7170343	No 15 Bore	377287	7169676
Gap Well	421803	7214598	No 16 Bore	381380	7170023
Gidgee Bore	413020	7192370	Nooloo Breakaway	456705	7135689
Glenayle	403830	7205383	Nunegnoo Pool	397734	7178188
Gooran Gooran Hill	494890	7129426	Nuneri Pool	415802	7142539
Granite Bore	441268	7216428	One Gum Bore	453880	7210707
Hamilton Bore	375541	7143865	Pinnacle Bore	443004	7176016
Hegarty Bore	382145	7149730	Point Montgomery	494135	7160988
Henderson Bore	353317	7178028	Point Sir John	492665	7158607
Henry Bore	363058	7175080	Pumpkin Well	406014	7219119
Hoskin Well	454073	7127722	Quarters Bore	368876	7173557
Hoskin Yard Well	459573	7125448	Quartz Bore	352468	7160687
Hunt Well	486099	7147395	Royal Bore	369000	7142850
Jackies Well No 1	431761	7160881	Sandstone Bore	474794	7189548
Jimmys Well	400350	7208975	Seven Bore	353023	7169041
Jimnyumbah Hill	470239	7170214	South Pope Bore	359436	7151296
Jioorgah Hill	481646	7150682	Stanley Bluff (Oyanjoo)	407527	7202838
Jublejarrah Pool	436158	7152098	Stony Point Bore	492178	7172808
Kaljahr Pinnacle	443017	7173460	Sunday Well	434182	7219374
Karinga Hill	484234	7153495	Sydney Head Pass	377560	7178580
King Bluffs	455092	7171554	Table Hill	491945	7163360
Kipillon Spring	436522	7150572	Thabiddie Hill	495782	7166715
Kiwi Bore	425946	7209393	The Hump	391300	7215300
Lake Augusta Well	457093	7153358	Thurraguddy Bore	402673	7133044
Lake Bore	368861	7151126	Trucking Yard Bore	406386	7206800
Lynn Bore	431793	7208895	Wallaby Bore	368693	7147135
Maiska Well	436903	7161267	Well Spring (No 9 Well)	357547	7232518
Malmac Bore	427360	7177614	Wilson Bore	373727	7148268
Marlooyanoo Hill	467432	7197355	Wommaoogalh Spring	471421	7159429
Max Bore	369208	7138080	Wonga Bore	366393	7146043
McIndoes Bore	372813	7167315	Yallum Bore	423985	7186656
Minda Hill	461456	7162027	Yallum Hill	427846	7186539
Mingol Camp	435652	7134130	Yarra Bore	447666	7204506
Mobadoo Bore	420769	7134587	Yunga Pool	396729	7130877

Appendix 2

Open-file surface geochemistry for STANLEY as at June 1999

Key

ID No:	Project reference number allocated for these notes (see Plate 3)
M No:	GSWA project reference number
	An asterisk beside the M number indicates that not all the samples for the listed activities fall within STANLEY; that is, the total number of samples includes some taken on adjacent sheets
I No:	The Item number, or the Department of Minerals and Energy's (DME's) 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
Year:	The year that the report was written
Activity Type:	The geochemical exploration activity (drilling details are only included if analytical samples are taken within 0–4 m depth): 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 FA: Fire assay ICP-OES: Inductively coupled plasma-optical emission spectrophotometry ICP-MS: Inductively coupled plasma-mass spectrometry MMI: Mobile metal ions SEM: Scanning electron microscope XRF: X-ray fluorescence
Activity elements:	The elements for which analyses were carried out
Analyst:	ALS: Australian Laboratory Services CRAE: CRAE Exploration Pty Ltd (Belmont Laboratory) SPL: Stockdale Prospecting Limited WMC: Western Mining Corporation Limited
DD:	A 'Y' in this column indicates deep drilling has taken place in the activity area
Comment:	Various sample details such as the sieve size fraction, sample density, and so on, depending on the information provided in the report

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

Appendix 2. Open-file surface geochemistry

ID no.	M no.	Item no.	A no.	Year	Activity type	No.	Method	Activity elements
1	2329	855	8454	1979	RAB	78	XRF	Cu,Ni,Pb,U,Zn
2	4950	3292	22119	1987	SSED SOIL	44 24		
3	4974	3373	22344	1987	SOIL	149		
4	5030/2	3409	23128	1988	SSED "	351	ICP / AAS	Cr,Ni,Ba
	5030/3	4248	31604	1990	SSED	641		
5	5306/1	8361	24045	1988	SOIL SOIL "	353 466		Co,Cr,Ni,Zn,Ti,Zr,Nb,Ba,Ce,Sb,Th As,Co,Cr,Cu,Fe,Ni,Pb,Zn,Na ₂ O,MgO,P ₂ O ₅ ,K ₂ O,CaO, TiO ₂ ,MnO,Y,Zr,Nb,Ba,La,Ce
					SSED	90		
					RC	1		Co,Cr,Ni,Sb,Zn,Ti,Zr,Nb,Ba,Ce,Th
					SOIL	20		As,Co,Cr,Fe,Ni,Pb,Sb,Th,U,Zn,Ba,Ce,Nb,Zr,CaO,K ₂ O,La, MgO,MnO,Na ₂ O,P ₂ O ₅ ,Se,Sr,Ti,TiO ₂ ,Y
5a			39265	1993	RC " " " SOIL	38 7	FA/ICP-MS AAS ICP-MS XRF	Au,Pt,Pd Ag,Cr,Cu,Fe,Mn,Ni,Pb,Zn,Mg Bi,Co,Mo,Sb,Th,U,W,Ba,Ce,La,Nb,Zr As,Sn
6	8626/3	9076	49260	1996	SOIL " " SOIL	36 47	ICP-MS ICP-OES MMI ICP-OES	As,Au Ag,Bi,Co,Cu,Fe,Mn,Mo,Ni,Pb,Sb,Th,U,W,Zn,I,Ba,Ca,Cd,Ce, Hg,Sc,Sn,Te,Tl,Zr,Hf,Nb Cu,Pb,Zn,Cd Ag,Au,Cu,Fe,Mn,Mo,Sb,Th,U,Zn,Ba,Cd,Hg,Sn,Te,Tl
6a			49262	1996	SOIL	90	ICP-OES	Ag,Au,Cr,Cu,Fe,Mn,Mo,Pb,Sb,Th,U,W,Zn,Ba,Cd,Hg,Sn,Te,T
6b			49263	1996	SOIL "	44	ICP-MS ICP-OES	As,Au,I,Ba,Ca,Cd,Ce,Hg,Sc,Sn,Te,Tl,Zr,Hf,Nb Ag,Bi,Co,Cu,Fe,Mn,Mo,Ni,Pb,Sb,Th,U,W,Zn
7	8630	7507	40845	1994	NGRD	11	SEM	

surveys for STANLEY as at June 1999

Analyst	DD	Comment on samples
WMC	Y	D: 0-4 m
WMC "		W: 20 kg, Mesh: -4 mm, samples inspected for heavy minerals, selected grains analysed "
CRAE		Samples inspected for chromite and diamonds, 10 chromite grains probed, sample density: 16km, Mesh: -4.0 mm, W: 40 kg
WMC		Mesh: -200 # Mesh: -1.68 mm, W: 2 kg, samples observed for kimberlite indicator minerals
WMC	Y	Sample characteristics and mineralogy determined, inspected for kimberlite minerals, some mineral grains analysed
Analabs CRAE Pilbara Laboratories	Y	Mesh: -80 #, W: 40 kg Loam samples inspected for kimberlite indicator minerals and microdiamonds
CRAE Analabs		Inspected for kimberlite indicator minerals and microdiamonds Auger samples
Analabs " " "	Y	D: 0-5 m
CRAE		W: 18 kg, Mesh: +0.25 mm, loam samples inspected for kimberlite indicator minerals
Ultra Trace Pty Ltd "		Mesh: -200 #, W: 30 gms Mesh: -200 #, W: 30 gms
Analabs Ultra Trace Pty Ltd		Mesh: -80 #, W: 300-500 gms Mesh: -200 #, DL: 0.04 ppm
Ultra Trace Pty Ltd		Mesh: -200 #, W: 30 gms
Ultra Trace Pty Ltd "		Mesh: -200 #, W: 30 gms
CRAE		Gravel samples inspected for kimberlite indicator minerals, selected grains submitted for SEM analysis

Appendix 2

ID no.	M no.	Item no.	A no.	Year	Activity type	No.	Method	Activity elements
8	9098	7917	42718	1994	SSED SOIL	53 65		
9	10060	9516	47489	1996	SOIL " SSED	28 1	AAS OES	Ag,Cu,Ni,Pb,Zn Cr,P,Ba
			49861	1997	SOIL SSED	36 3	OES	Ag,Cr,Cu,Ni,Pb,Zn,Ba,P
			52886	1997	SOIL SSED	38 3	OES	Ag,Cr,Cu,Ni,Pb,Zn,Ba,P
10	10166	8693	48034	1996	SSED "	36	BCL ICP	Ag,Au,Pd,Cd Ag,As,Bi,Co,Cr,Cu,Fe,Mn,Ni,Pb,Sb,V,Zn,Ba,K,Cd,Mg,Zr
11	10167	8694	48035	1996	SOIL "	95	FA ICP	Au,Pd As,Bi,Co,Cr,Cu,Mo,Ni,Pb,Sb,V,W,Zn,Ba,Cd,Zr
12	10168	8695	48036	1996	SOIL	158	ICP	Ag,Au,Bi,Co,Cr,Cu,Mo,Ni,Pb,Sb,V,W,Zn,Ba,Cd,Pd,Zr

(continued)

Analyst	DD	Comment on samples
SPL Perth / SPL Melbourne "	Y	Mesh: -1.0 + 0.3 mm and -2.0 mm, samples inspected for chromite grains Mesh: -1.0 + 3.0 mm, Vol: 20 litres, loam samples inspected for chromite grains
Genalysis "		Mesh: - 2 mm and +2 mm - 5 mm
Independent Diamond Laboratories		Mesh: - 2 mm, W: 24 kg, Samples inspected for kimberlite indicators and other minerals
Genalysis Diamond Metallurgical Services		Mesh: -2 mm, +2 mm -5 mm Mesh: - 2mm, W: 20-28 kg, samples inspected for kimberlite indicator minerals
Genalysis Diamond Metallurgical Services		W: 1-2 kg Mineralogy observed for size fractions -1.0 mm and -0.2 mm, W: 22-26 kg
Assay Research Australia ALS		DL: 0.1 ppb, W: 2 kg, Mesh: -2 mm W: 500 gm
ALS "		Mesh: -80 #, D: 20 cm, W: 100 gms
ALS		DL: 0.001 ppm, Mesh: -80 #, D: 20 cm, W: 100 gm, poor sample location

Appendix 3

Summary of sampling procedure, regolith classification, and analytical procedures

Regolith sampling

The aim of the Geological Survey of Western Australia's (GSWA's) regolith sampling program is to sample regolith from sites representative of the 4 × 4 km sampling polygon of interest. The preferred sampling medium is active stream sediment, sampled from lower order streams draining the sample polygon. In areas where drainage is absent or only weakly developed, sheetwash (colluvium), soil, sand, or lake sediment is sampled. Sampling sites are chosen using Landsat Thematic Mapper (TM) imagery and topographic maps, combined with a 4 × 4 km grid overlay. The site locations are digitized and assigned a unique site name made up of part of the relevant 1:100 000 map sheet name and a number. For example, GRA95 would correspond to site 95 on the GRANITE PEAK* 1:100 000 sheet (on the NABBERU 1:250 000 sheet).

The actual sampling site in the field is determined by the geologist, who can move the site from the designated position in order to facilitate access, or avoid areas of human or animal activity, or areas of standing water.

Stream sediments

Stream sediments in single, well-defined channels are sampled by trenching perpendicular to the flow direction. Narrow streams are sampled from pits excavated along their length, whereas braided stream systems are sampled from pits in several individual channels.

Sheetwash (colluvium) or soil

Sample sites are selected towards the centre of the 4 × 4 km polygon. Where a clear slope direction can be identified, regolith is composited from three pits excavated 30 m apart, perpendicular to the slope direction. Where no clear slope direction can be identified, regolith is sampled from three pits forming the apices of an equilateral triangle, whose sides are 30 m long.

Lake sediments

Lake sites are chosen to maximize ease of access. They are sampled as for sheetwash with no discernible slope.

Sandplain

In areas of active sand dunes, sandplain samples are taken from three pits along the swale. In sandplain areas lacking active dunes, sampling is carried out as for sheetwash sites.

Prior to excavating pits or trenches, the top 5–10 cm of material is removed to minimize any surface-related contamination. Pits and trenches are excavated to a depth of 30 cm. If the excavated material is sufficiently dry, it is sieved at the site to –6 mm through a plastic sieve into a graduated sieve pan, then thoroughly mixed using a small shovel. Regolith, either sieved or unsieved, is divided into an archive sample (weighing about 3 kg) and an analytical sample (weighing about 2 kg) using graduated rings in the sieve pan. Information such as the unique GSWA sample number, site number, a map sheet identifier, and the relevant geologist's initials are recorded on each bag. A soft aluminium tag, on which the GSWA number is written, is included with the analytical sample. Analytical and archive samples are distinguished by the use of different-coloured nylon bag ties.

Sample-recording form

An example of the sample-recording form is shown in Figure 3.1. At each sampling site, the sample's MGA coordinates (GDA94 grid, read from a hand-held GPS), the sample-site number, GSWA number, sampling date, sampler's initials, and nature of sample (e.g. stream, sheetwash, channel, or pit) are recorded. The cross section is used to record the position of the sample in an idealized landform profile. The composition of the regolith is recorded in terms of iron-rich, lithic, and non-lithic components, using a series of letters signifying abundance (i.e. **Abundant**: > 30%; **Common**: 5–30%; **Rare**: 1–5%; **Trace**: < 1%). Within each category, the relative abundance of each component is recorded using a numerical system from 1 (most abundant) to > 1 (least abundant), or the A, C, R, T designations. Fresh bedrock-fragment types (if present) are recorded in the same way. Fields also exist for recording the nature of the surrounding regolith, any grain coatings, nature of fine-grained material, nature and distribution of bedrock and secondary units, and characteristics of the stream site (if appropriate). A free form section (Remarks) allows for specific entries pertinent to the site that are not covered in the preceding sections.

Regolith-materials classification

Three regolith-materials classification schemes have been used during the course of the GSWA regional regolith and geochemical mapping program. All three are based on the regolith-landform RED scheme of Anand et al. (1993) and

* Capitalized names refer to standard 1:100 000 and 1:250 000 map sheets.

Sheet <u>Stanley</u> Zone <u>51</u>	Loc/n No _____	GSWA No _____	Date _____
Site Ref _____	E _____	N _____	Sampler _____
Photo Y/N (Describe) _____			
Gravity		G1	G2
Channel <input type="checkbox"/>	Pit/Hole <input type="checkbox"/>	Single point <input type="checkbox"/>	Multipoint <input type="checkbox"/>
		Shtwsh	Creek Soil Lake Sand
Site Description:			
CLASTS	Gravel (2-5 mm) <input type="checkbox"/>	Stones (5-64 mm) <input type="checkbox"/>	Surrounding Regolith Code: Left _____ Right _____
	cobbles (64-256 mm) <input type="checkbox"/>	Boulders (>256 mm) <input type="checkbox"/>	
Abundant : >30% Common : 5-30% Rare : 1-5% Trace : <1%			Regolith Description:
Iron-rich Abnt/Comn/Rare/Tr <input type="checkbox"/> Lithic Abnt/Comn/Rare/Tr <input type="checkbox"/>			
<input type="checkbox"/> Pisoliths			
<input type="checkbox"/> Nodules <input type="checkbox"/> Ferrig/ granules			
<input type="checkbox"/> Ferrug. duricrust			
<input type="checkbox"/> Gossan fragments			
<input type="checkbox"/> Ferrug. Lithic fragments			
<input type="checkbox"/> Saprolite fragments			
<input type="checkbox"/> Ferruginous Saprolite fragments			
<input type="checkbox"/> Saprock fragments			
<input type="checkbox"/> Fresh b'rock fragments (below)			
<input type="checkbox"/> Vein quartz <input type="checkbox"/> Other silica			
Non-lith Abnt/Comm/Rare/Tr <input type="checkbox"/>		Clast lithology	
<input type="checkbox"/> Quartz (sand) <input type="checkbox"/> Feldspar		<input type="checkbox"/> Mafic	<input type="checkbox"/> BIF <input type="checkbox"/>
<input type="checkbox"/> Calcrete		<input type="checkbox"/> Ultramafic	<input type="checkbox"/> Sandstone <input type="checkbox"/>
<input type="checkbox"/> Hardpan		<input type="checkbox"/> Felsic	<input type="checkbox"/> Ark / Gwk
<input type="checkbox"/> MnO ₂		<input type="checkbox"/> Granite	<input type="checkbox"/> Shale/Siltstone
<input type="checkbox"/> Silcrete <input type="checkbox"/> Other _____		<input type="checkbox"/> Quartzite	<input type="checkbox"/> Chert
Secondary coating <input type="checkbox"/>		<input type="checkbox"/> Fe / Mn	<input type="checkbox"/> Siliceous <input type="checkbox"/> Calcareous <input type="checkbox"/> Clay
-2 mm Material <input type="checkbox"/>		<input type="checkbox"/> Sand (0.1-2 mm)	<input type="checkbox"/> Clay <input type="checkbox"/> Other _____ Colour _____
Rock O/c	Dist.	Dir.	Secondary Units Nearby
1. _____	_____ m	_____	Hardpan <input type="checkbox"/> Consolidated colluvium <input type="checkbox"/>
2. _____	_____ m	_____	Calcrete <input type="checkbox"/> Duricrust <input type="checkbox"/>
3. _____	_____ m	_____	Mot zone <input type="checkbox"/> Saprolite <input type="checkbox"/> Saprock <input type="checkbox"/>
4. _____	_____ m	_____	Gyps dune <input type="checkbox"/> Sand dune <input type="checkbox"/> Salt <input type="checkbox"/>
		Heading _____	Width _____ m
		<input type="checkbox"/> Single <input type="checkbox"/> Braided <input type="checkbox"/> Incised	
		Sieved to size: Y/N	Depth: _____
		Osize: _____ %	Usize: _____ %

REMARKS: _____

Figure 3.1. Sample-recording form, STANLEY

Anand and Smith (1994), where regolith is classified according to its position in an idealized landform profile as relict (R), erosional (E), or depositional (D). Relict-regime regolith is commonly in areas of higher topographic elevation (e.g. upland surfaces and plateaus), and includes areas of siliceous and ferruginous duricrust ('laterite'). The erosional regime includes areas of outcrop and subcrop where there is a net loss of material caused by downslope transport. Areas of net material gain comprise the depositional regime, including active alluvial channels, areas of sheetwash, overbank deposits, sandplain, and lakes.

The three schemes reflect an ongoing change in the focus of the GSWA's regolith geochemistry program, from relatively simple granite–greenstone associations of the Yilgarn Craton to more complex associations such as the Capricorn and Albany–Fraser Orogens.

Maps produced early in the GSWA regional regolith and geochemical mapping program focused on Archaean granite–greenstone associations of the Yilgarn Craton (e.g. MENZIES 1:250 000: Kojan and Faulkner, 1994; LEONORA 1:250 000: Bradley et al., 1995), which had few regolith-landform divisions, reflecting the lack of relief and limited number of lithologies. Regolith was subdivided according to its landform position (using R, E, D), slope position, and lithology. For example, in the erosional regime, E2v corresponded to erosional-regime regolith (E) derived from mafic igneous rock (v) that was upslope (2) from lithologically similar material that would be termed E4v. Alluvium of the depositional regime was separated using numerical qualifiers, such as DA4 (alluvium in active alluvial channels), DA5 (overbank deposits), DA7 (playa lake and associated deposits), and DA8 (calcrete). Sandplain was denoted as D9. This system has drawbacks, in that it only works well for lithologically simple map sheets, relies on a qualitative determination of slope position, and requires identification of the parent rock type to indicate the composition of regolith — the latter was commonly difficult for fine-grained, better sorted regolith, such as that of the depositional regime.

The shift in focus of the GSWA's regolith geochemistry program to Proterozoic successions of the Capricorn Orogen involved a change to map sheets with a relatively diverse lithology and physiography, combined with a less arid climate. This resulted in an increase in the number of regolith-landform divisions and increasingly complex regolith-landform maps. Several factors prompted a revision of the regolith-classification scheme. These included a need to simplify the regolith-landform maps, produce a more objective classification scheme, and introduce criteria that would enable the compositional classification of regolith independent of parent rock type. This change in scheme also coincided with the need for a universal regolith-classification scheme that could be used throughout GSWA.

The revised scheme retained the regolith-landform approach, and used a set of 11 primary codes for the subdivision of regolith in terms of landform position (Table 3.1). These codes aimed to satisfy a wide range of physiographic associations. The issue of regolith composition was addressed by a series of secondary codes,

including some designations for common regolith types (e.g. h: hardpan; w: consolidated colluvium) that were not strictly compositionally based. These secondary codes highlighted the composition of the regolith rather than the parent rock type. In situations where the parent rock type was identifiable (usually in the erosional regime), this could be designated using a set of tertiary codes (Table 3.1)

This revised scheme relied on placing the regolith in an idealized landform profile, and making basic macroscopic and mesoscopic (hand lens) observations about regolith composition. The scheme did not rely on detailed knowledge of regolith-forming processes. The revised scheme resulted in a reduction in the number of regolith-landform types, and hence a more simple regolith-landform map. In addition, the revised scheme allowed a more rigorous approach to statistical analysis of regolith chemistry according to regolith type, as there were usually larger sample populations for each regolith-landform subdivision.

Following implementation of this revised regolith-classification scheme on several GSWA 1:250 000 regolith-landform maps (e.g. MOUNT EGERTON: Morris et al., 1998; TUREE CREEK: Coker et al., 1998), several improvements were made to the scheme, as discussed by Hocking et al. (in prep.). These changes included expansion and some modification of the primary (environment or process), secondary (compositional), and tertiary (parent rock or cement) code sets, and the optional use of subscripts to primary, secondary, and tertiary codes to allow further subdivision of regolith.

An example of this approach to describe a gravel bar in an alluvial channel derived from ferromagnesian volcanic rock (basalt) would result in the code A_gmv_b , where A is a primary code denoting an alluvial environment, and the subscript ($_g$) indicates a gravel bar. The secondary code (m) defines the composition as ferromagnesian material, whereas the tertiary code (v) indicates derivation from volcanic parent rock. The subscript ($_b$) denotes the parent lithology as basalt. Lists of primary codes, selected primary code qualifiers, secondary codes and qualifiers, and tertiary codes with common qualifiers are shown in Tables 3.2 to 3.5.

Quality control during the analysis of regolith

Quality control aims to assess the precision and accuracy of chemical analysis using a series of standards (for which compositions are known), replicate and duplicate samples, and blank determinations. Precision is the closeness of agreement of independent test results obtained under prescribed conditions, whereas accuracy is the closeness of agreement between the result of a measurement and the true value (Thompson and Ramsey, 1995). Both precision and accuracy can only be reliably assessed when the analyte concentration is sufficiently above the detection level, which is the lowest level at which the analyte can be reliably measured using the technique under consideration. Precision is assessed using a series of

Table 3.1. Primary, secondary, and tertiary codes, prior to revision

Regolith code		Description
Primary codes — environment		
R	relict	Relicts of an ancient land surface, including overlying and proximal reworked material
E	erosional	Exposed rock, saprock, saprolite, with thin locally derived debris
C	colluvial	Proximal mass-wasting products grading into sheetwash. Noticeable slope
W	diluvial	Distal sheetwash; minimal gradient; poorly defined drainage
A	alluvial	Alluvium in fluvial channels, and distal floodplain deposits with recognizable drainage systems
O	overbank	Overbank alluvial deposits
L	lacustrine	Inland lakes, associated dunes, and playa deposits, and some coastal lakes (not formed by coastal barring). Includes saline and freshwater playas, and eolian deposits (e.g. gypsiferous dunes) associated with such lake systems
S	eolian	Eolian dunes and sandplains, including interdunes
B	beach	Deposits at or above high water mark, adjacent to marine and tidal-related areas
T	tidal	Deposits between high- and low-water marks
M	marine	Sea-bed deposits, extending from below wave base. Includes reefs
Secondary codes — composition		
b	black soil, gilgai	
c	clay-mineral rich	
e	evaporite	
f	iron rich (ferruginous)	
g	quartzofeldspathic	
h	hardpan	
k	carbonate rich (including calcrete)	
m	ferromagnesian	
q	quartz rich	
r	carbonaceous	
u	ultramafic	
w	compacted and/or weakly cemented material (includes consolidated colluvium)	
x	mineral-rich material	
y	gypsiferous	
z	siliceous (including silcrete)	
Tertiary codes — rock qualifiers and specified compositional qualifiers		
m	metamorphic	
p	plutonic	
v	volcanic	
s	sedimentary	
h	halite	
a	aluminous	
n	magnesite	

GSWA and laboratory reference standards for which there are consensus or recommended values. In the GSWA regional regolith and geochemical mapping program, precision is deemed acceptable if the percent relative standard deviation ($RSD\% = (\text{standard deviation}/\text{mean}) \times 100$) is less than 20 for multiple analyses, provided the analyte concentration is more than 20 times (in some cases 10 times) the detection level. Measurement of a replicate sample (i.e. a second analysis of the same sample pulp) also assesses precision, as well as any change in analytical conditions during a sample run (machine drift), and any variation in analytical conditions between batches (batch effects). The Half Relative Difference (HRD) factor ($(\text{assay \#1} - \text{assay \#2})/(\text{assay \#1} + \text{assay \#2}) \times 100$; Shaw et al., 1998) has been used to assess replication, with a value of 10% deemed acceptable.

Accuracy is assessed using GSWA and laboratory standard analyses, with an acceptable accuracy if the analyte concentration lies within 20% of the recommended or consensus value, provided the analyte concentration is greater than 10 or 20 times the detection

level. These data can also be used to assess machine drift and batch effects.

Background levels are assessed by periodic analysis of blanks, with acceptable background levels in the GSWA program being less than three times the detection level.

For each analytical batch of between 120 and 200 samples (batch size depends on the laboratory), up to three GSWA standards are included as blind checks (i.e. with the GSWA number only), resulting in about 10 standard analyses per map sheet. These standards include a laterite (IQC47), a gossan (IQC45), and an amphibolite (IQC42), which span a wide SiO_2 interval of 42–88%.

Rigorous application of criteria for acceptability of results in terms of accuracy and precision assumes sample homogeneity and the suitability of the analytical technique to the analyte under consideration. With a wide range in composition — Morris et al. (1997) reported a SiO_2 range of 7% to 96% for regolith on NABBERU (1:250 000) — and the concentration of resistate phases (e.g. rutile, chromite,

and zircon) lower in the landform profile, it is unlikely that one preparation or analytical technique is suitable for all samples. Morris et al. (1998) discussed this problem with regard to analysis of niobium on MOUNT EGERTON and TUREE CREEK (1:250 000). They concluded that precise and accurate analysis of high field strength elements such as niobium is difficult, as these elements were common in resistate phases, such as rutile, which are difficult to dissolve prior to analysis by inductively coupled plasma (ICP) techniques. One approach to reducing these problems is to use different preparation or analytical techniques depending on analyte concentration. For example, Morris et al. (1998) report chromium data for regolith on MOUNT EGERTON according to two techniques: for concentrations of less than 100 ppm, data are reported after mixed acid digestion and inductively coupled plasma mass spectrometric (ICP-MS) analysis; for values greater than 100 ppm, data are reported following fusion and mixed acid digest and inductively coupled plasma optical emission spectrometric (ICP-OES) analysis. Although this approach can produce more acceptable data, the niobium issue on MOUNT EGERTON and TUREE CREEK as discussed by Morris et al. (1998) was not resolved by using different preparation or analytical techniques. Another factor in this approach is that of cost, which increases with the number of sample digests or techniques employed.

Batch effects have been noted for gold in regolith on EDMUND (1:250 000; Pye et al., 1998) and GLENBURGH (1:250 000; Sanders et al., 1998). In both cases, gold at levels of less than 4 ppb (detection level of 1 ppb) were subject to batch control.

Quality-control data for regolith on STANLEY are presented as a series of digital datafiles on the accompanying floppy disk. A guide to this list of datafiles is presented as a digital file GUIDE.TXT. For GSWA standards, the consensus values are taken as averages of analyses carried out at individual laboratories during the course of the GSWA regolith program. Consensus values for laboratory standards have been provided by the respective laboratories.

Typical analytical schemes from three commercial laboratories are outlined below.

Genalysis Laboratory Services

All regolith samples were oven dried at GSWA's Carlisle base. Approximately 2 kg of each sample (either sieved to < 2 mm or to < 6 mm) was supplied to the laboratory. Following further drying, an aliquot of each sample was sieved to between 2 and 0.45 mm. This material was pulverized to < 75 µm in a zirconia ring mill (for analysis of SiO₂, TiO₂, Fe₂O₃, Al₂O₃, MnO, MgO, K₂O, and Cr), or a chrome-steel jumbo ring mill (for analysis of CaO, Na₂O, P₂O₅, Ag, As, Ba, Be, Bi, Cd, Ce, Co, Cu, Ga, In, La, Li, Mo, Nb, Ni, Pb, Rb, Sc, Se, Sn, Sr, Ta, Te, Th, U, V, W, Y, Zn, and Zr).

Seven different analytical methods were used:

1. Silver, As, Ba, Be, Bi, Cd, Ce, Co, Ga, In, La, Li, Mo, Pb, Rb, Sb, Sn, Sr, Te, Th, U, W, and Y were analysed

Table 3.2. Revised primary regolith codes

Primary landform code	Environment and process	Notes
R	Residual	Principally relicts of an ancient weathered land surface, derived by in situ weathering. Includes overlying proximal disaggregated and reworked material. Does not refer to relict-depositional regimes
X	Exposed	Used for rock (optional) and weathered rock of uncertain protolith
C	Colluvial	Proximal mass-wasting deposits grading into sheetwash with a significant to perceptible slope
W	Low-gradient slope	Distal sheetwash and slope deposits where the gradient is minimal, and drainage is not clearly defined
A	Alluvial/fluvial	Alluvium in channels. Includes deltaic deposits
F	Floodplain/overbank	Floodplain deposits in recognizable drainage systems, alluvial terrace deposits Grades into alluvium
L	Lacustrine	Inland lakes, dune and playa terrain, and some coastal lakes (those not formed by coastal barring). Includes saline and fresh-water playas and claypans, and minor eolian deposits directly associated with the lake system (fringing gypsiferous dunes, etc.)
E	Eolian	Eolian dunes, interdune areas, and sandplain
S	Sandplain	Dominantly sandplain, may be of residual or mixed origin
B	Wave-dominated coastal (beach)	Beaches, beach ridges, barrier bars and lagoons, and back-beach dunes
T	Tide-dominated coastal	Intertidal and supratidal flats and channels, estuaries, and mangrove flats
M	Marine	Marine deposits such as coralgal reefs, shell banks, and sea-grass banks

Table 3.3. Examples of primary code qualifiers

<i>Primary landform/process</i>	<i>Landform element or pattern</i>	<i>Suggested primary code</i>	<i>Suggested subscript code</i>
Colluvial (proximal slope)	Landslide	C	C _l
Wash (sheet-flood, distal slope)	Playa, pan	W	W _p
Floodplain	Delta	F	F _d
	Alluvial plain		F _p
Alluvial	Stream channel	A	A _c
	Delta		A _d
	Alluvial fan		A _f
	Gravel bar		A _g
Lacustrine	Fringing dunes	L	L _d
	Fringing bedded deposits		L _g
	Dune and playa terrain		L _m
	Lake, excluding fringing deposits		L _l
	Playa, pan		L _p
Eolian	Dunefield	E	E _d
	Dune		E _e
	Longitudinal dunefield		E _l
	Mobile dune		E _m
	Interdune pavements		E _p
	Lunette		E _u
Sandplain, residual, uncertain, and mixed	Gravel deflation pavement	S	S _p
Wave-dominated coastal (beach)	Beach (foreshore)	B	B _f
	Mobile dunes		B _m
Tide-dominated coastal	Tidal bar, in channel	T	T _b
	Tidal delta		T _d
	Estuary		T _e
	Lagoon		T _l
Marine	Coral reef	M	M _r

by ICP-MS using a combined mixed acid digest (Genalysis code A/MS). The pulverized sample was digested in a hydrofluoric-perchloric-nitric acid mixture for at least 24 hours, evaporated to fume dryness and leached in hydrochloric acid.

- Manganese oxide, Na₂O, P₂O₅, Cr, Cu, Ni, Sc, V, and Zn were analysed by ICP-OES using a mixed acid digest (Genalysis code A/OES). The pulverized sample was digested in a hydrofluoric-perchloric-nitric acid mixture for at least 24 hours, evaporated to fume dryness, and leached in hydrochloric acid.
- SiO₂, TiO₂, Al₂O₃, Fe₂O₃, MgO, CaO, K₂O, and S were analysed by ICP-OES using an alkaline oxidative fusion with sodium peroxide in a nickel crucible

followed by leaching with hydrochloric acid (Genalysis code DX/OES).

- Niobium, Ta, and Zr were analysed by ICP-MS using an alkaline oxidative fusion with sodium peroxide in nickel crucibles followed by leaching with hydrochloric acid (Genalysis code DX/MS).
- The precious metals Au, Pd, and Pt were analysed by fire-assay lead collection and ICP-MS analysis (Genalysis code FA*MS).
- Selenium was analysed by precipitation of selenium metal followed by aqua-regia digestion and ICP-MS analysis (Genalysis code A*MS)
- Loss on ignition (LOI) was determined by gravimetric means (Genalysis code GRAV).

Table 3.4. Revised secondary codes and qualifiers

Code	Composition	Qualifier	Composition
a	aluminous/bauxitic		
b	black soil, gilgai		
c	clay	<i>c_c</i>	chlorite
		<i>c_g</i>	glauconite
		<i>c_l</i>	illite
		<i>c_k</i>	kaolin
		<i>c_m</i>	montmorillonite
		<i>c_s</i>	smectite
d	undivided		
e	evaporite	<i>e_a</i>	anhydrite
		<i>e_g</i>	gypsum
		<i>e_h</i>	halite
f	ferruginous		
g	quartzofeldspathic		
h	heavy mineral	<i>h_a</i>	apatite
		<i>h_g</i>	garnet
		<i>h_i</i>	ilmenite
		<i>h_l</i>	leucoxene
		<i>h_m</i>	magnetite
		<i>h_o</i>	monazite
		<i>h_r</i>	rutile
		<i>h_z</i>	zircon
i	limonite		
k	carbonate	<i>k_a</i>	aragonite
		<i>k_c</i>	calcite
		<i>k_d</i>	dolomite
		<i>k_m</i>	magnesite
l	heterogeneous		
m	ferromagnesian		
o	goethite		
q	quartz		
r	carbonaceous/organic	<i>r_c</i>	coal
		<i>r_h</i>	humus
		<i>r_p</i>	peat
u	ultramafic		
x	other mineral	<i>x_i</i>	mica
		<i>x_m</i>	manganese
z	siliceous		

Analabs

The total sample was dried to 110°C, jaw crushed if necessary, split then milled in a chromium-free mill to a nominal particle size of 90% less than 75 µm. An analytical pulp of approximately 200 g was subsampled from the bulk and the milled residue and any split retained for future reference. All the preparation equipment was flushed with barren feldspar prior to the commencement of the job and after each batch.

The following analytical schemes were used:

1. Silica, TiO₂, Al₂O₃, Fe₂O₃, MnO, MgO, CaO, Na₂O, K₂O, and P₂O₅ were measured by X-ray fluorescence spectrometry (XRF) on a glass fusion disc (Analabs code X408).

2. Loss on ignition (LOI) was determined gravimetrically, by heating the sample to 1000°C (Analabs code V955).
3. A series of trace elements were measured by ICP-MS, following sample digestion with nitric, hydrochloric, hydrofluoric, and perchloric acids (Analabs code G104). Elements measured include: Ag, As, Ba, Be, Bi, Cd, Ce, Co, Ga, In, La, Li, Mo, Nb, Ni, Pb, Rb, Sb, Sc, Sn, Ta, Th, U, W, and Y (Analabs code M104).
4. The G104 digest (at 3. above) was used for the analysis of Sr, V, and Zr by ICP-OES (Analabs code I104).

Table 3.5. Revised tertiary codes and qualifiers for parent rock or cement type

Parent rock or cement		Parent rock qualifier	
a	aluminous cement		
c	chemical/biochemical sedimentary deposit	<i>c_c</i>	chert
		<i>c_d</i>	dolomite
		<i>c_i</i>	iron-formation
		<i>c_l</i>	limestone
		<i>c_i</i>	diatomite
f	duricrust		
h	hyperbyssal	<i>h_d</i>	dolerite
		<i>h_p</i>	porphyry
i	iron cement		
k	carbonate cement		
m	metamorphic	<i>m_g</i>	gneiss
		<i>m_p</i>	pelite
		<i>m_m</i>	psammite
		<i>m_s</i>	schist
o	fossiliferous	<i>o_s</i>	shells
		<i>o_c</i>	coral/coralgal
p	plutonic	<i>p_a</i>	alkali granite
		<i>p_g</i>	gabbro
		<i>p_d</i>	diorite
		<i>p_g</i>	granite
		<i>p_m</i>	monzogranite/monzonite
		<i>p_o</i>	granodiorite
		<i>p_s</i>	syenogranite/syenite
		<i>p_t</i>	tonalite
s	siliciclastic sedimentary rock	<i>s_c</i>	conglomerate
		<i>s_m</i>	mudstone, siltstone, shale
		<i>s_s</i>	sandstone, arenite, wacke
u	ultramafic	<i>u_d</i>	dunite
		<i>u_k</i>	komatiite
		<i>u_p</i>	peridotite
		<i>u_y</i>	pyroxenite
		<i>u_s</i>	serpentine/talc rock
v	volcanic	<i>v_a</i>	andesite
		<i>v_b</i>	basalt
		<i>v_d</i>	dacite
		<i>v_l</i>	latite
		<i>v_r</i>	rhyolite
		<i>v_t</i>	trachyte
		<i>v_v</i>	volcaniclastic
z	silica cement		

5. An aliquot of the G104 digest (at 3. above) was analysed by atomic absorption spectrometry (AAS) for Cr, Cu, and Zn (Analabs code A104).
6. The volatile metals Se and Te were analysed by hydride generation AAS (Analabs code H109), from a chromate-enhanced hydrochloric and nitric acid digestion carried out at low temperature (Analabs code G109).
7. Sulfur (as S) was evolved at high temperature in a stream of oxygen, and the resultant gas was measured in an infrared cell (Analabs code V821).
8. A 50 g subsample of the assay pulp was fused in a lead collection fire assay. The prill was dissolved in aqua regia (i.e. hydrochloric and nitric acid) and the resultant solution presented to an ICP-MS (Analabs code F627) for analysis of Au, Pd, and Pt.

Amdel Laboratories

Following oven drying, an aliquot of each sample was sieved to between 2 and 0.45 mm. This material was pulverized to < 75 µm in a chrome-free bowl pulverizer; imparted contamination during milling estimated by the manufacturer is 50 ppm Mn and 5000 ppm Fe, with no detectable contamination for Co, Cu, Mo, Ni, Pb, V, or Zn.

Six analytical methods were used:

1. Silica, TiO₂, Al₂O₃, Fe₂O₃, MnO, MgO, CaO, Na₂O, K₂O, and P₂O₅ were analysed by ICP-OES following a lithium metaborate fusion and dilute hydrochloric acid digestion (Amdel code IC4).
2. Silver, As, Bi, Cd, Ce, Co, Cu, Ga, In, La, Mo, Nb, Pb, Rb (up to 20 ppm; IC4M > 20 ppm), Sb, Se, Sn, Sr (up to 500 ppm; IC3E > 500 ppm), Te, Th, U, W, and Y were analysed by ICP-MS following mixed-acid sample digestion (hydrofluoric–perchloric–nitric–hydrochloric) for 24 hours. Samples were evaporated to fume dryness and dissolved in hydrochloric acid prior to analysis (Amdel code IC3M).
3. Barium, Be, Cr (up to 100 ppm; IC4E > 100 ppm), Li, Ni, S (up to 5 %; analysis by Leco (Amdel code VOL2) > 5 %), Sc, V, and Zn were analysed by ICP-OES (Amdel code IC3E). Samples were digested using a hydrofluoric–perchloric–nitric–hydrochloric acid mixture for 24 hours, then evaporated to fume dryness and dissolved in dilute hydrochloric acid.
4. Tantalum and Zr were analysed by ICP-MS following a lithium metaborate fusion and dilute hydrochloric acid digestion (Amdel code IC4M).
5. Gold, Pt, and Pd were collected in a lead collection fire-assay fusion. Following cupellation, the prill was dissolved in aqua regia (i.e. hydrochloric and nitric acids), then analysed by graphite furnace AAS (Amdel code FA3).
6. Loss on ignition (LOI) was determined by gravimetric means (Amdel code GRAV7).

Determination of regolith pH and total dissolved solids

The acidity–alkalinity (pH) and total dissolved solids (TDS) of all regolith samples were measured at the GSWA Carlisle base. For both types of measurements, a subsample was mixed with deionized water in the ratio of 1:5, then shaken vigorously. After standing overnight, the pH was measured using a portable Jenway pH meter, calibrated using standard solutions of pH=4 and pH=7. The electrode was rinsed in deionized water between each measurement of unknowns. The conductivity of each sample (i.e. a measure of the TDS) was made using a SCAN4 conductivity meter, calibrated using a buffer solution of 11.67 millisiemens/centimetre (mS/cm). Electrodes were rinsed between every measurement of unknowns.

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Figures

1. Status of GSWA regional regolith and geochemical mapping program
2. Simplified locality plan
3. Simplified geological interpretation
4. Generalized regolith

Element-distribution and other maps

5. SiO₂
6. TiO₂
7. Al₂O₃
8. Fe₂O₃
9. MnO
10. MgO
11. CaO
12. Na₂O
13. K₂O
14. P₂O₅
15. LOI
16. Ag
17. As
18. Au
19. Ba
20. Be
21. Bi
22. Cd
23. Ce
24. Co
25. Cr
26. Cu
27. Ga
28. In
29. La
30. Li
31. Mo
32. Nb
33. Ni
34. Pb
35. Pd
36. Pt
37. Rb
38. S
39. Sb
40. Sc
41. Se
42. Sn
43. Sr
44. Ta
45. Te
46. Th
47. U
48. V
49. W
50. Y
51. Zn
52. Zr
53. Schematic cross section showing bedrock–regolith relationships for northern STANLEY
54. Contoured dolerite additive-index scores (Fe+Ti+Cr+Sc+V+In)
55. Dolerite index and total magnetic intensity
56. pH of regolith
57. Conductivity of regolith

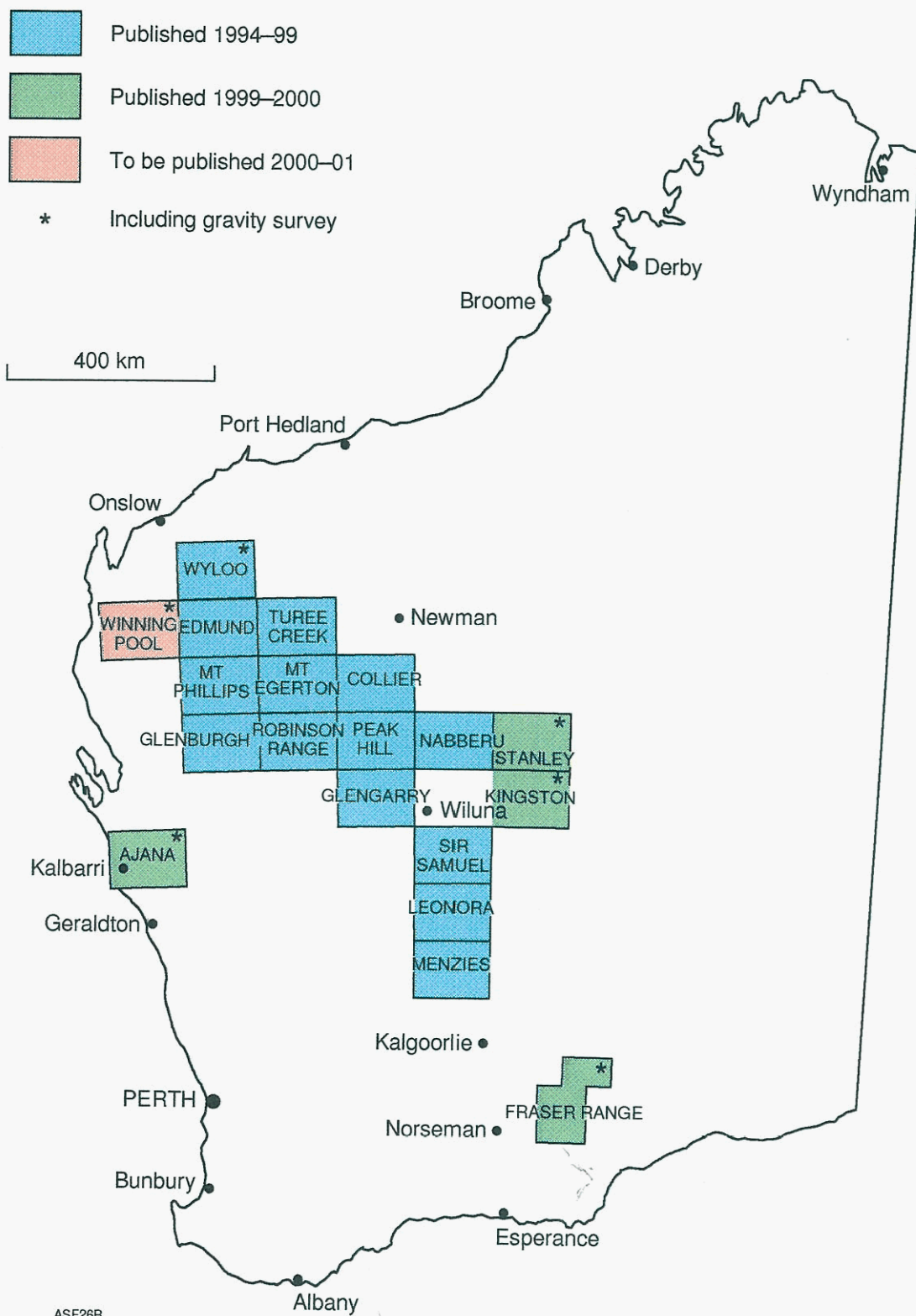
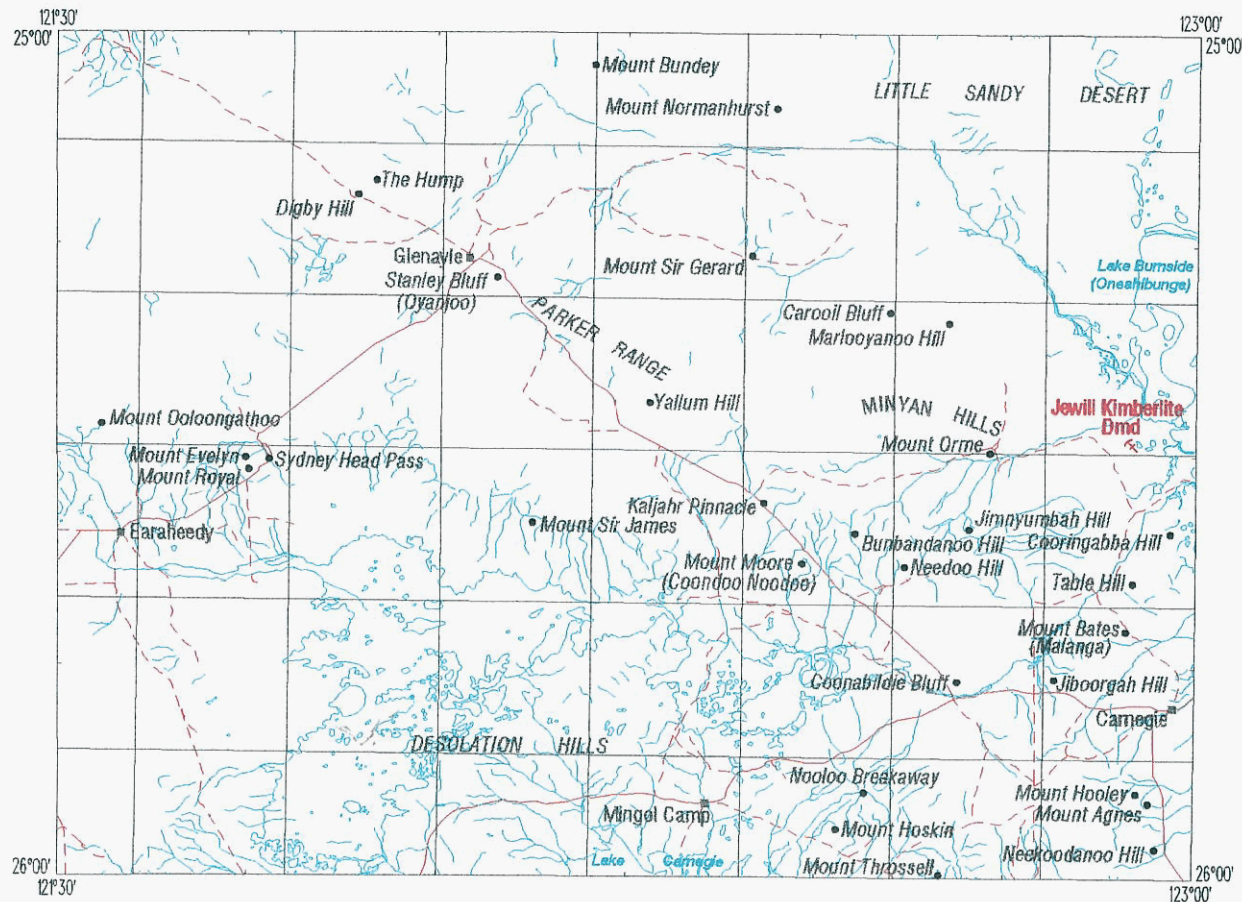


Figure 1. Status of GSWA regional regolith and geochemical mapping program.

SIMPLIFIED LOCALITY PLAN

SYMBOLS

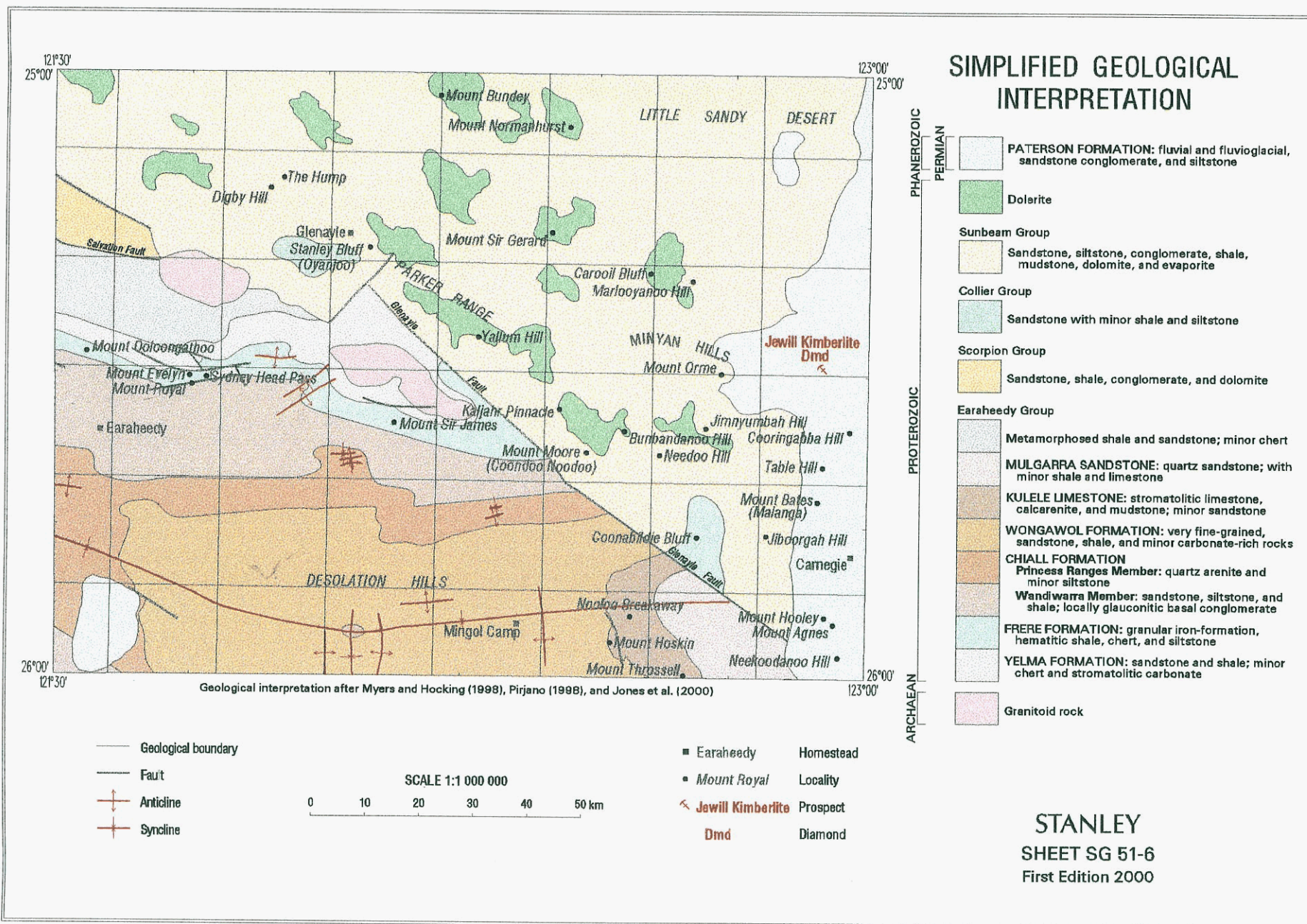
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	Watercourse
	Lake
	Earaheedy Homestead
	Mount Royal Locality
	Jewell Kimberlite Prospect
	Diamond

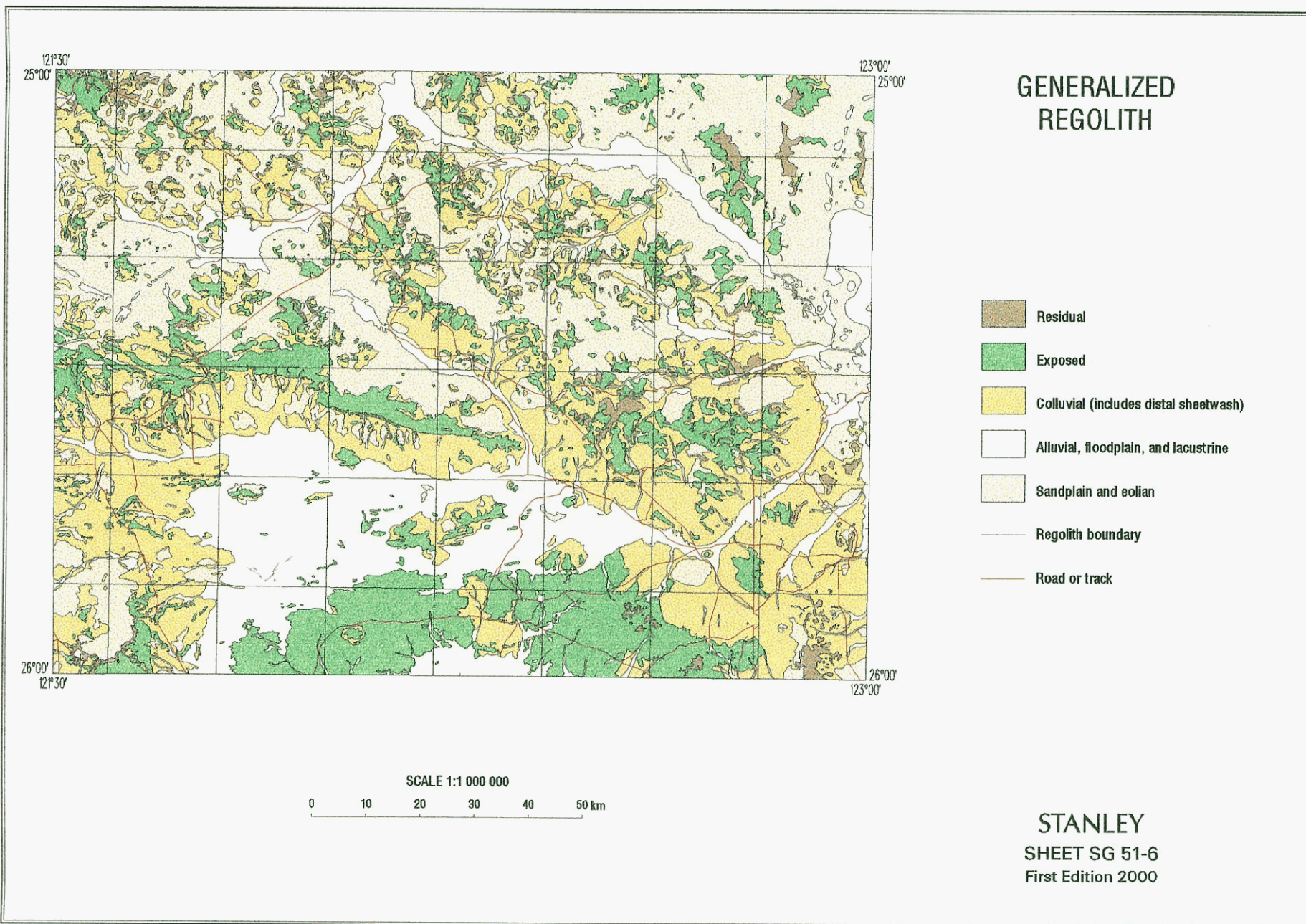


SCALE 1:1 000 000



STANLEY
SHEET SG 51-6
First Edition 2000





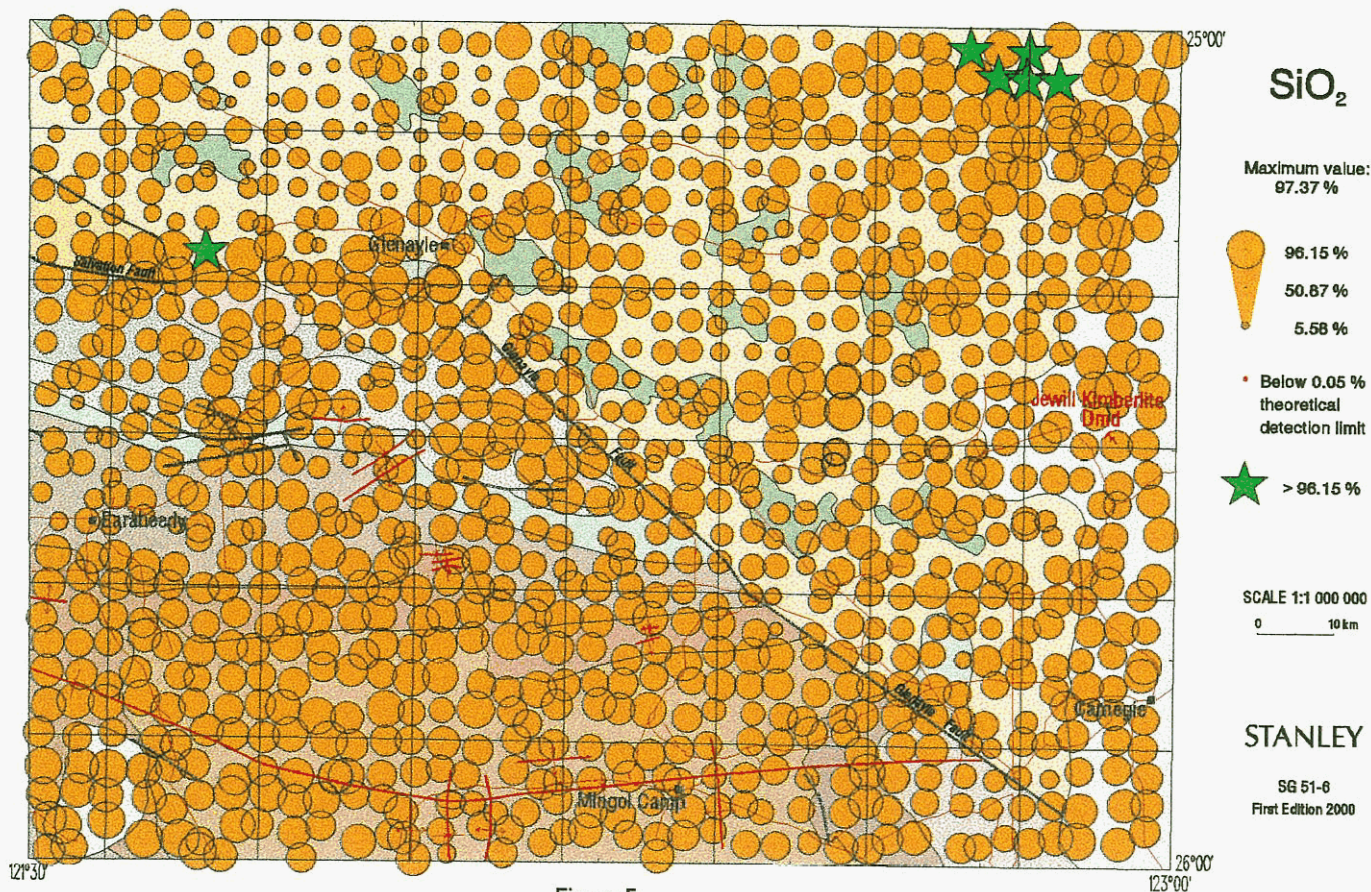


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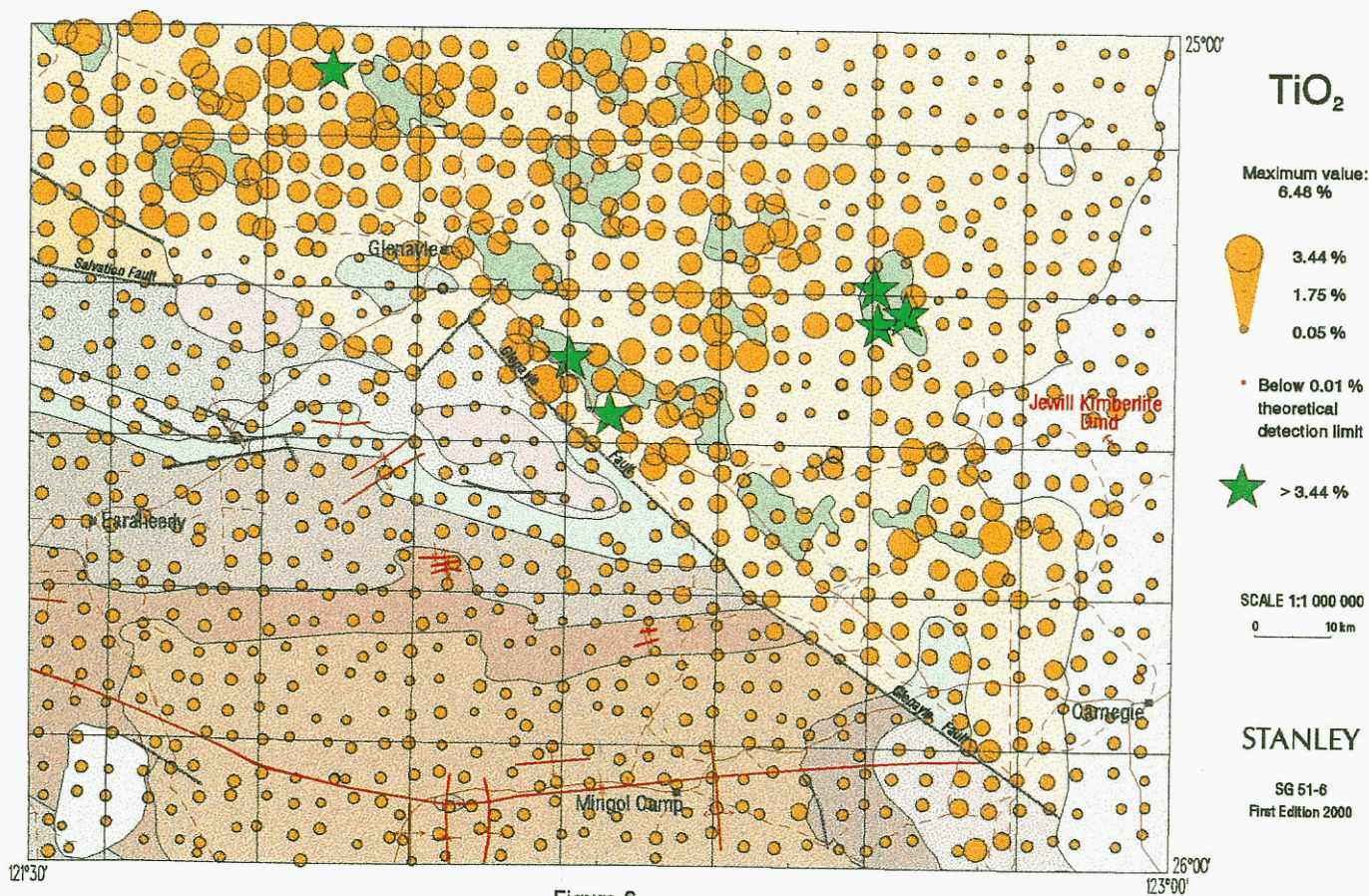
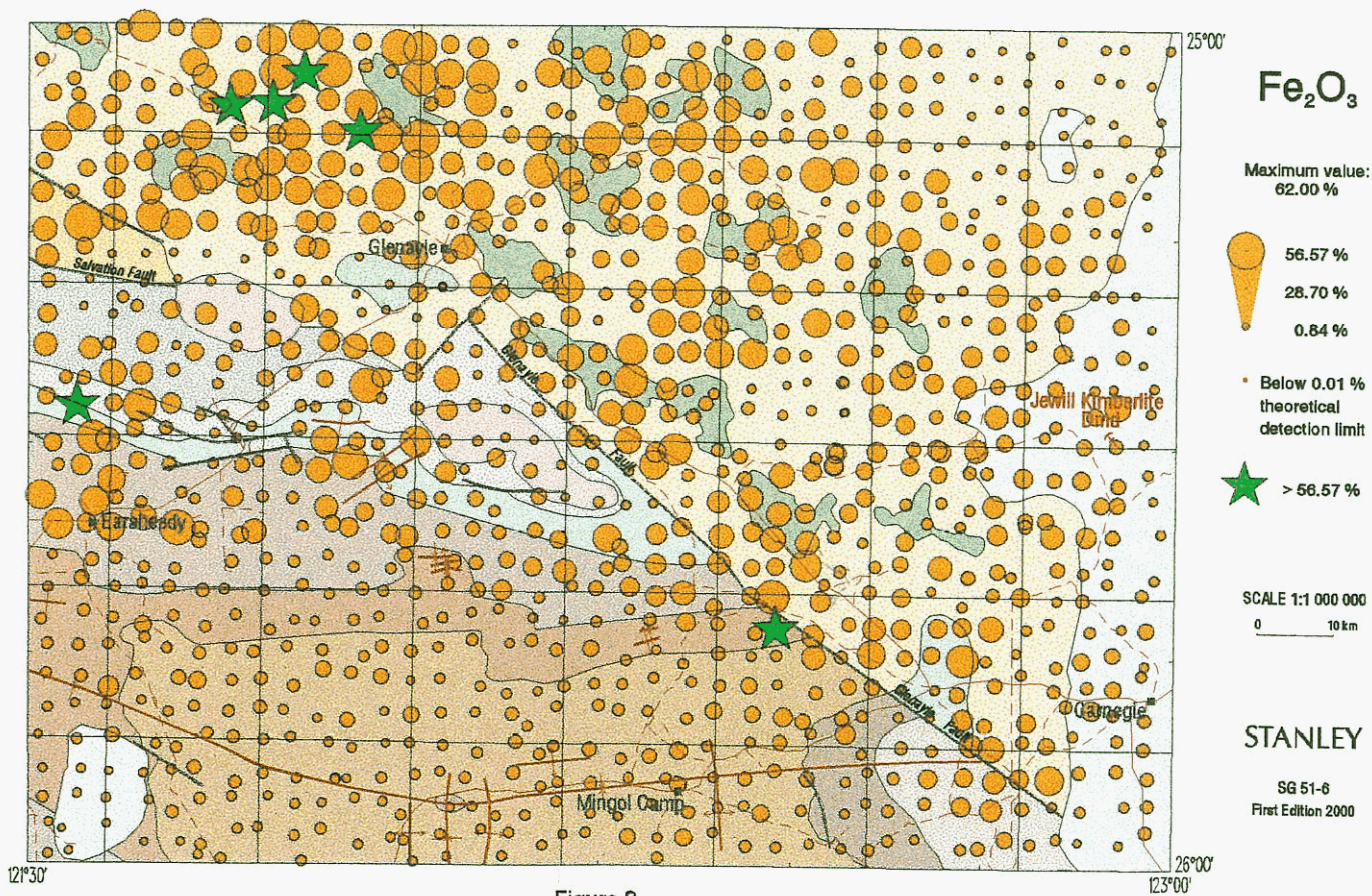
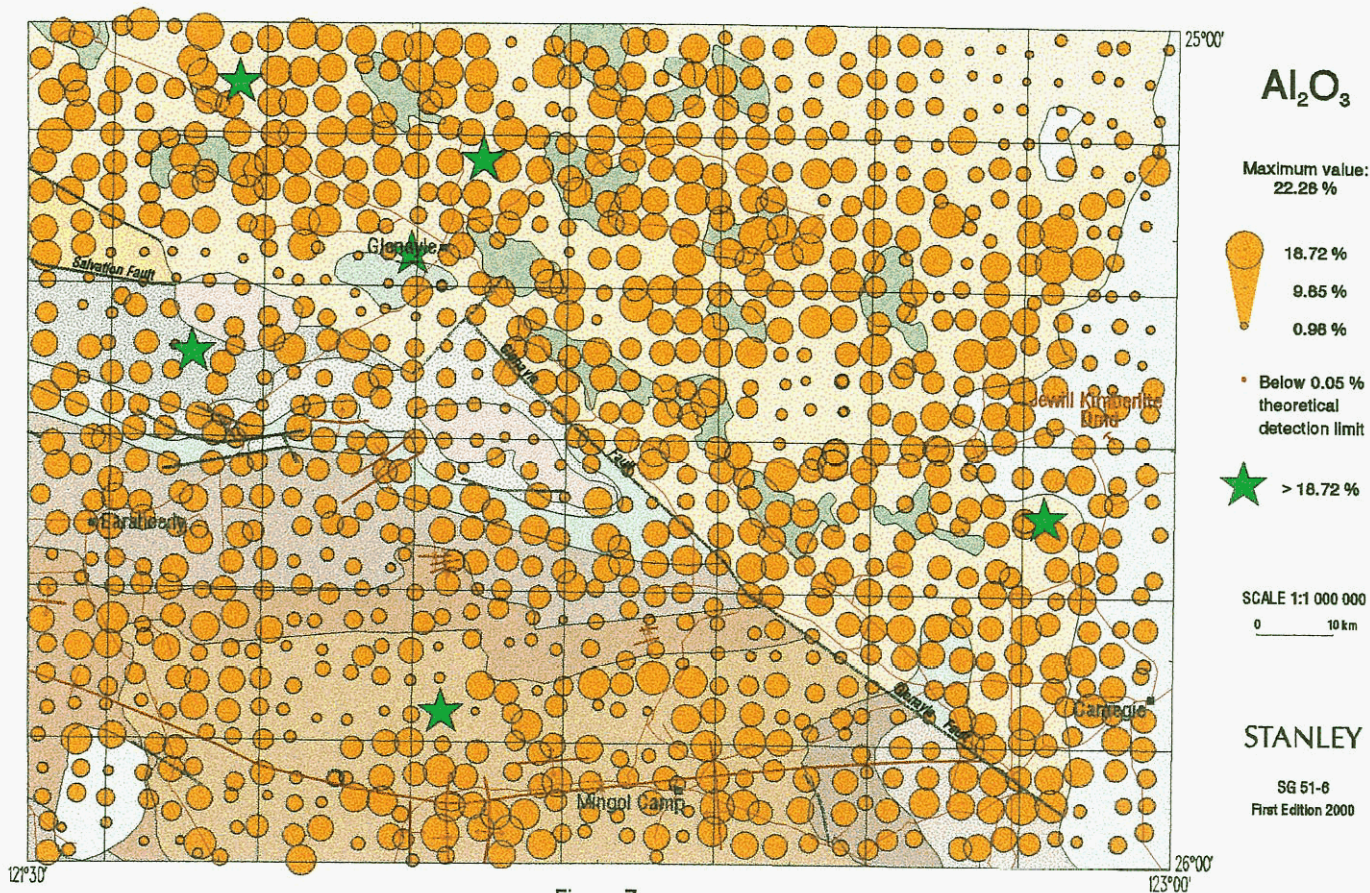
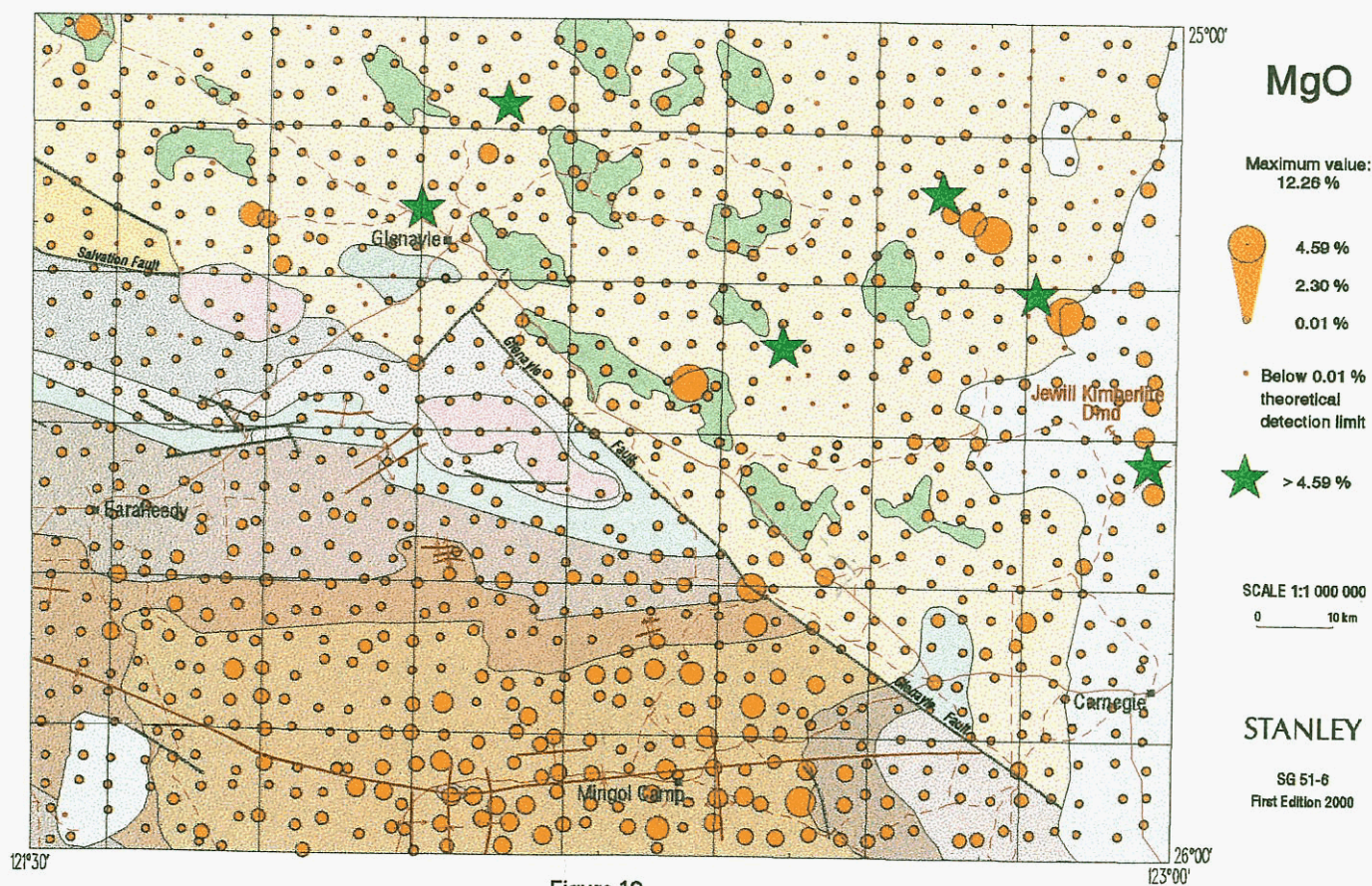
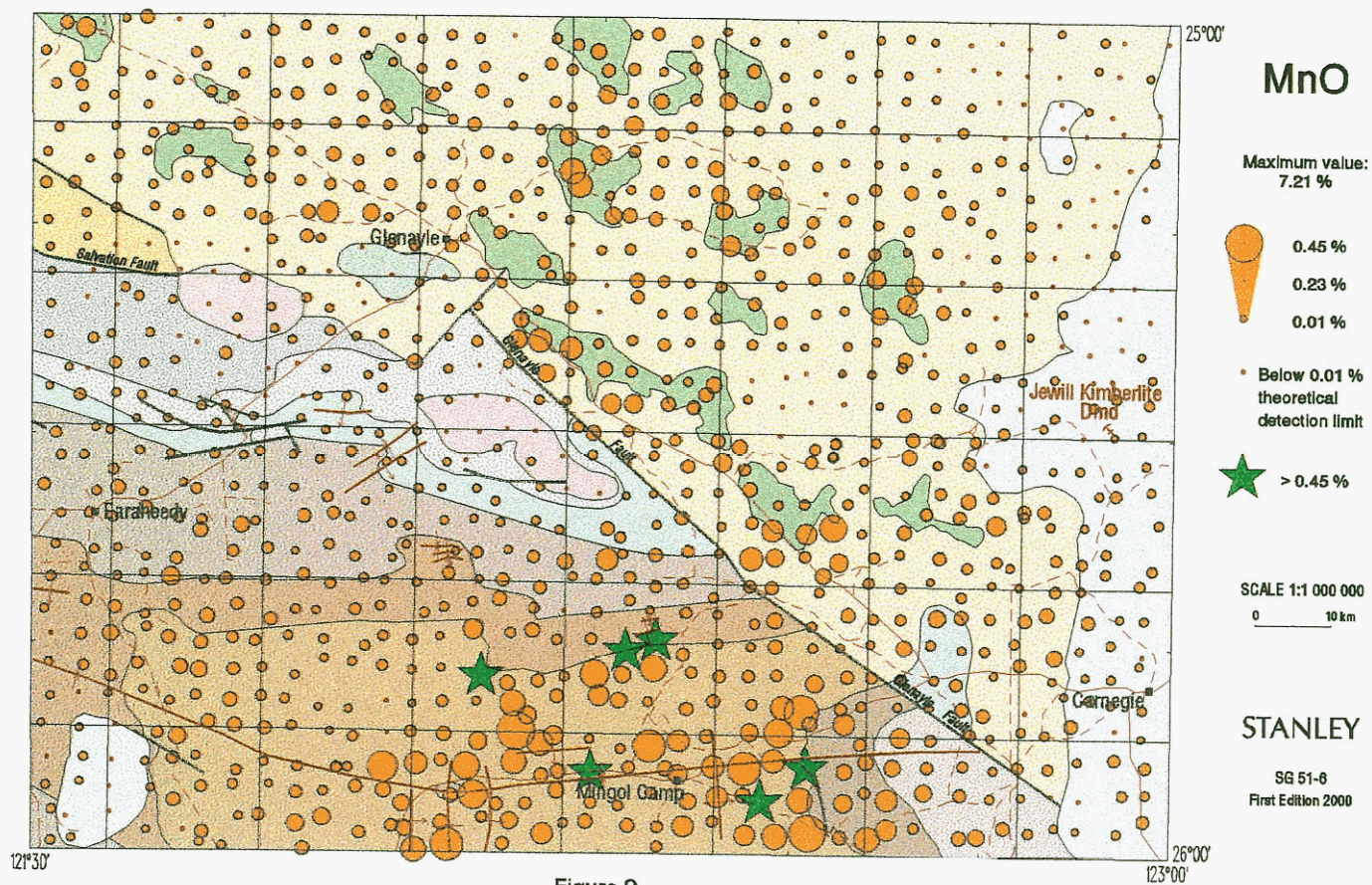


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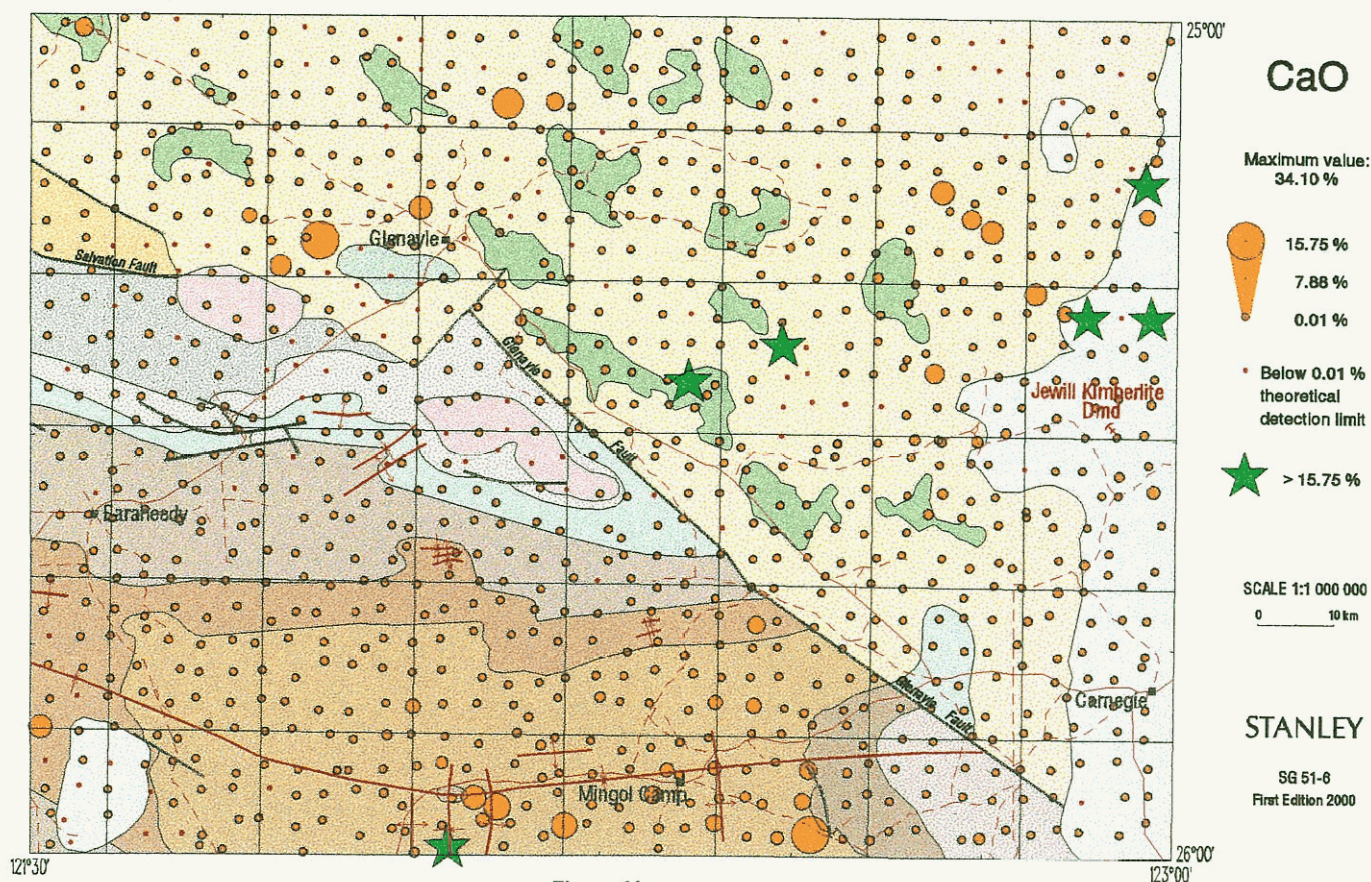


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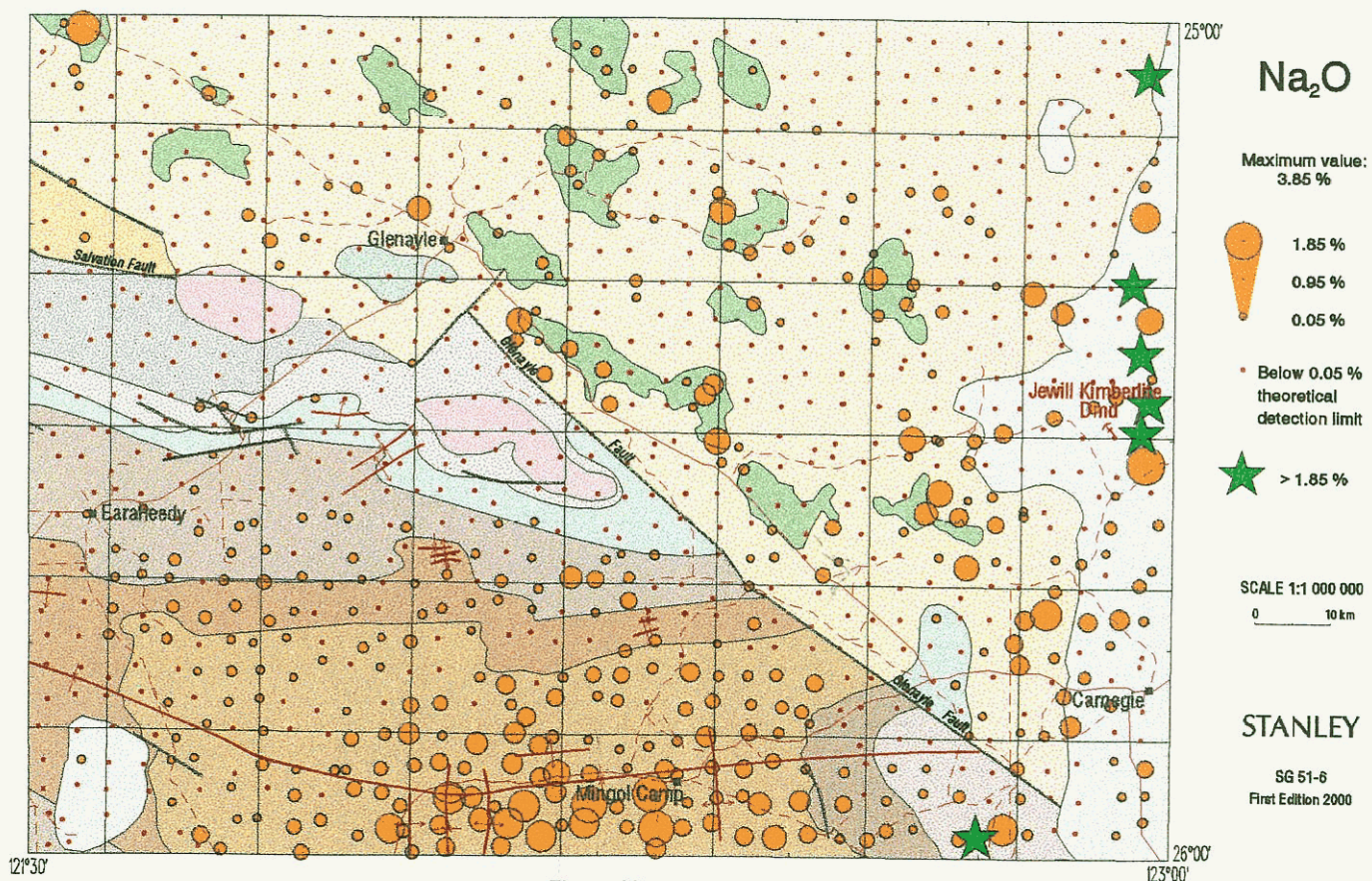
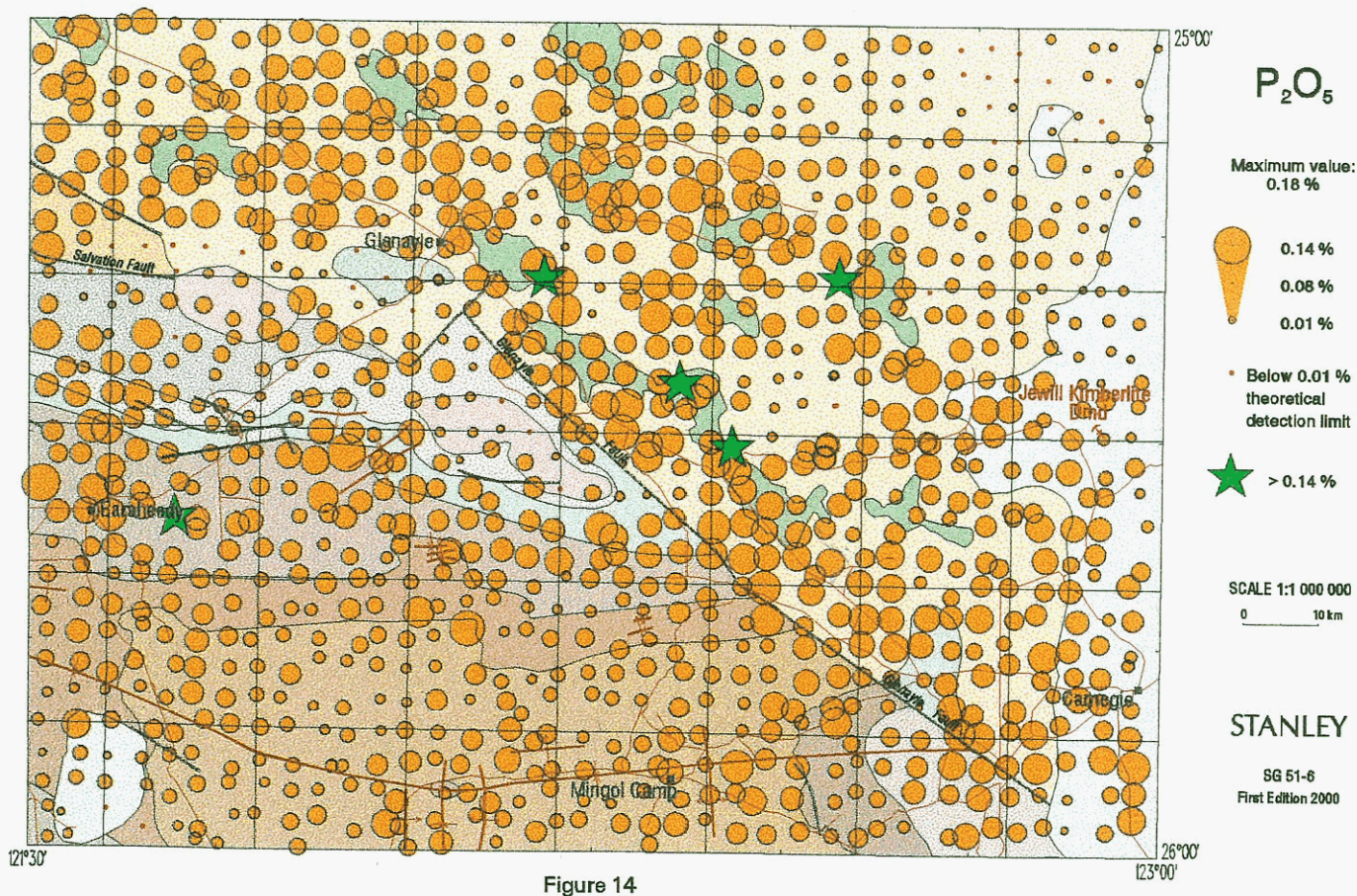
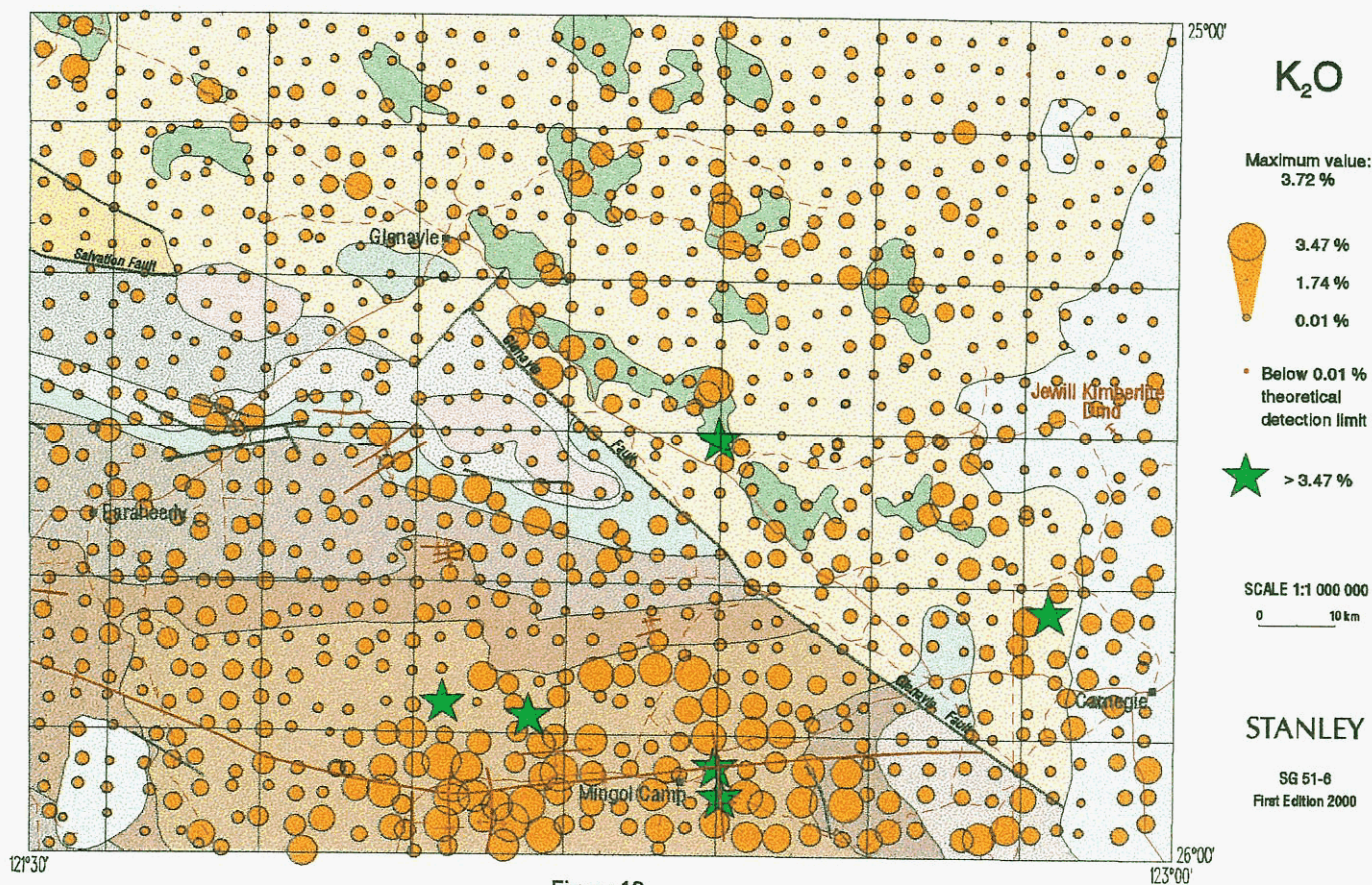


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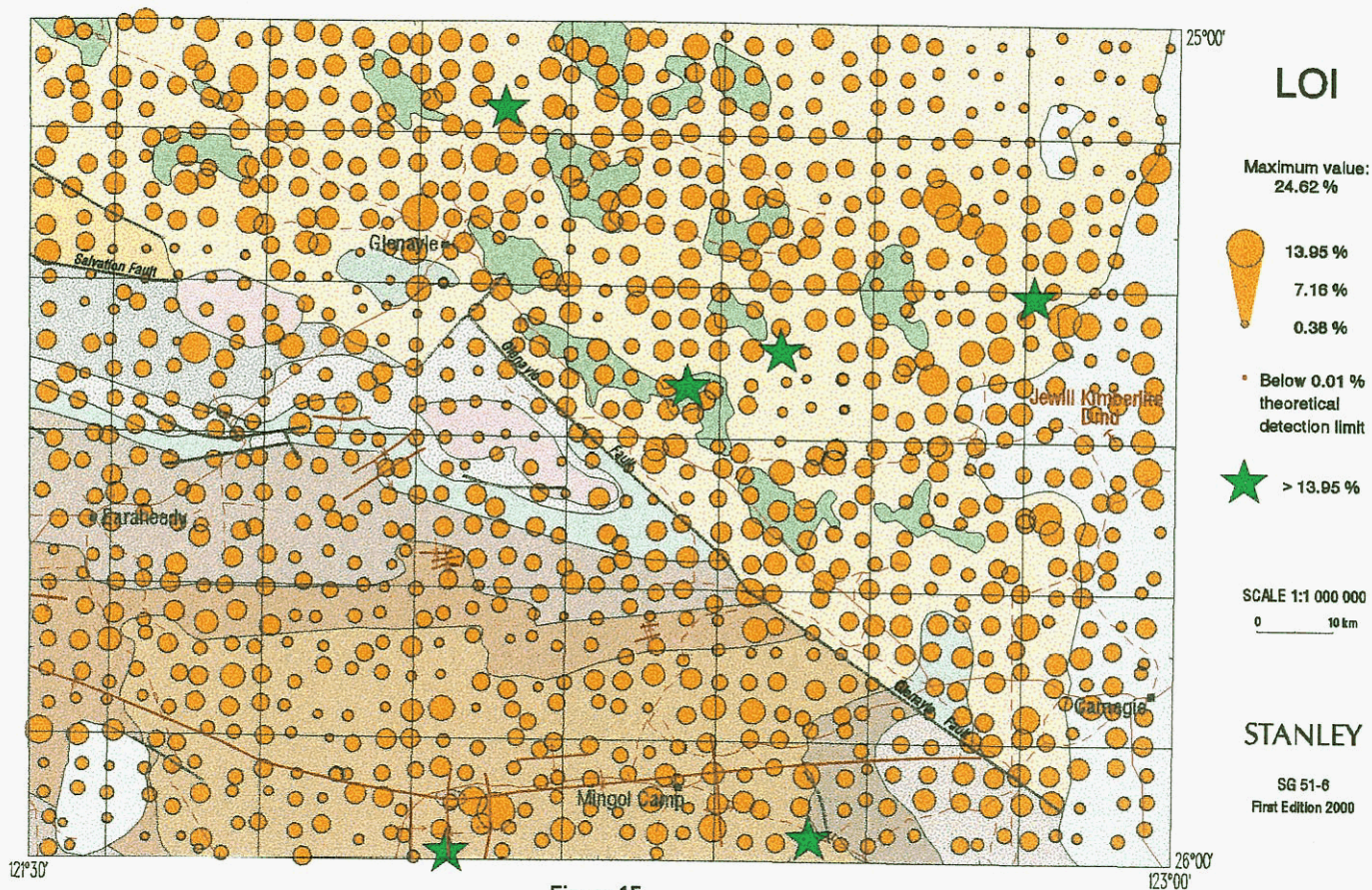


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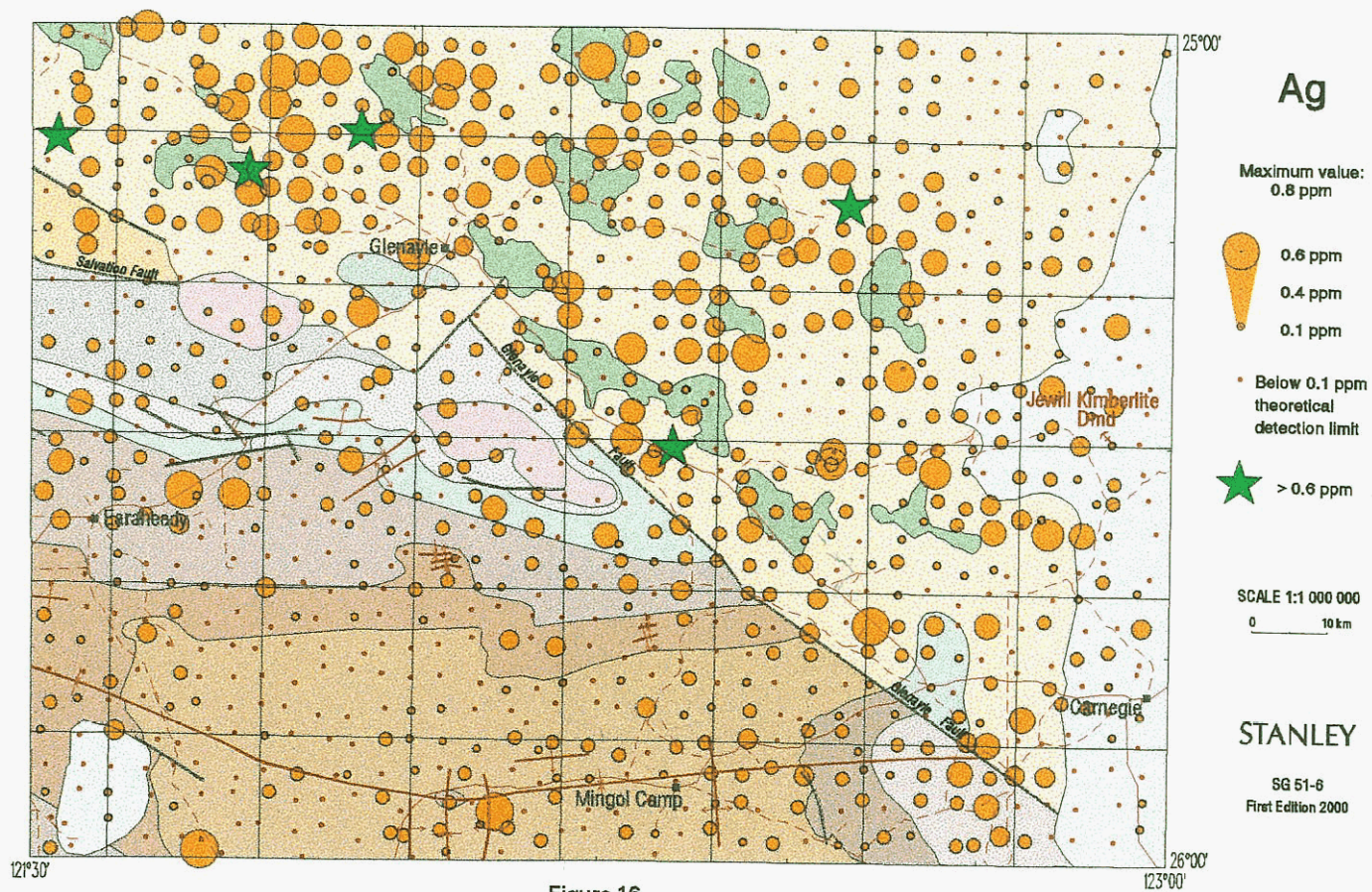


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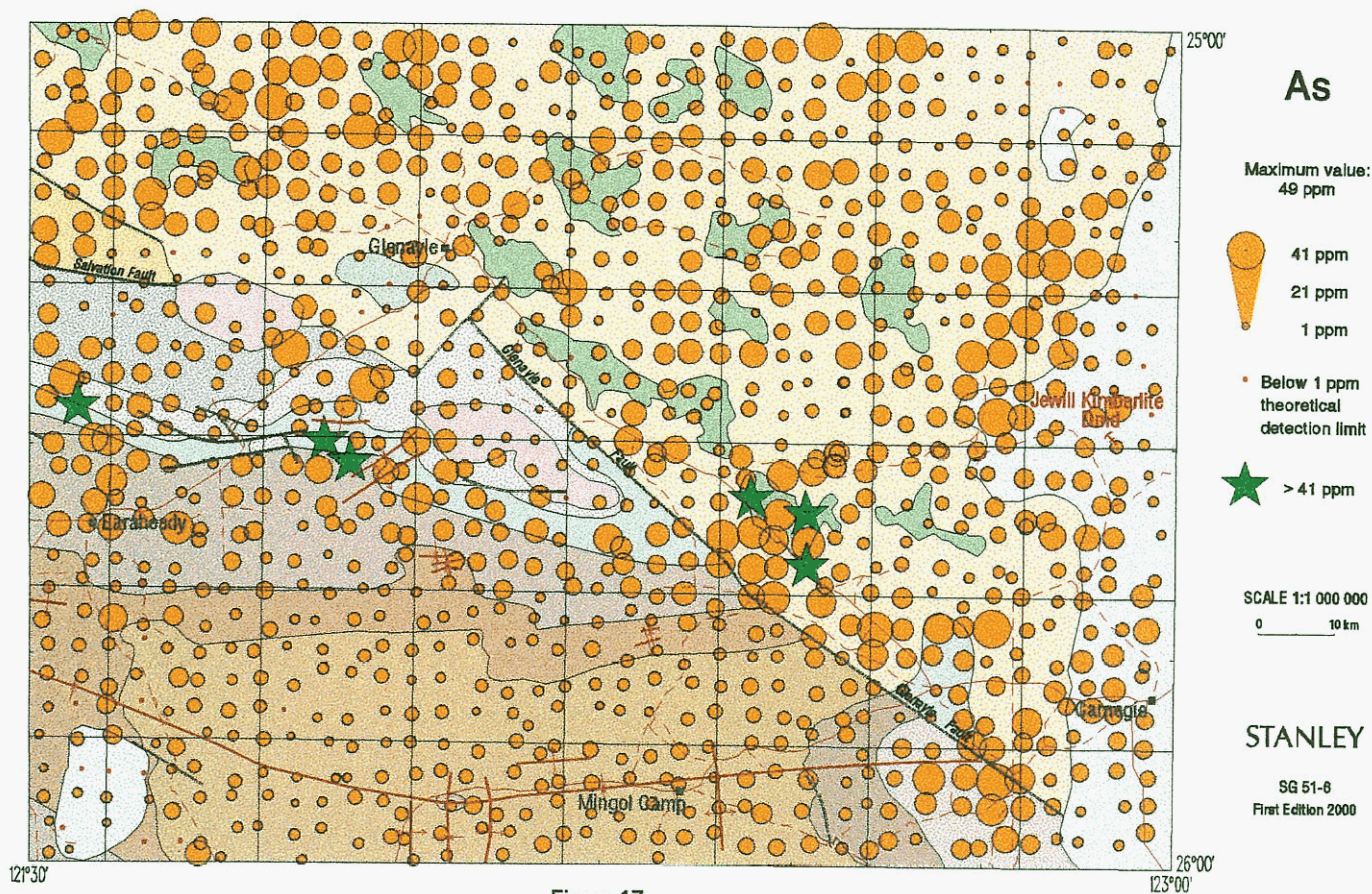


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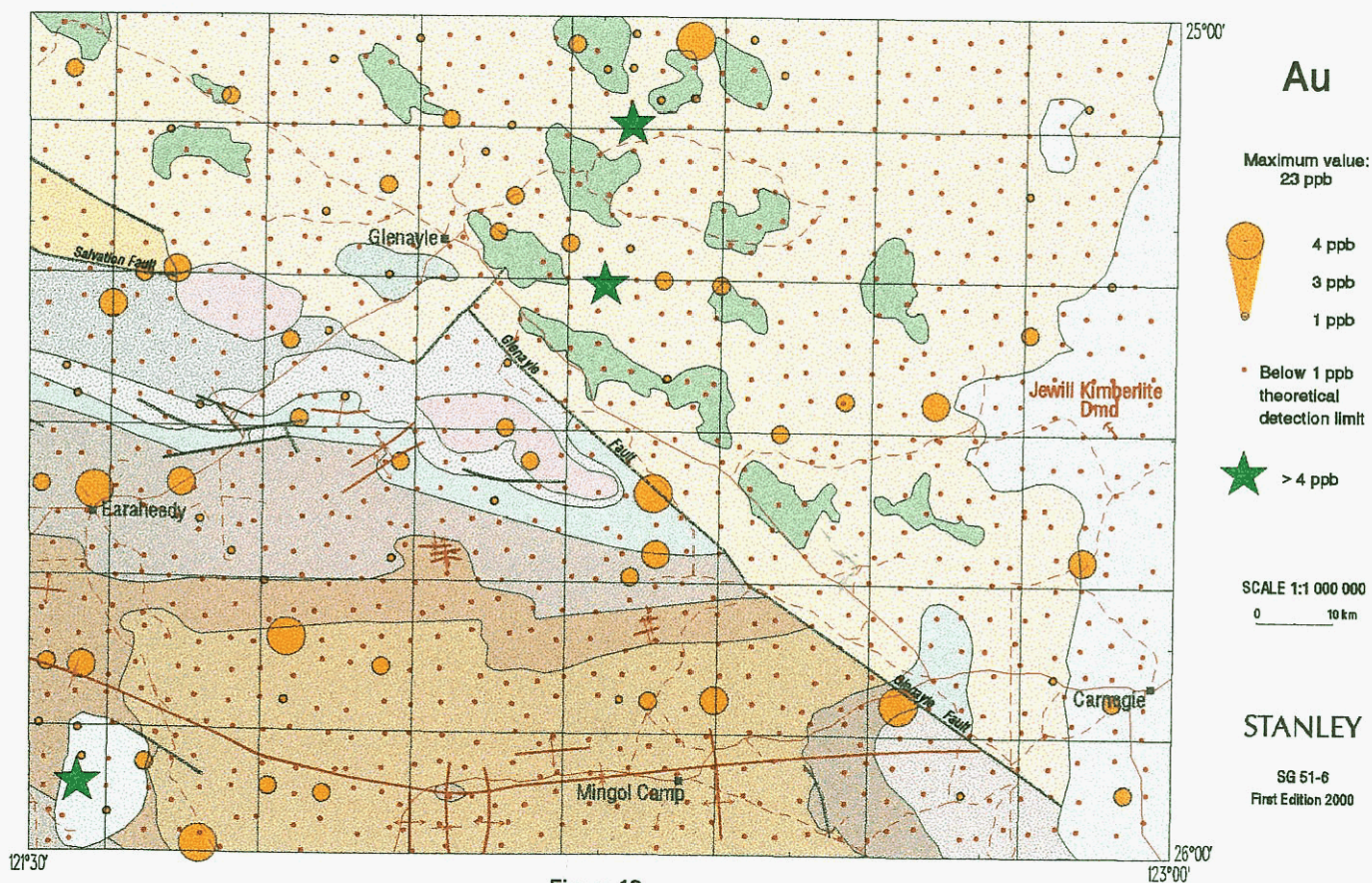


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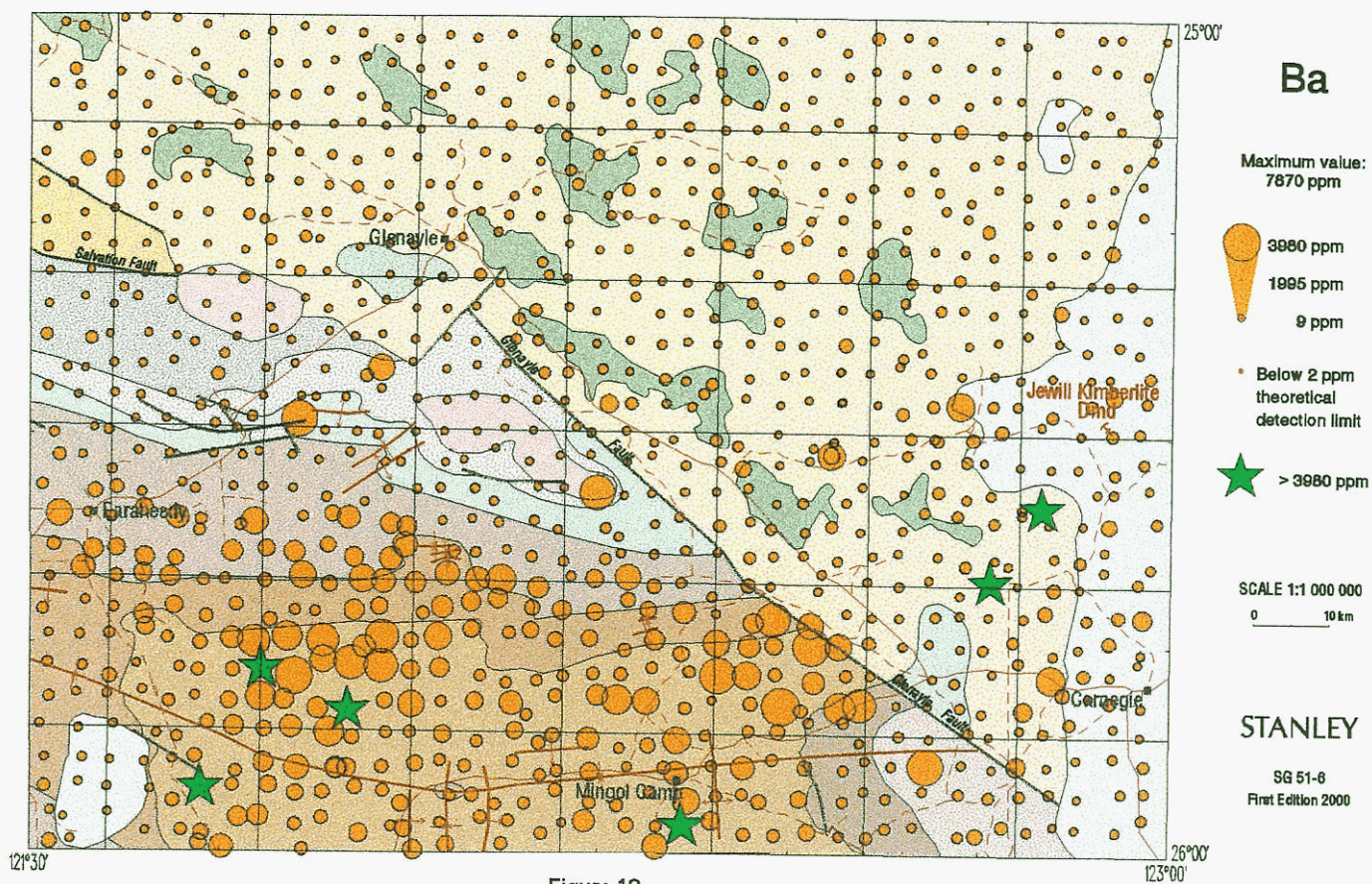


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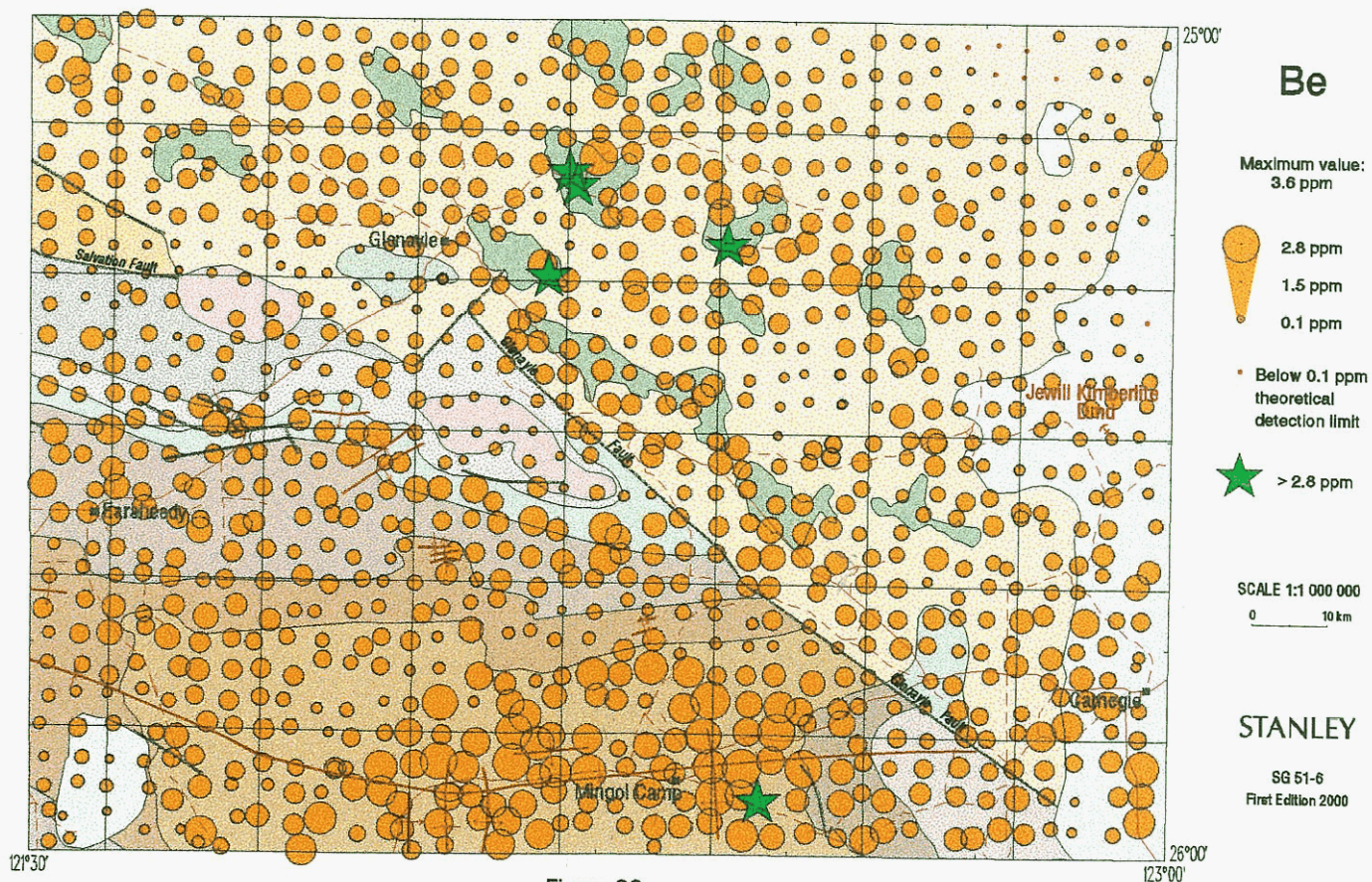


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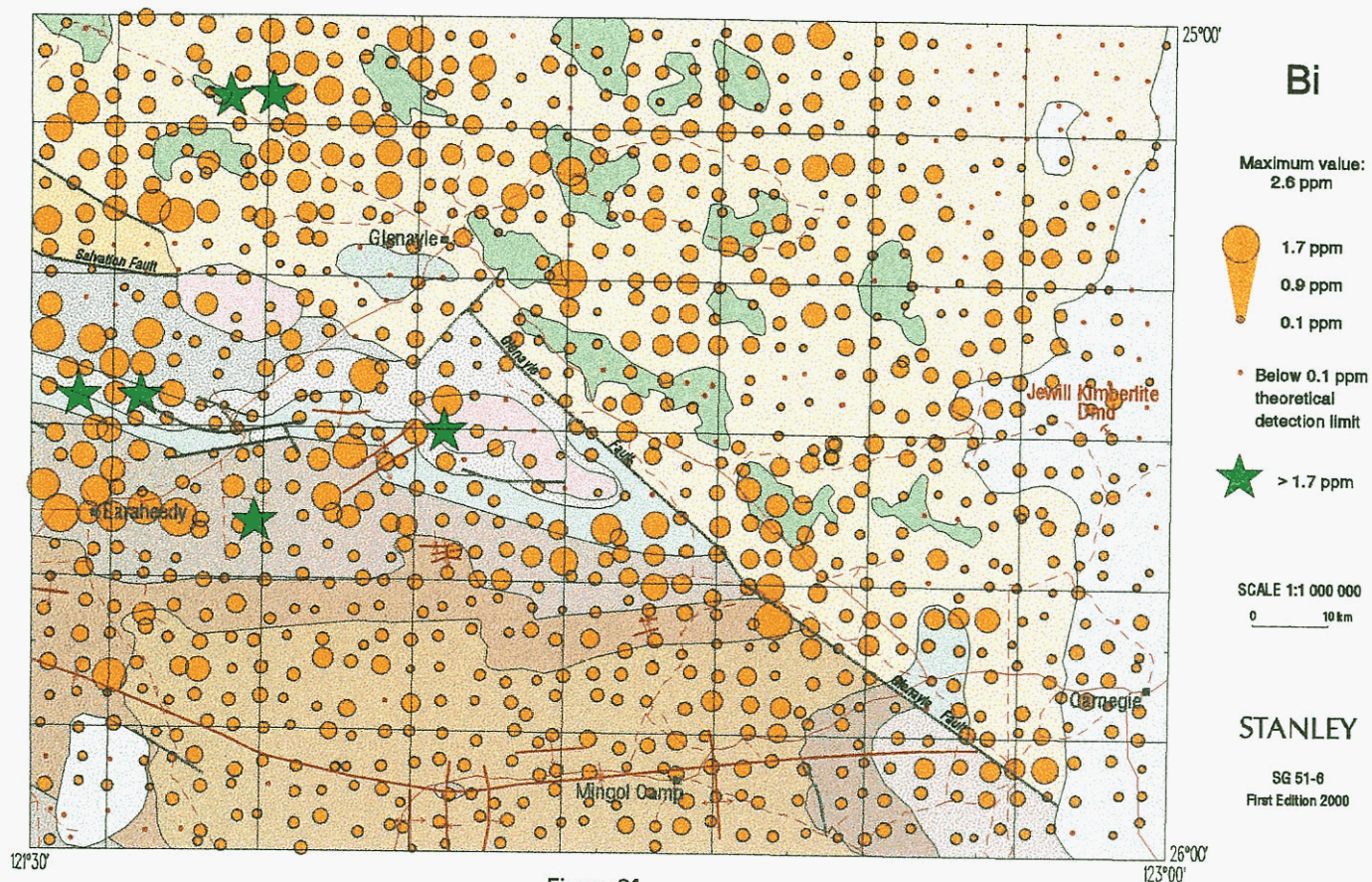


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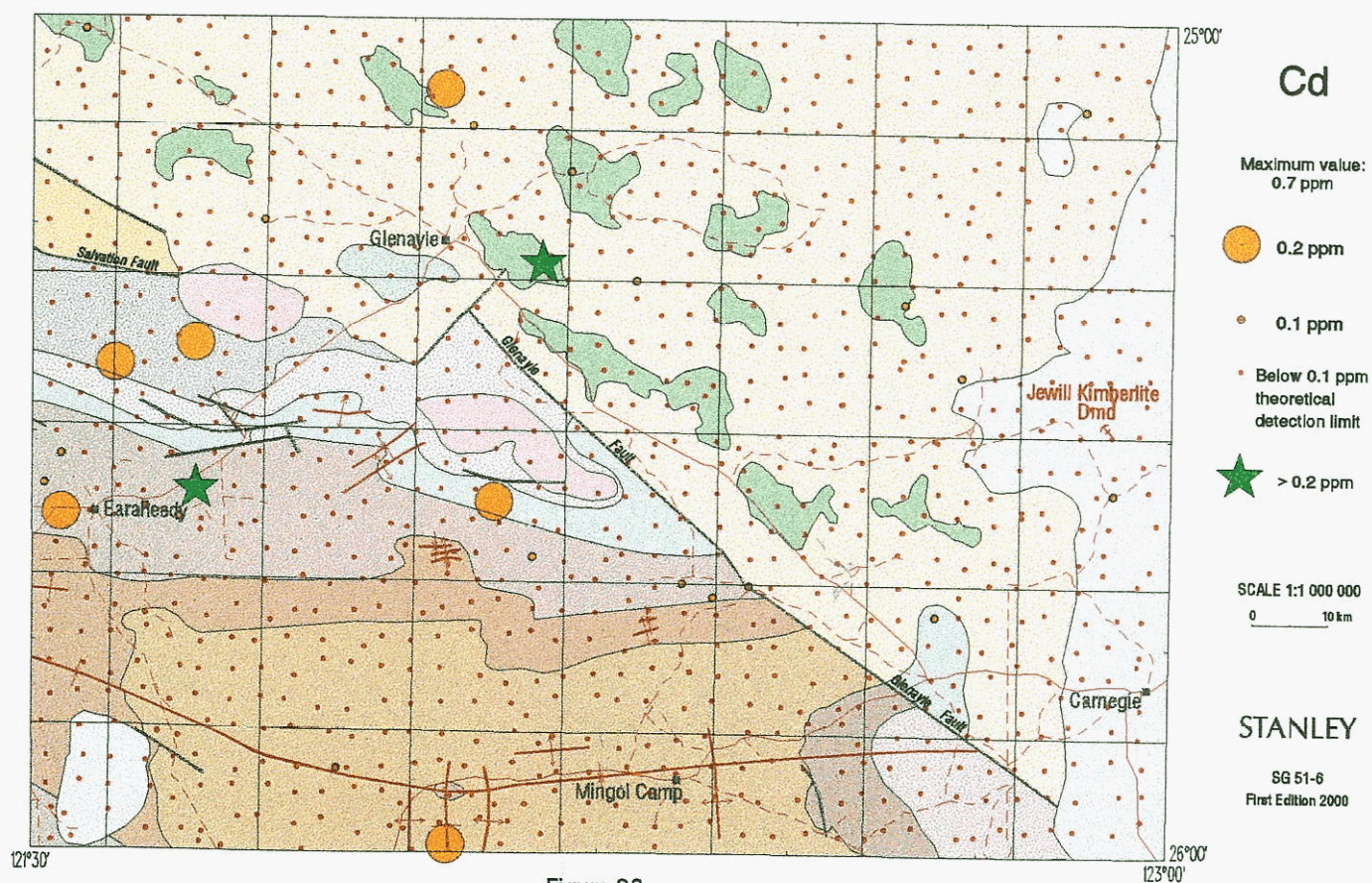


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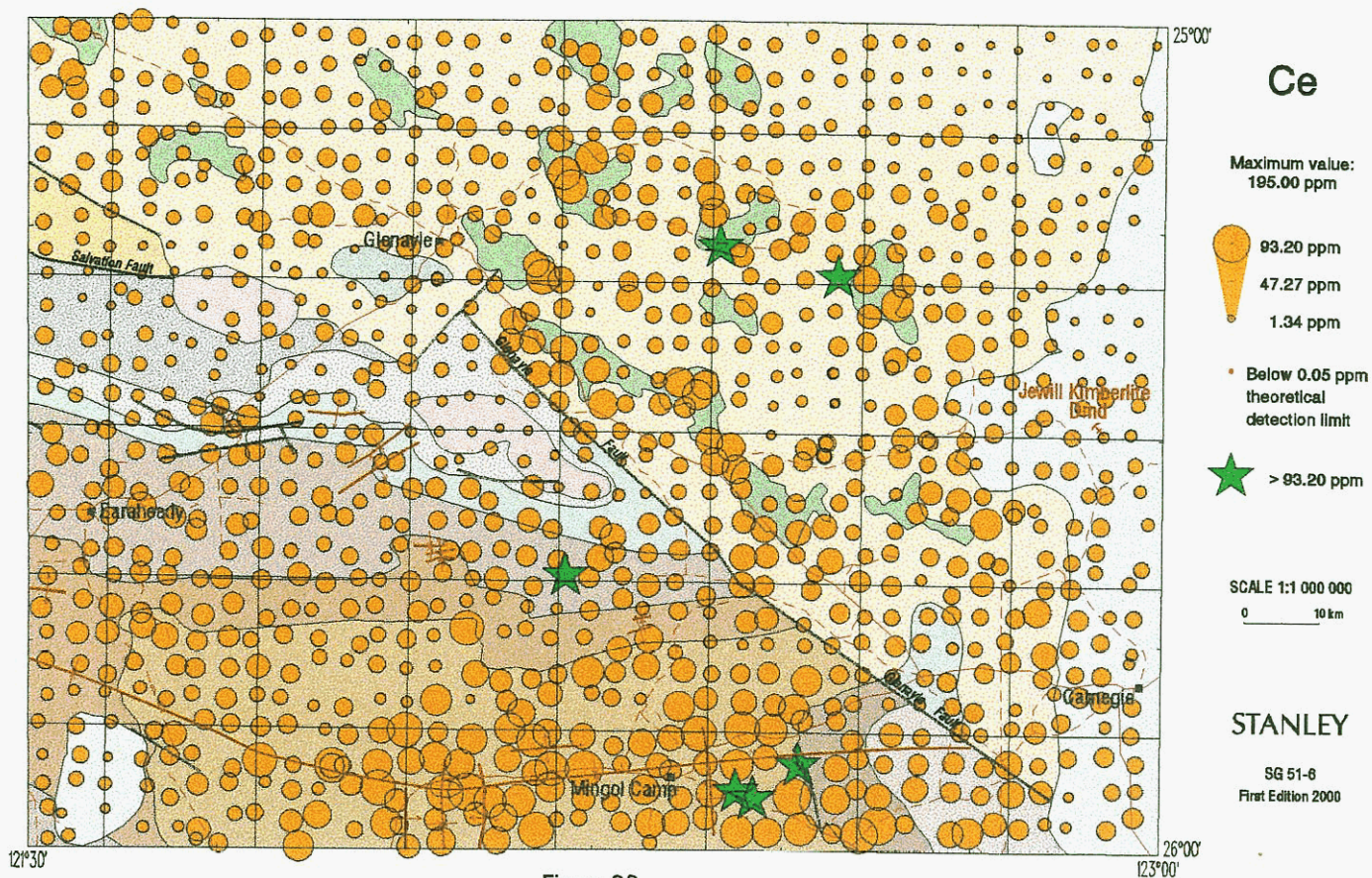


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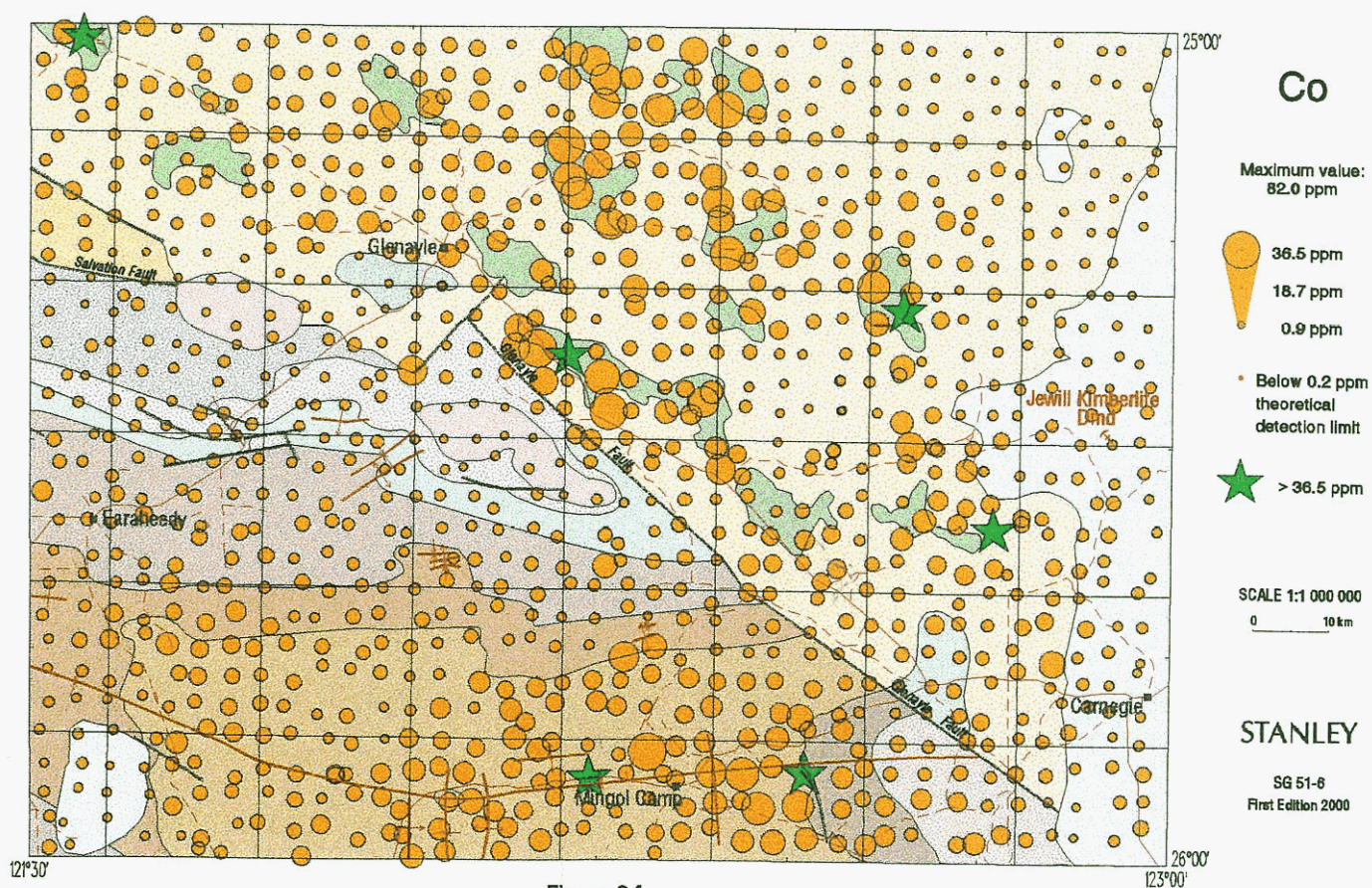
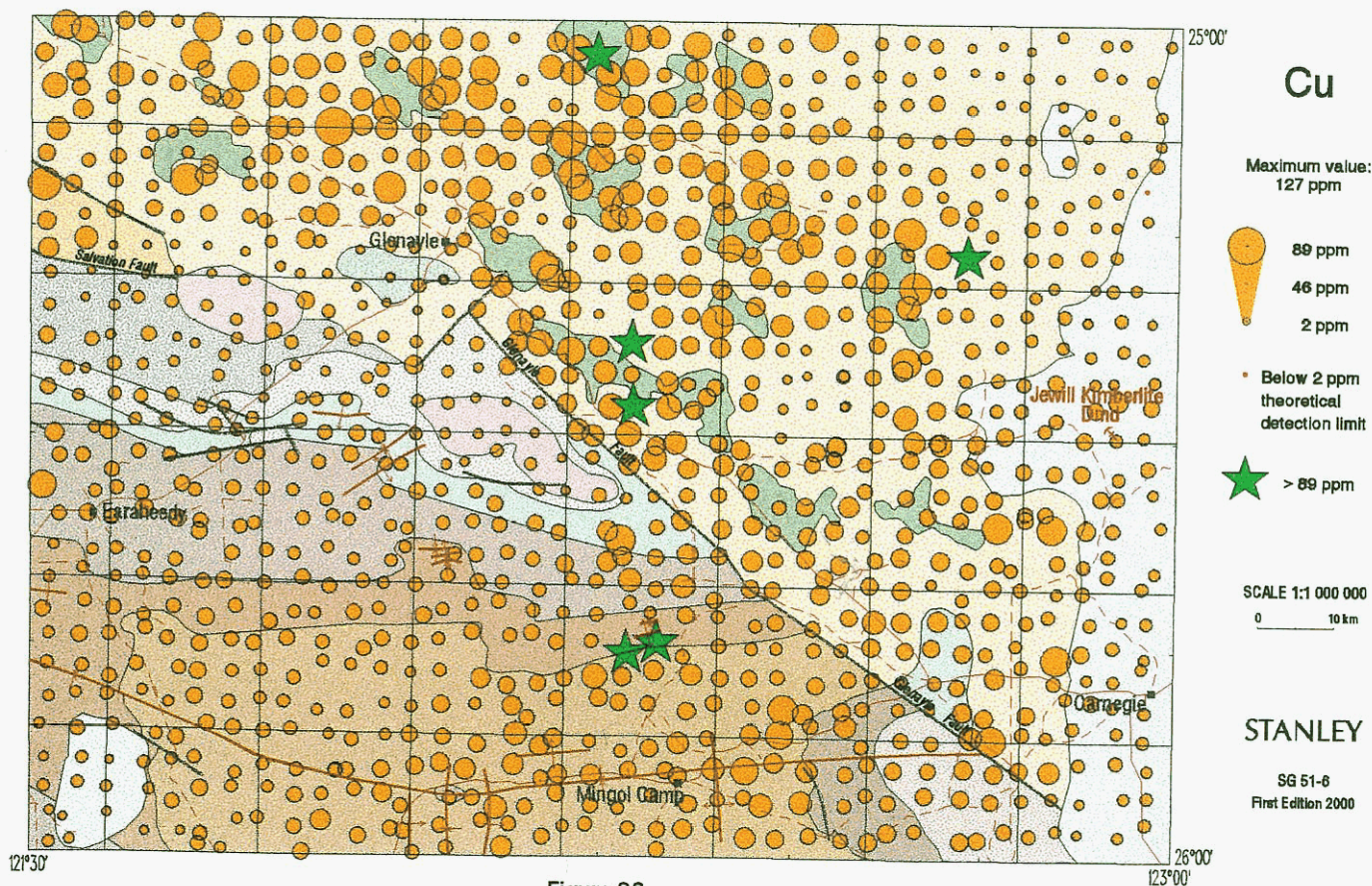
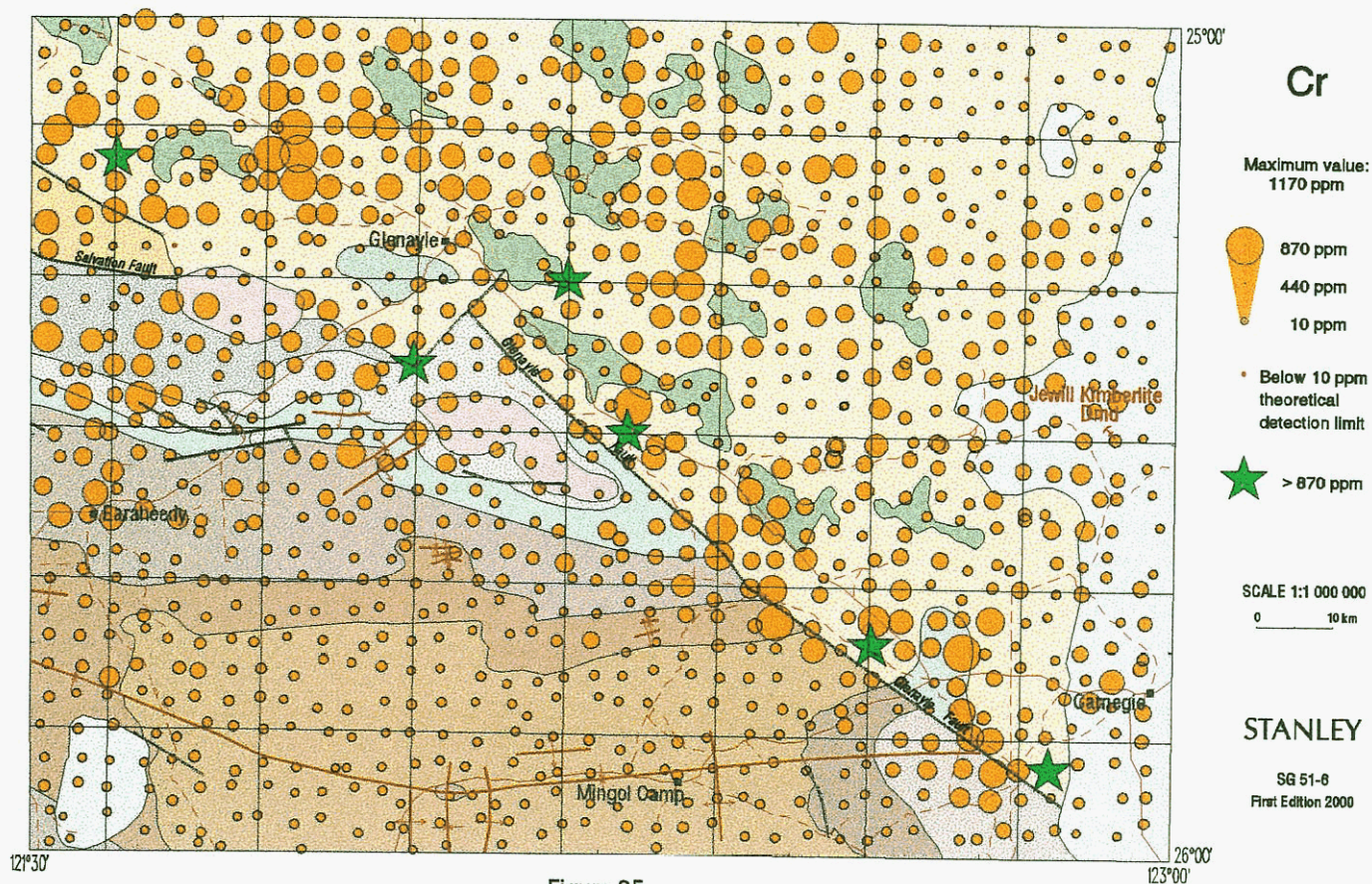


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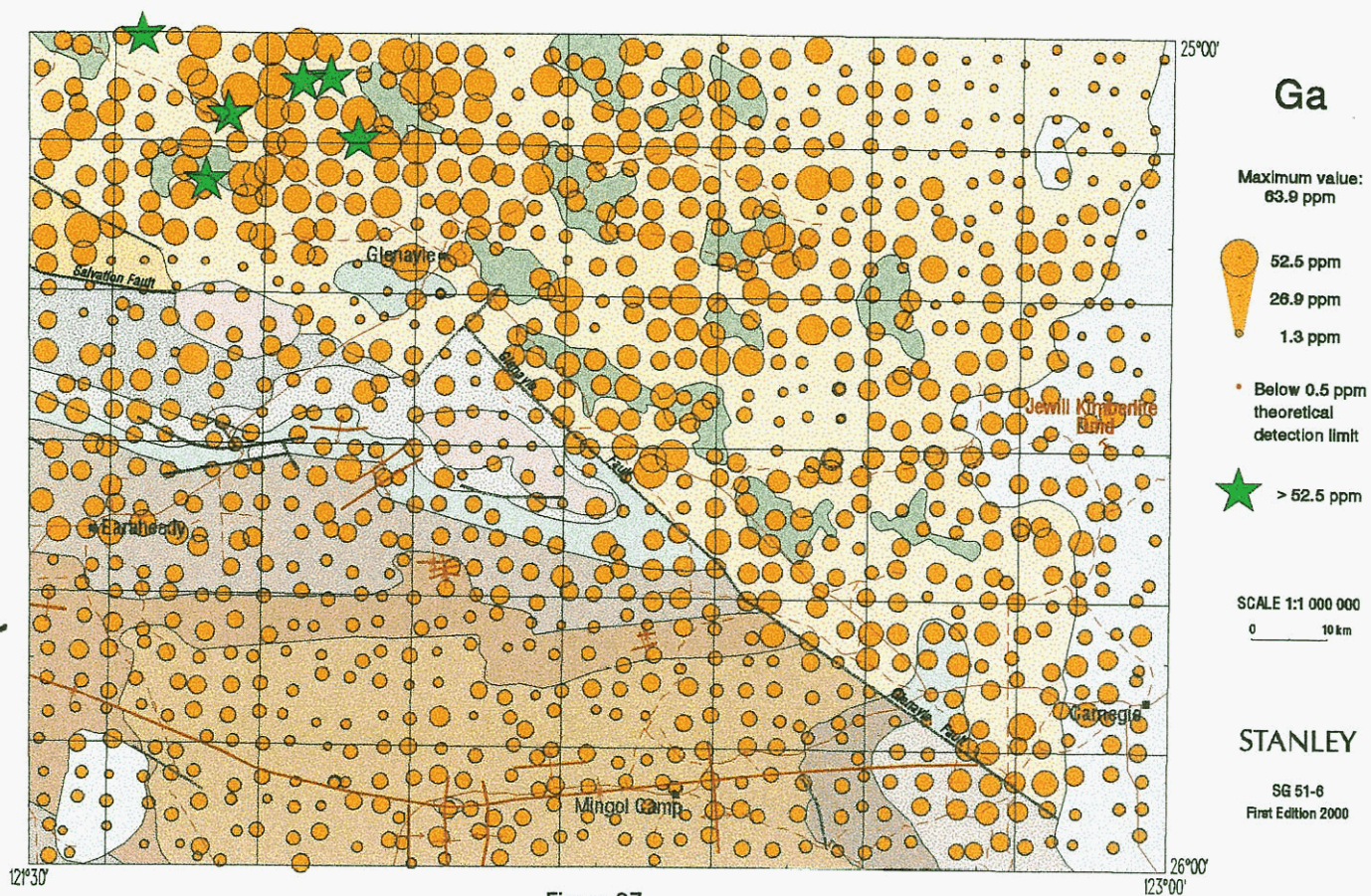


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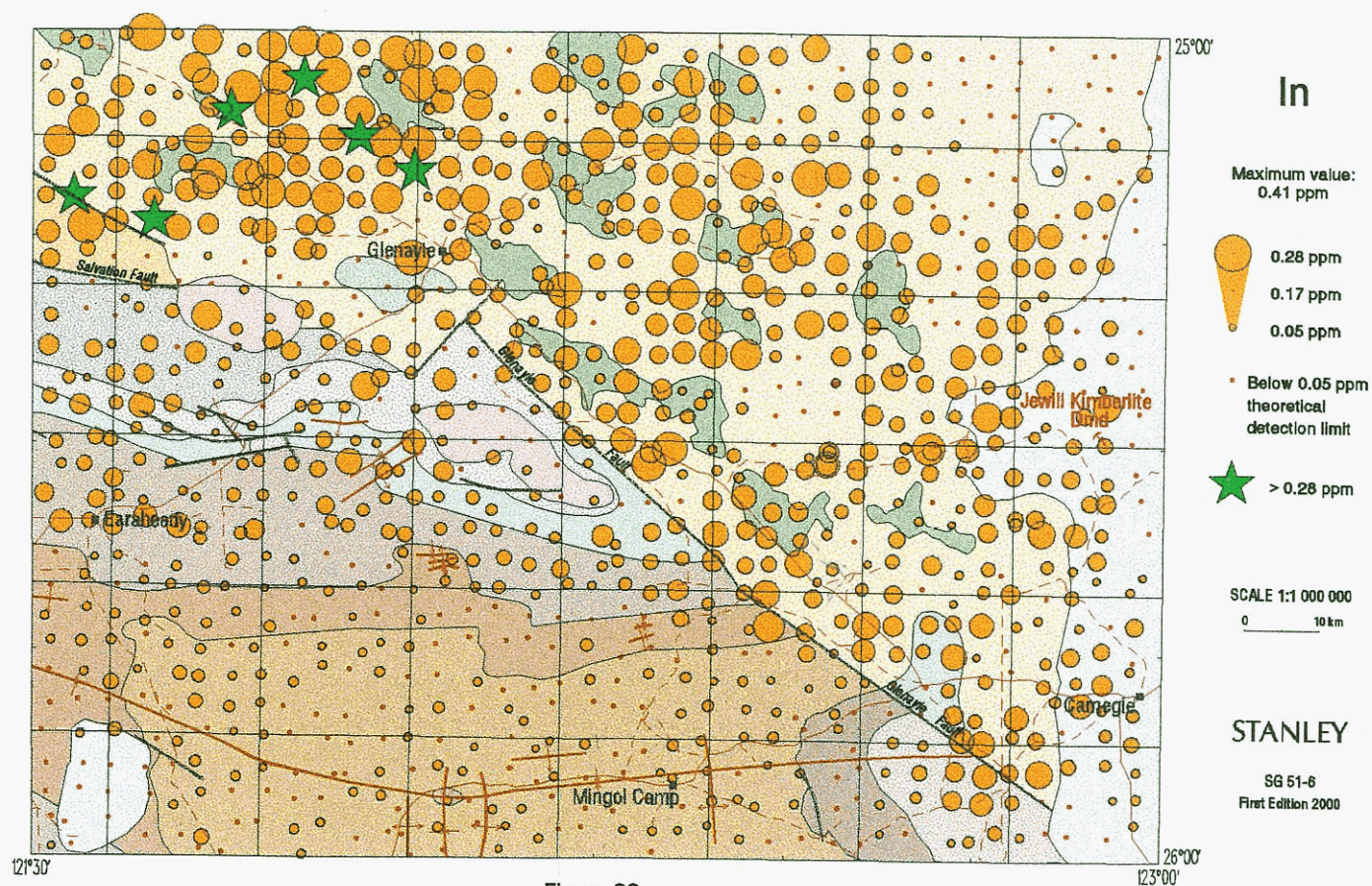


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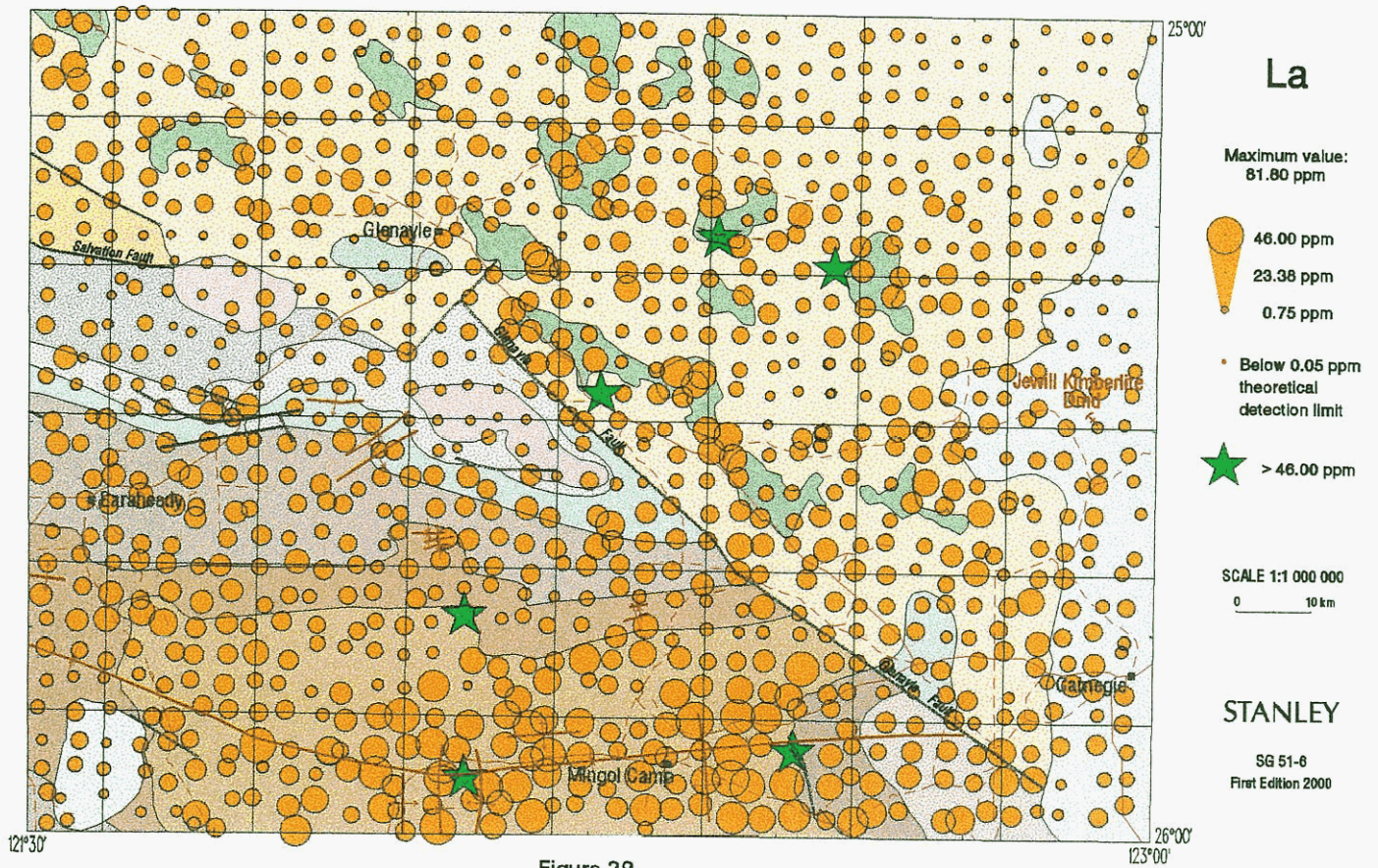


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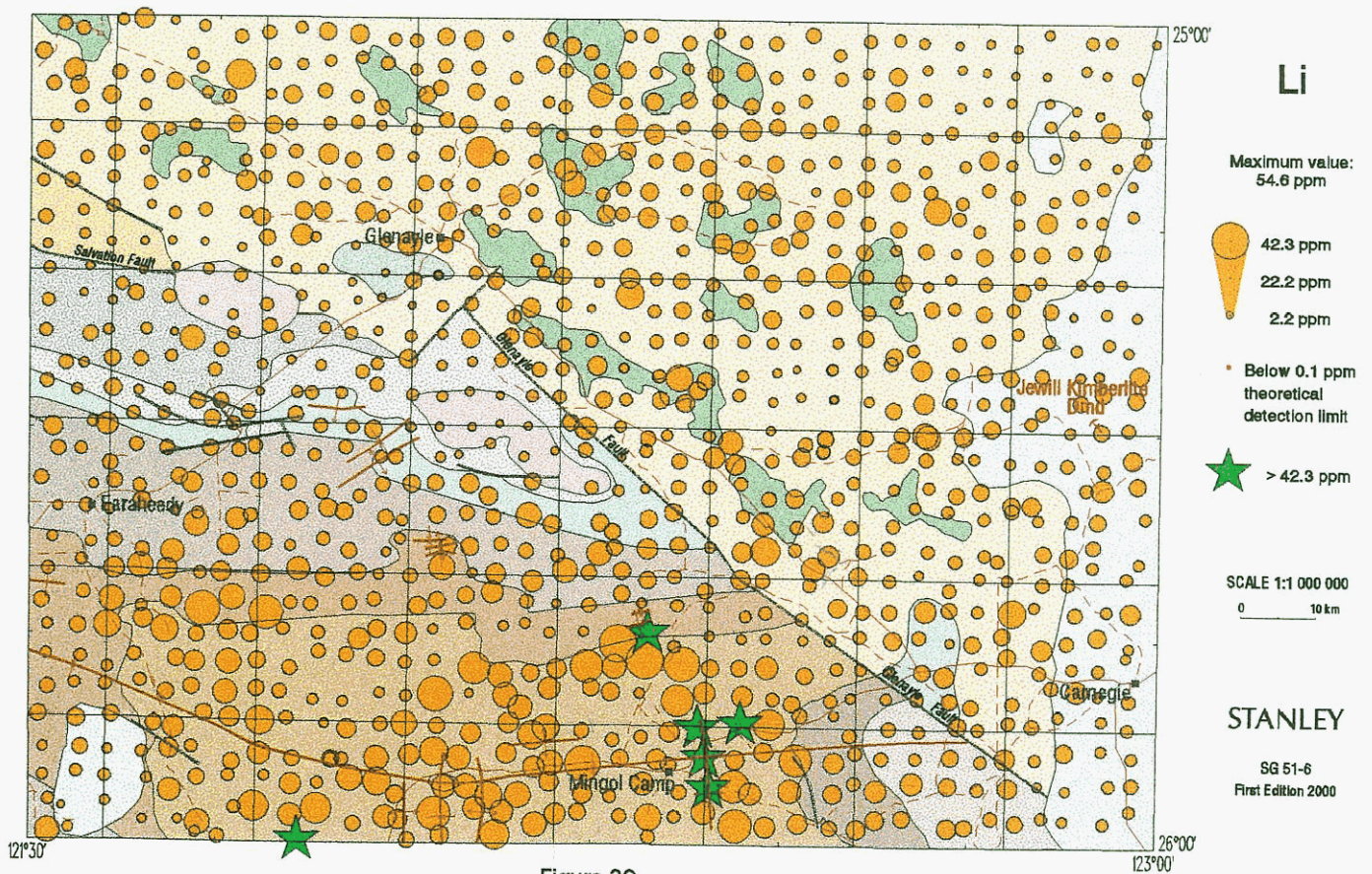
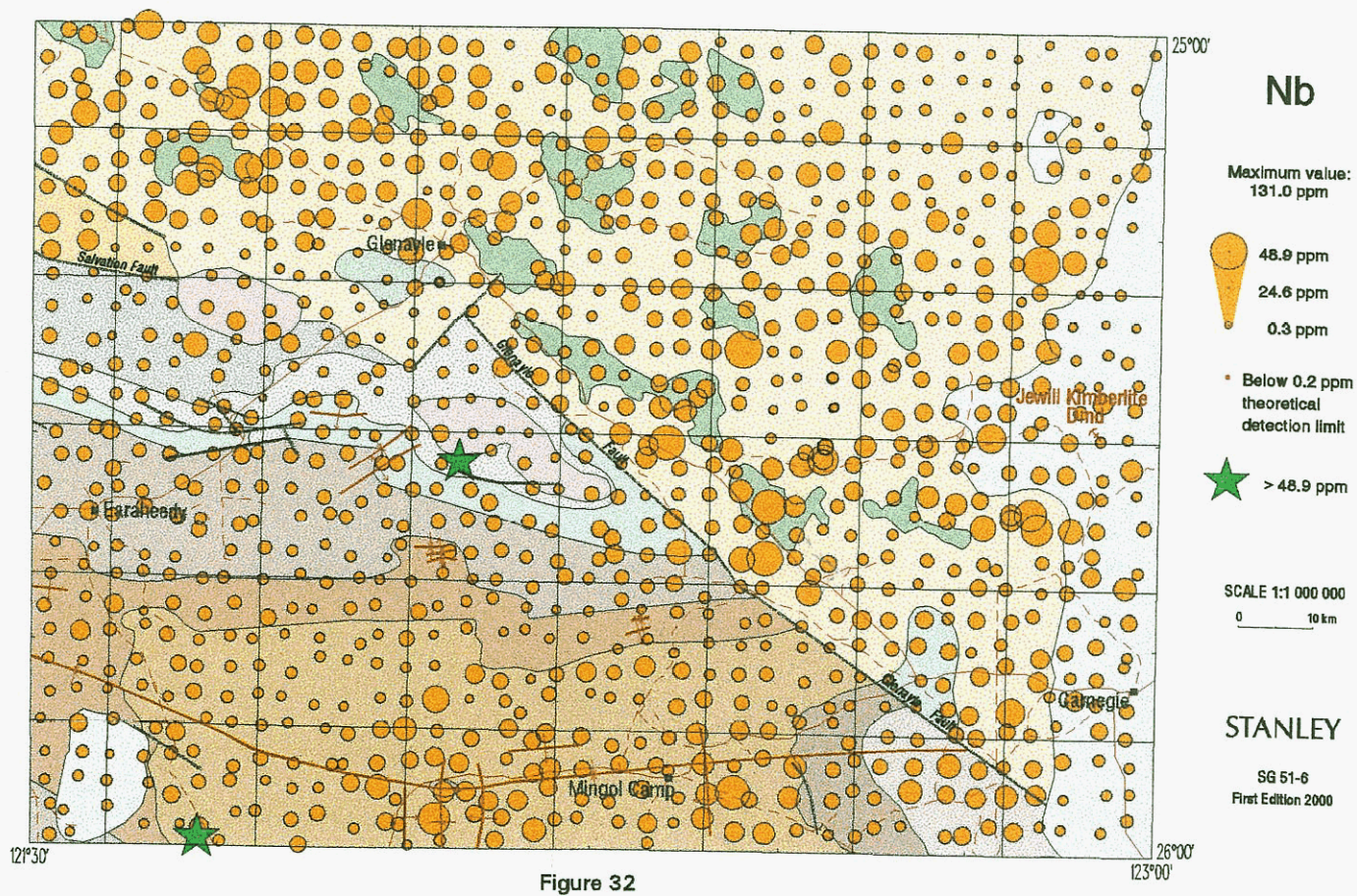
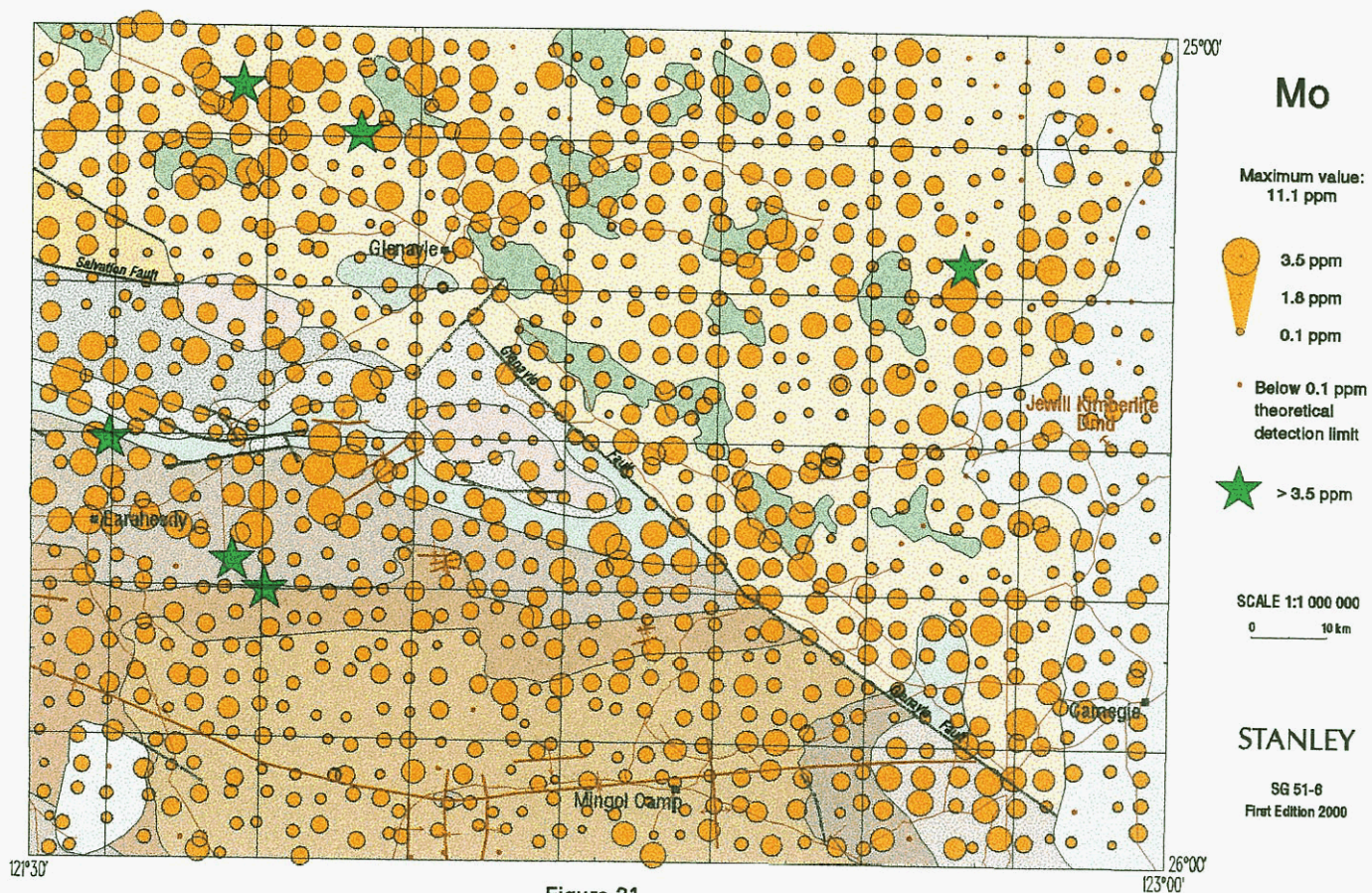


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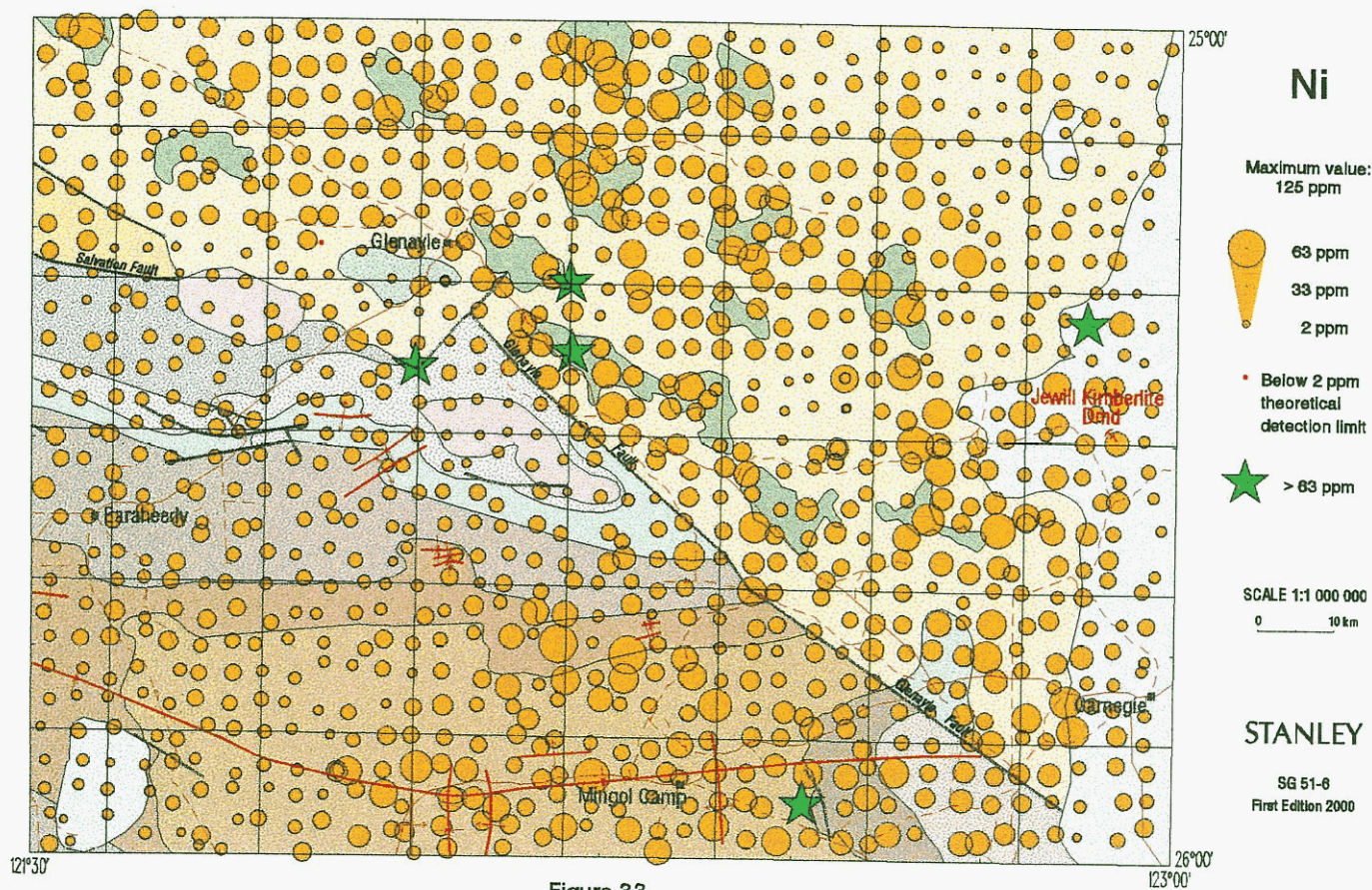


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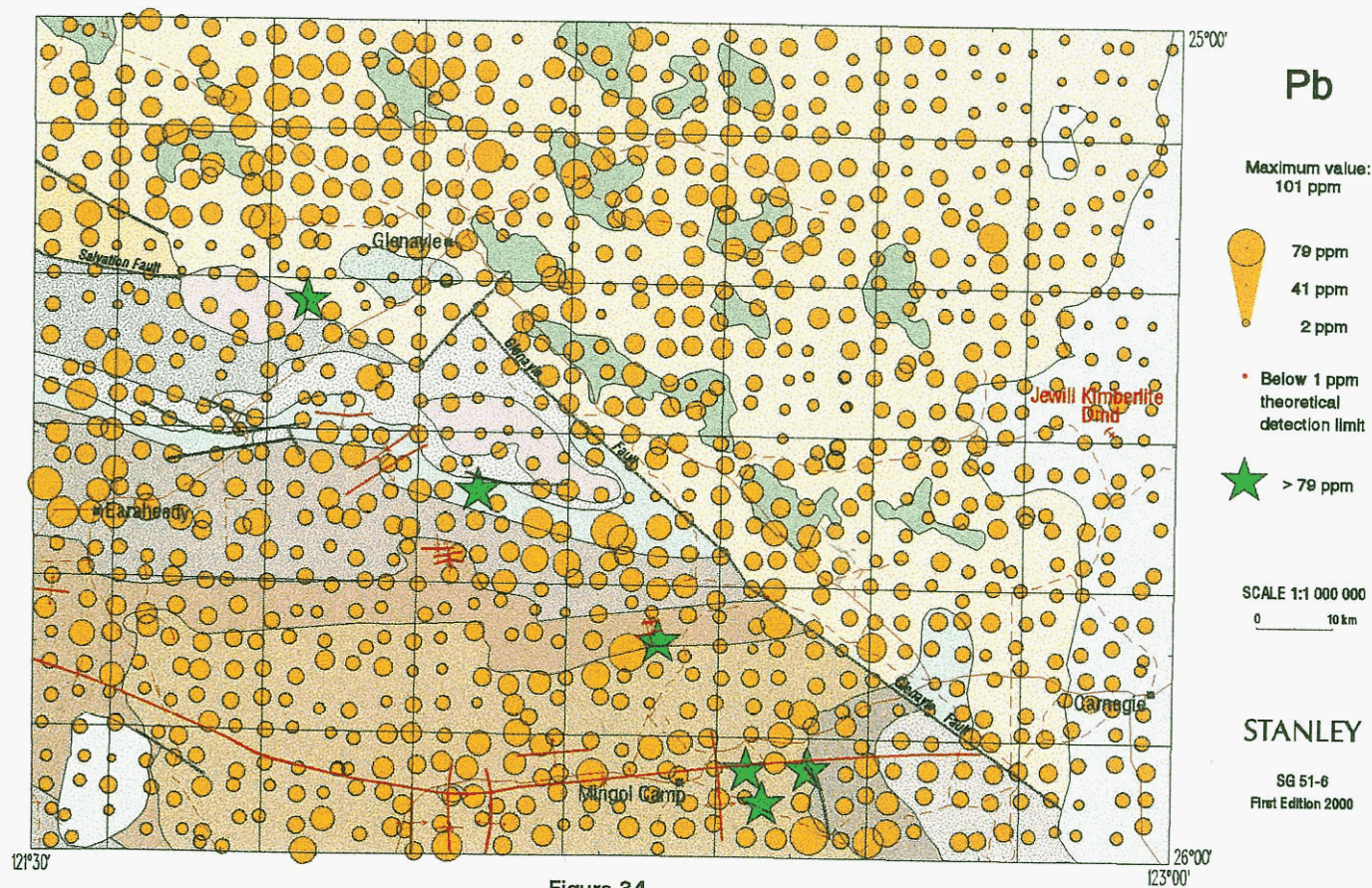


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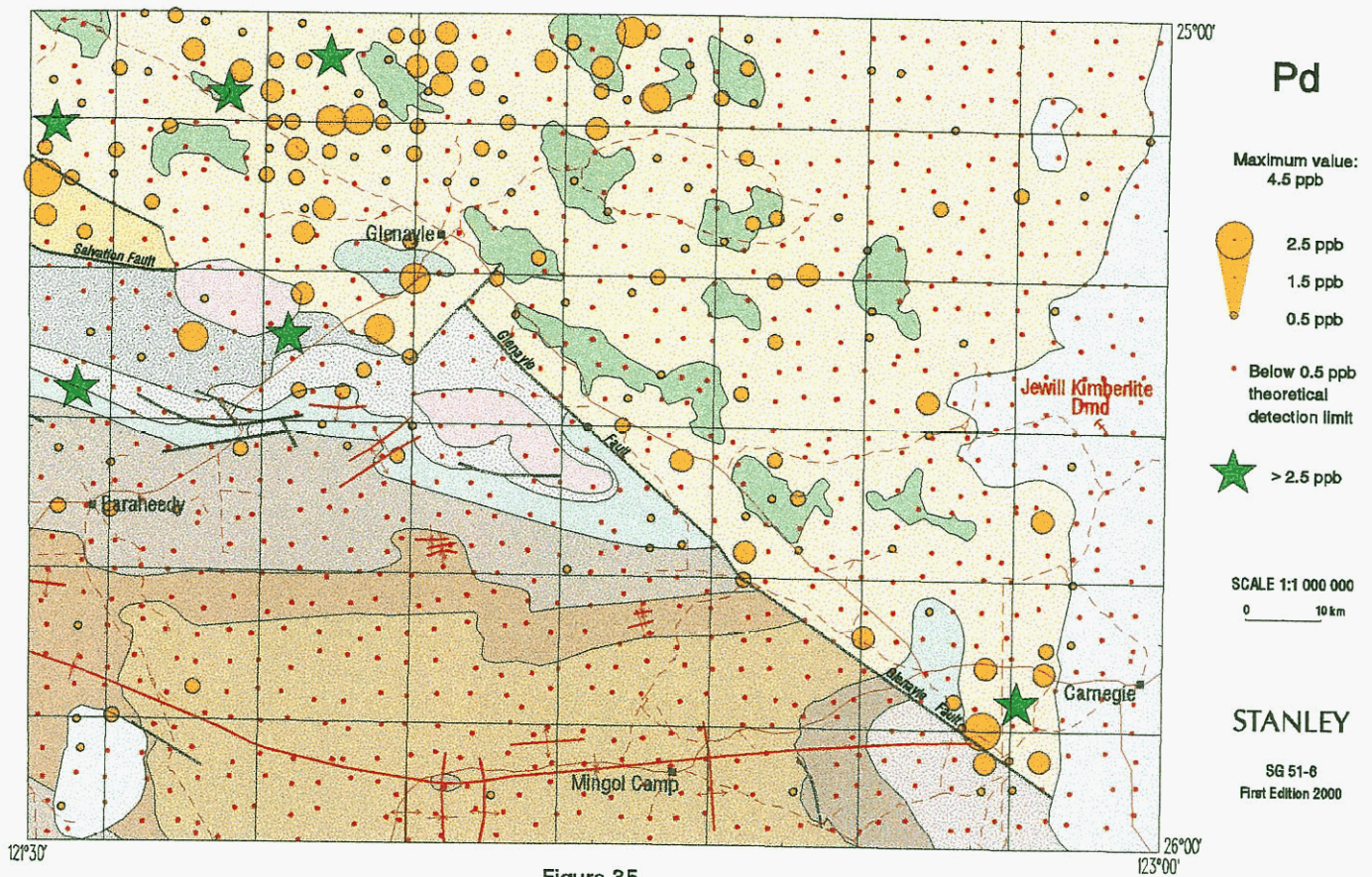


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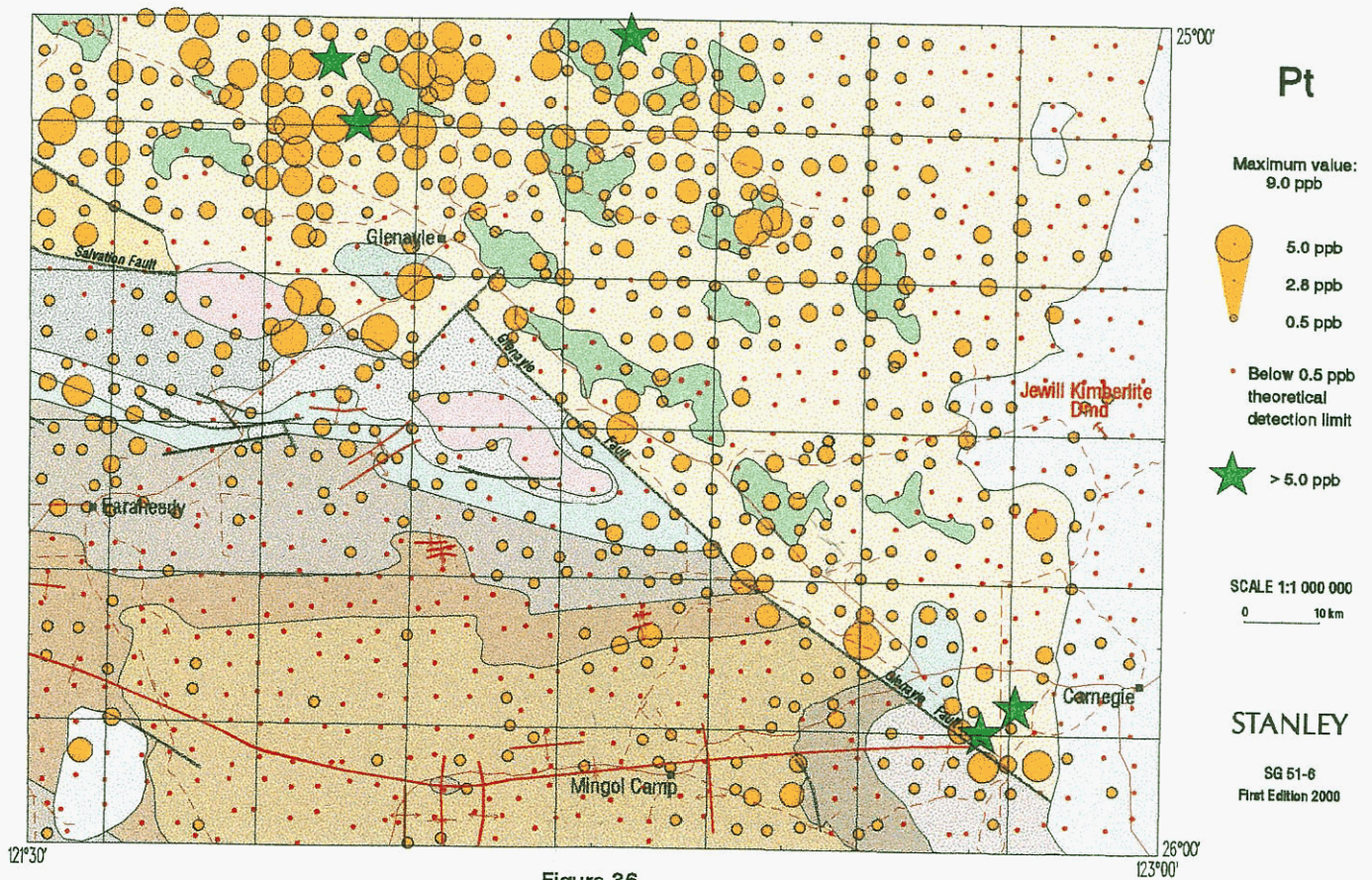


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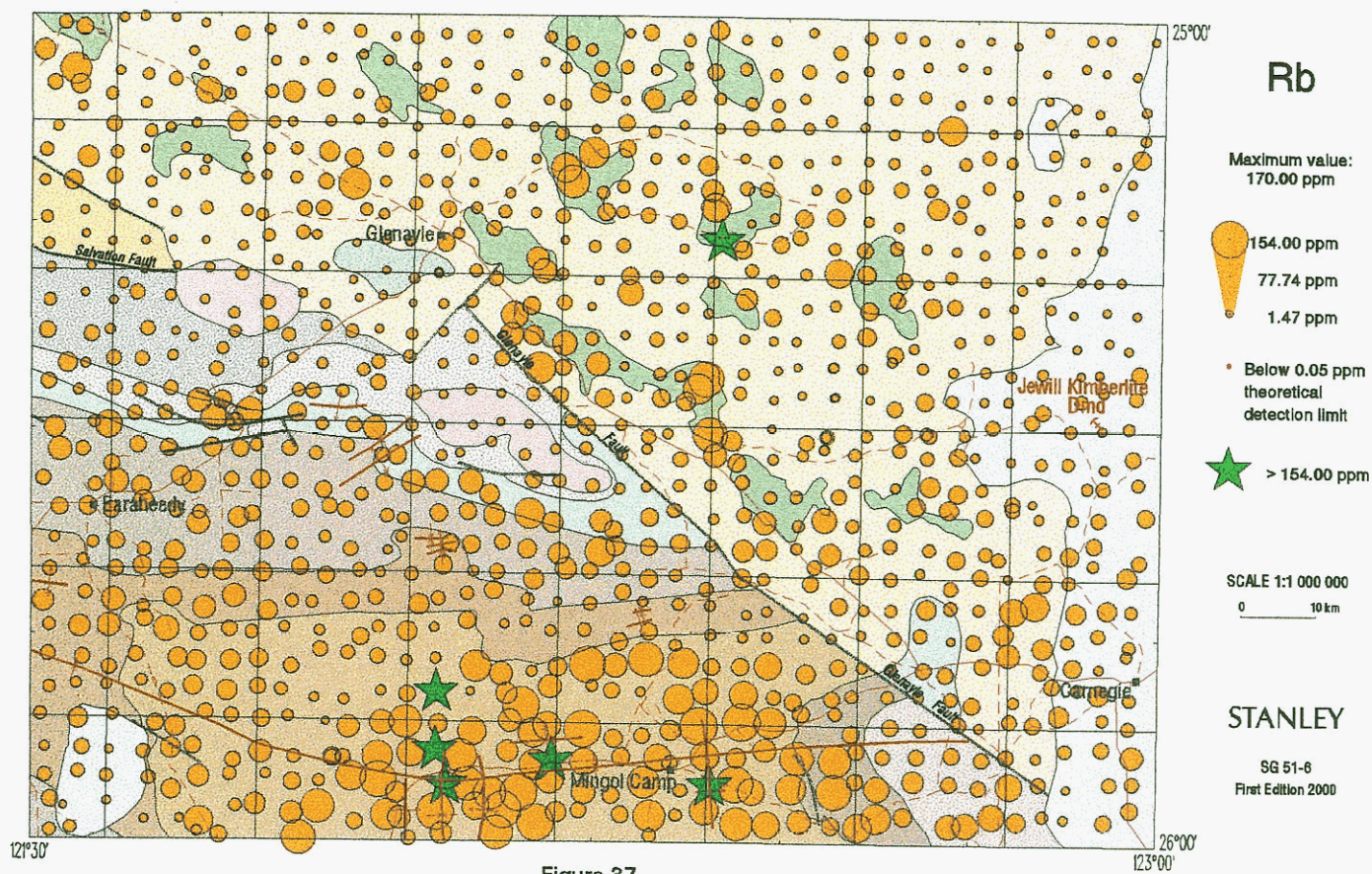


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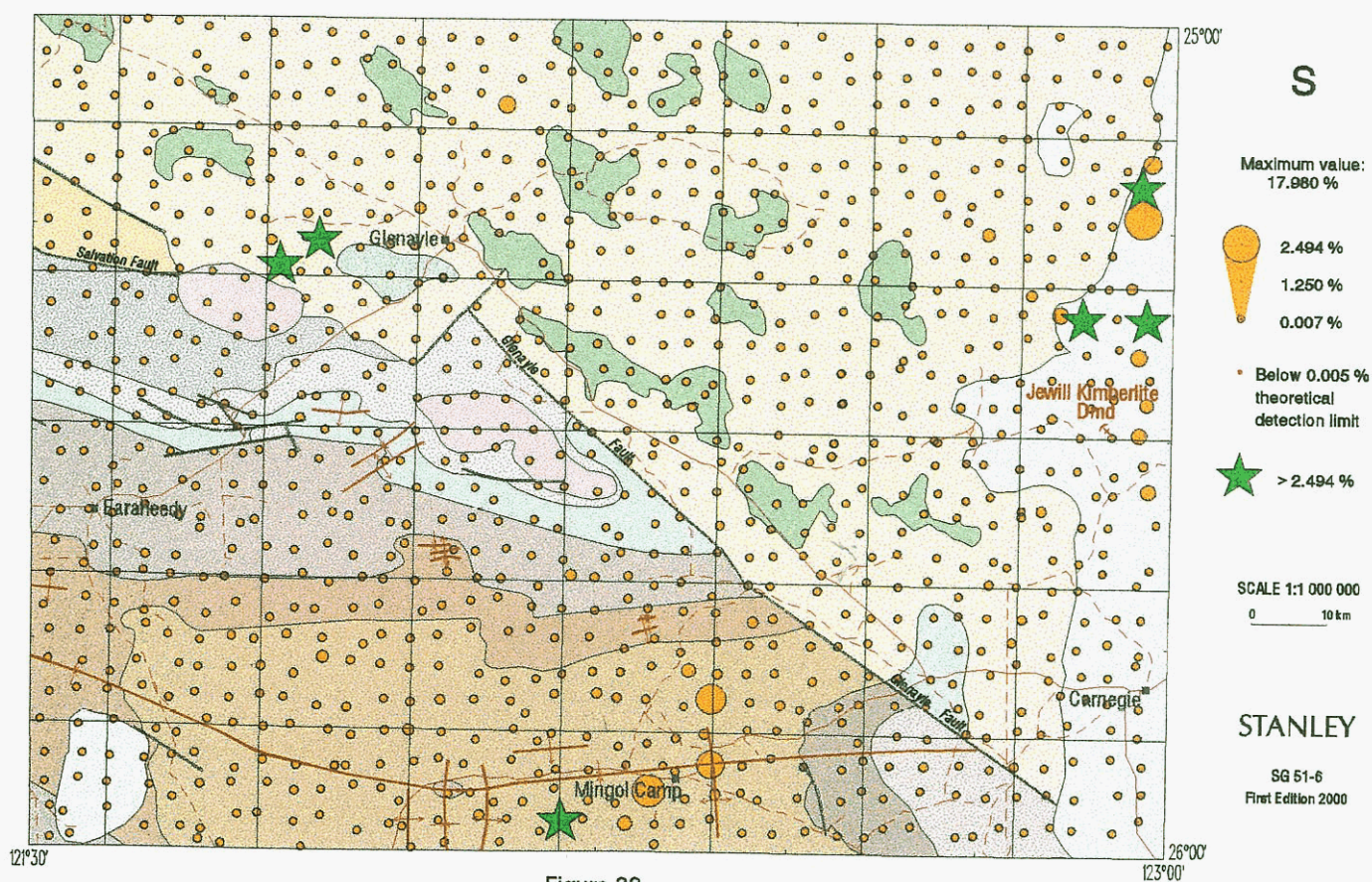


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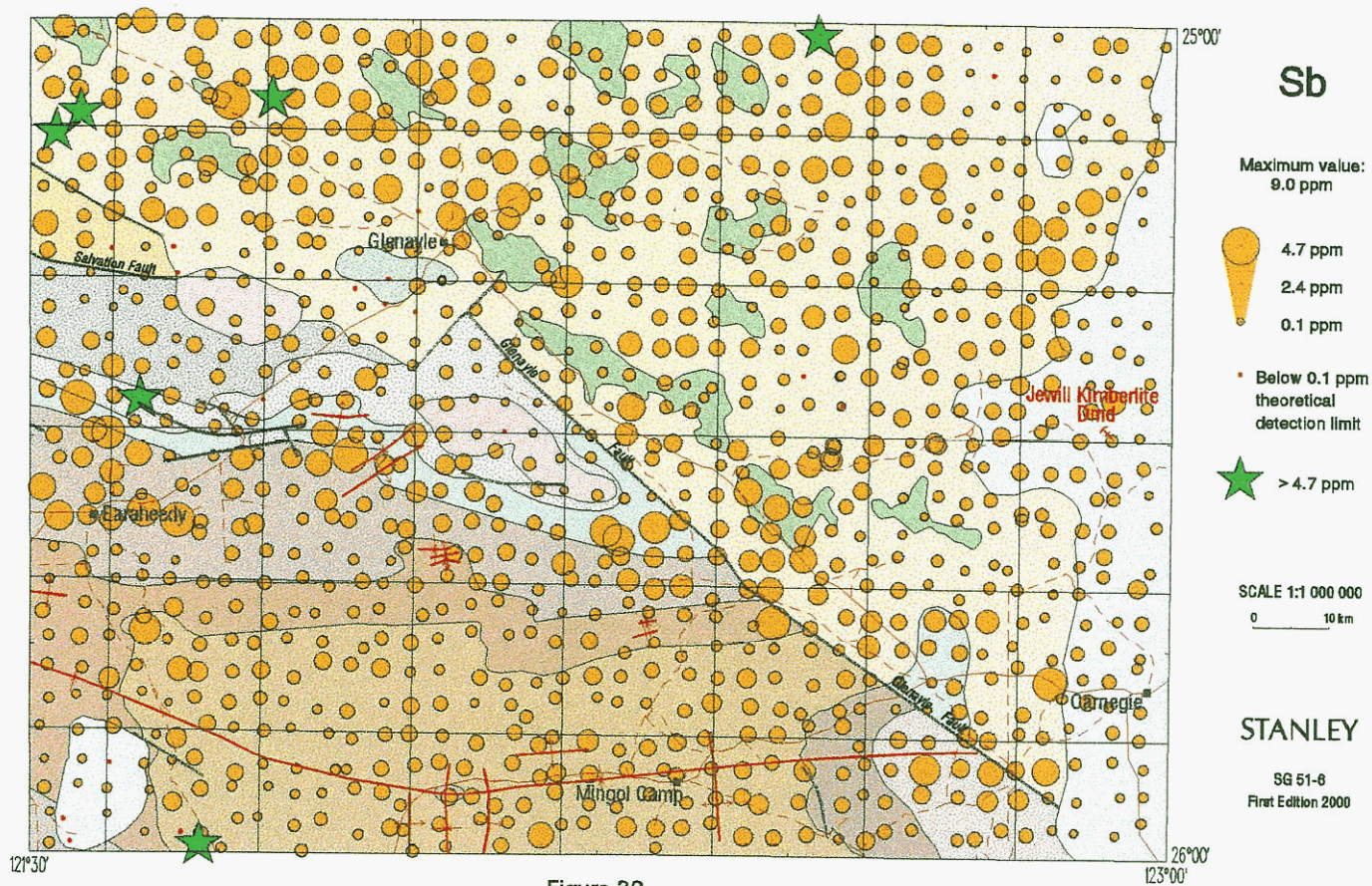


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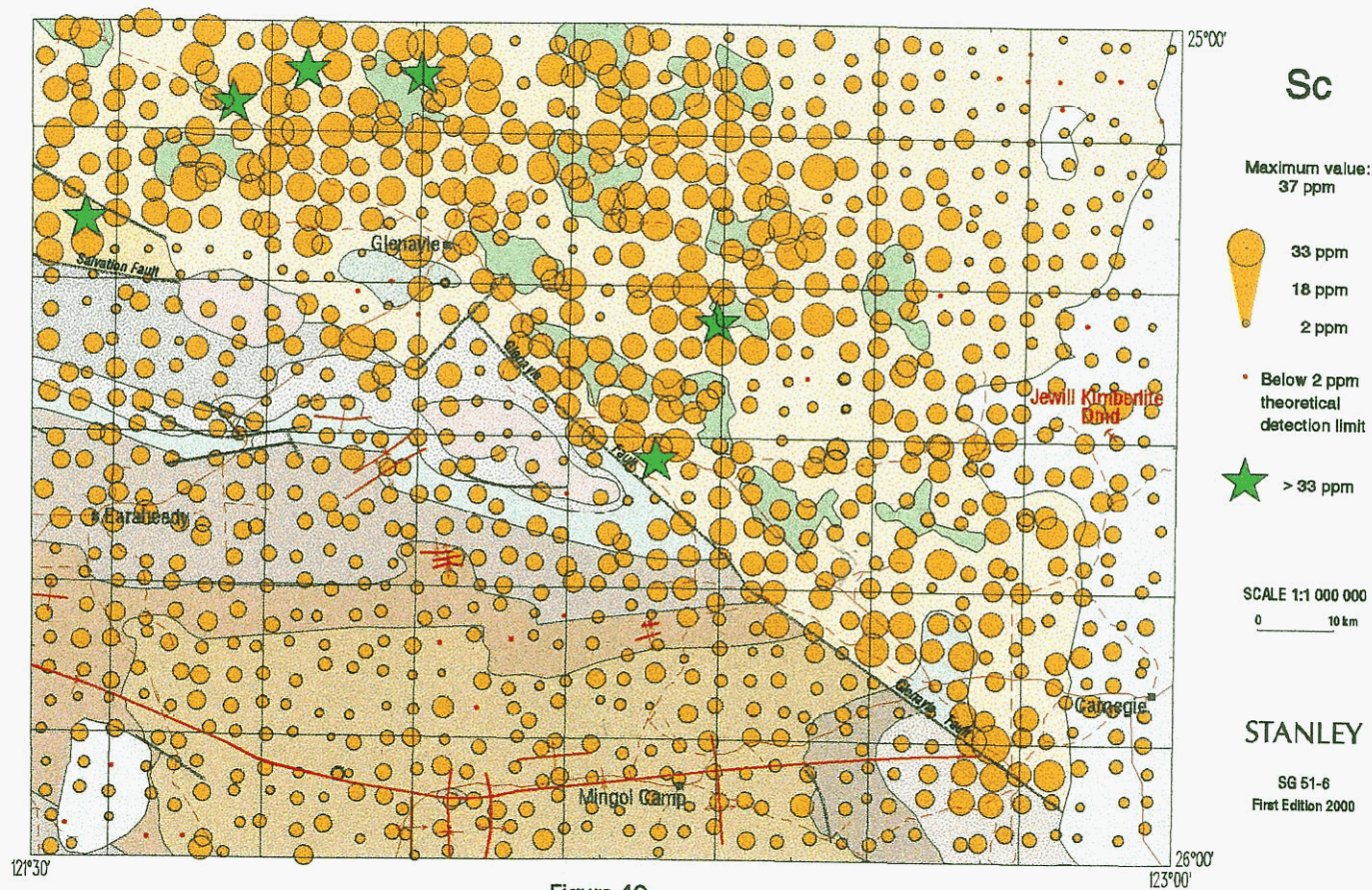


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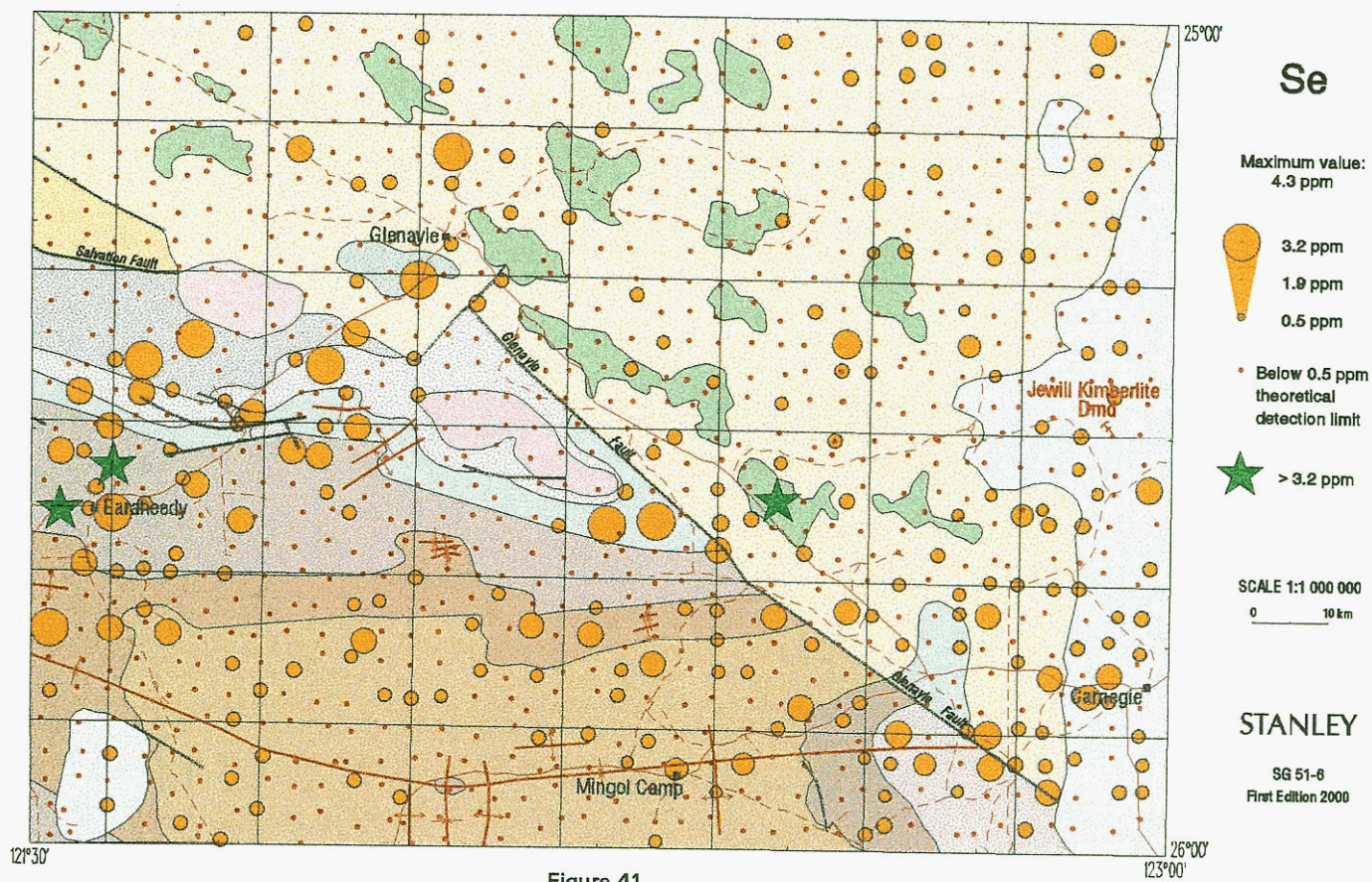


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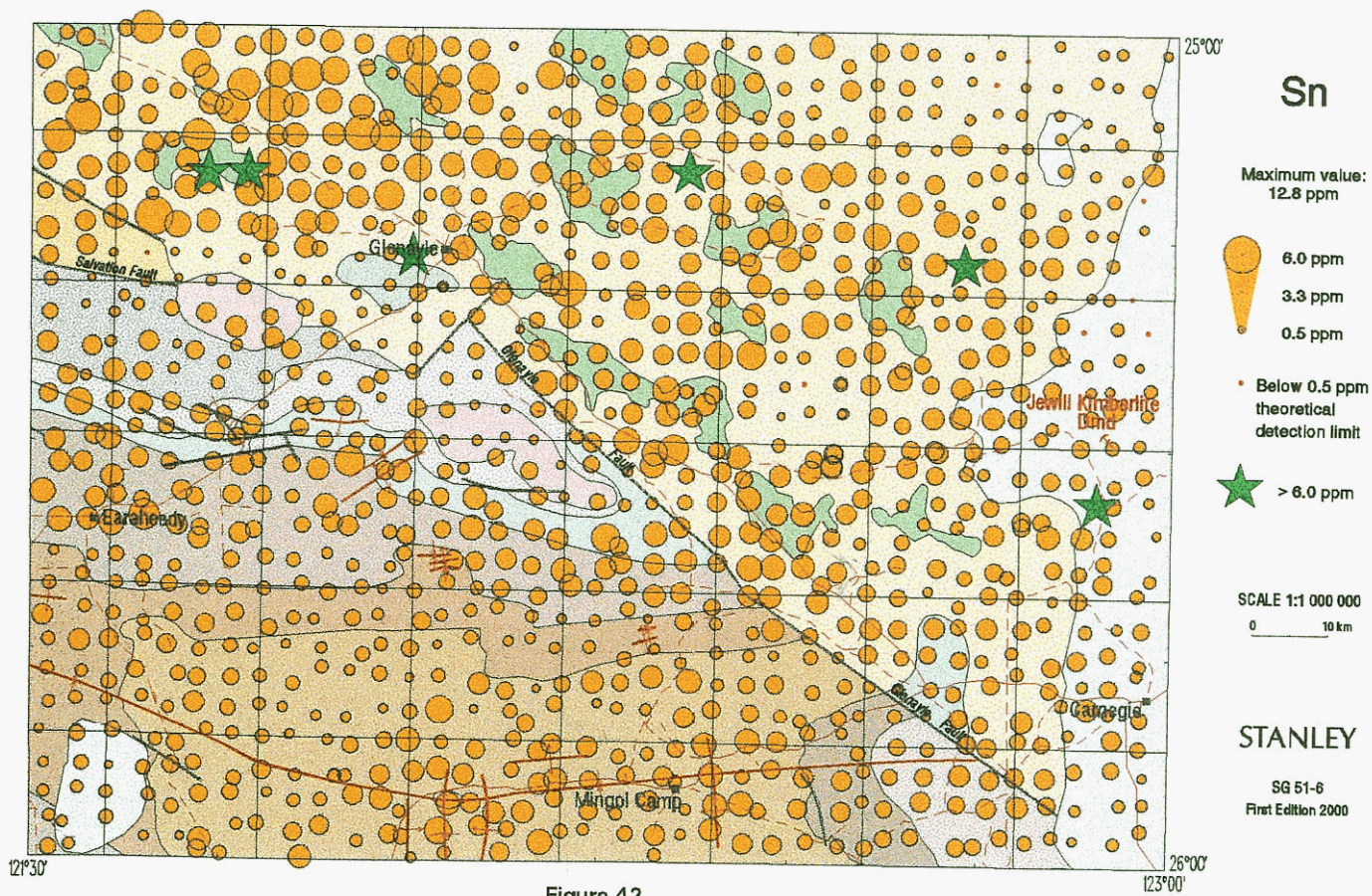


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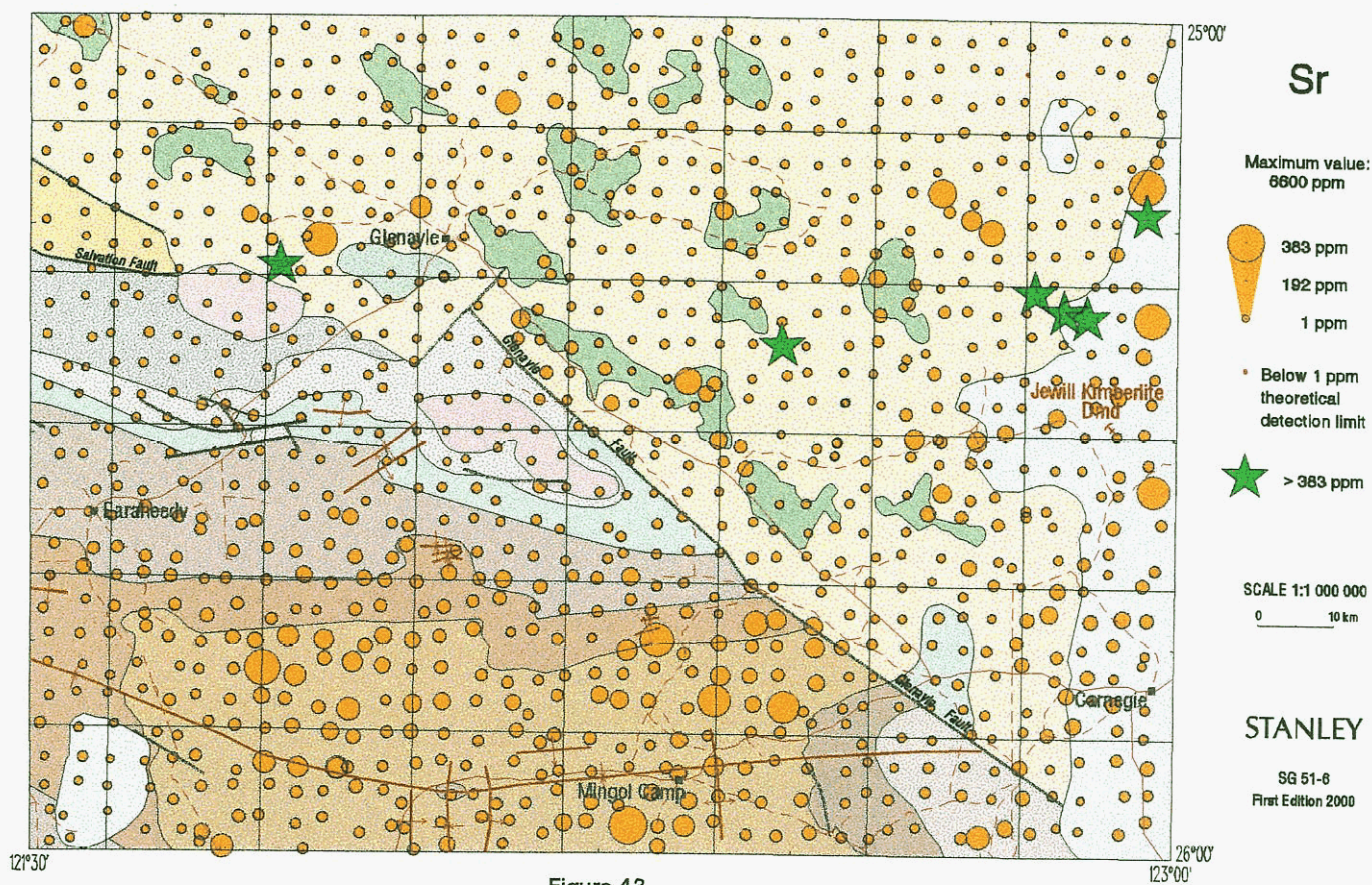


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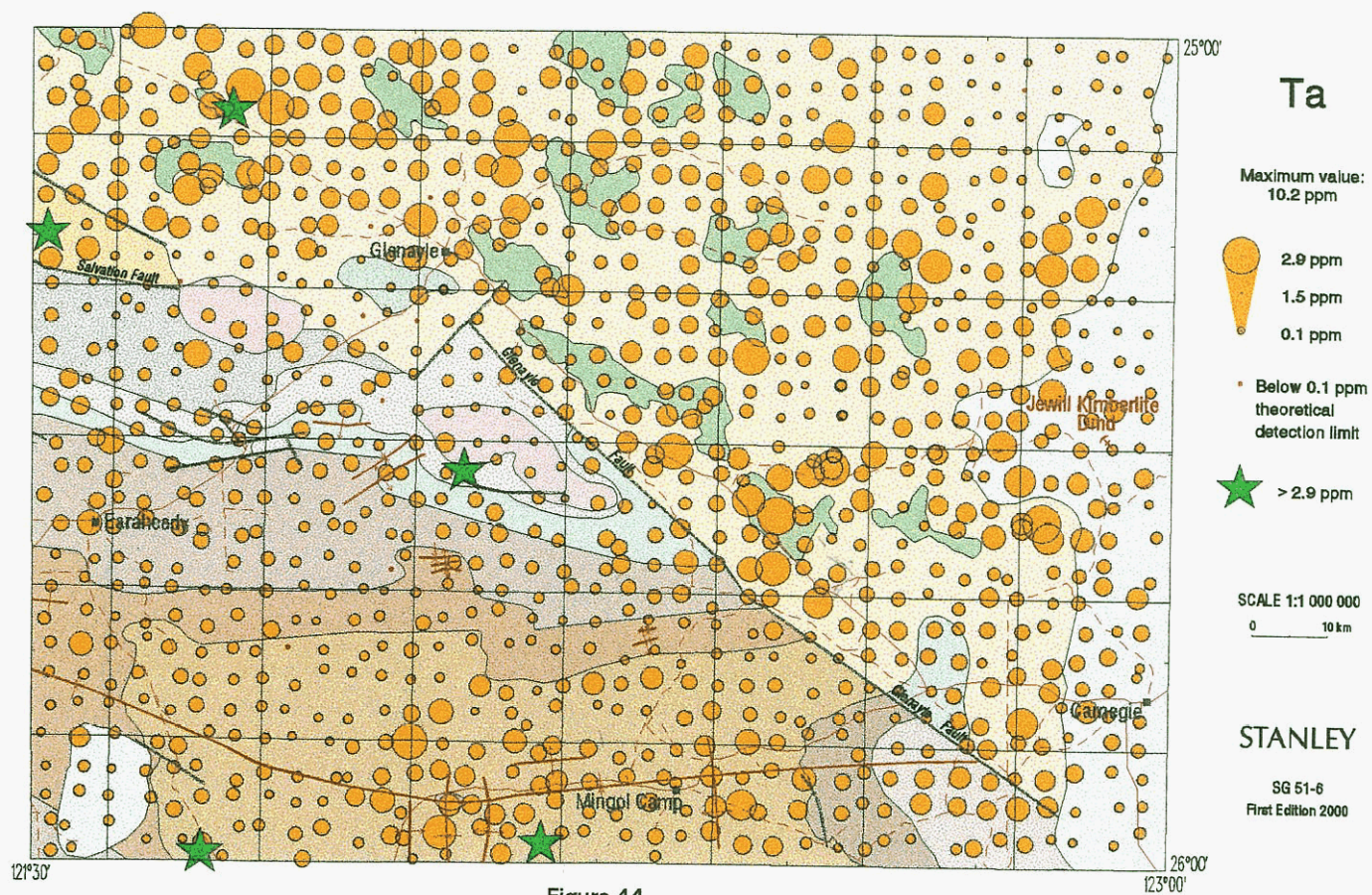


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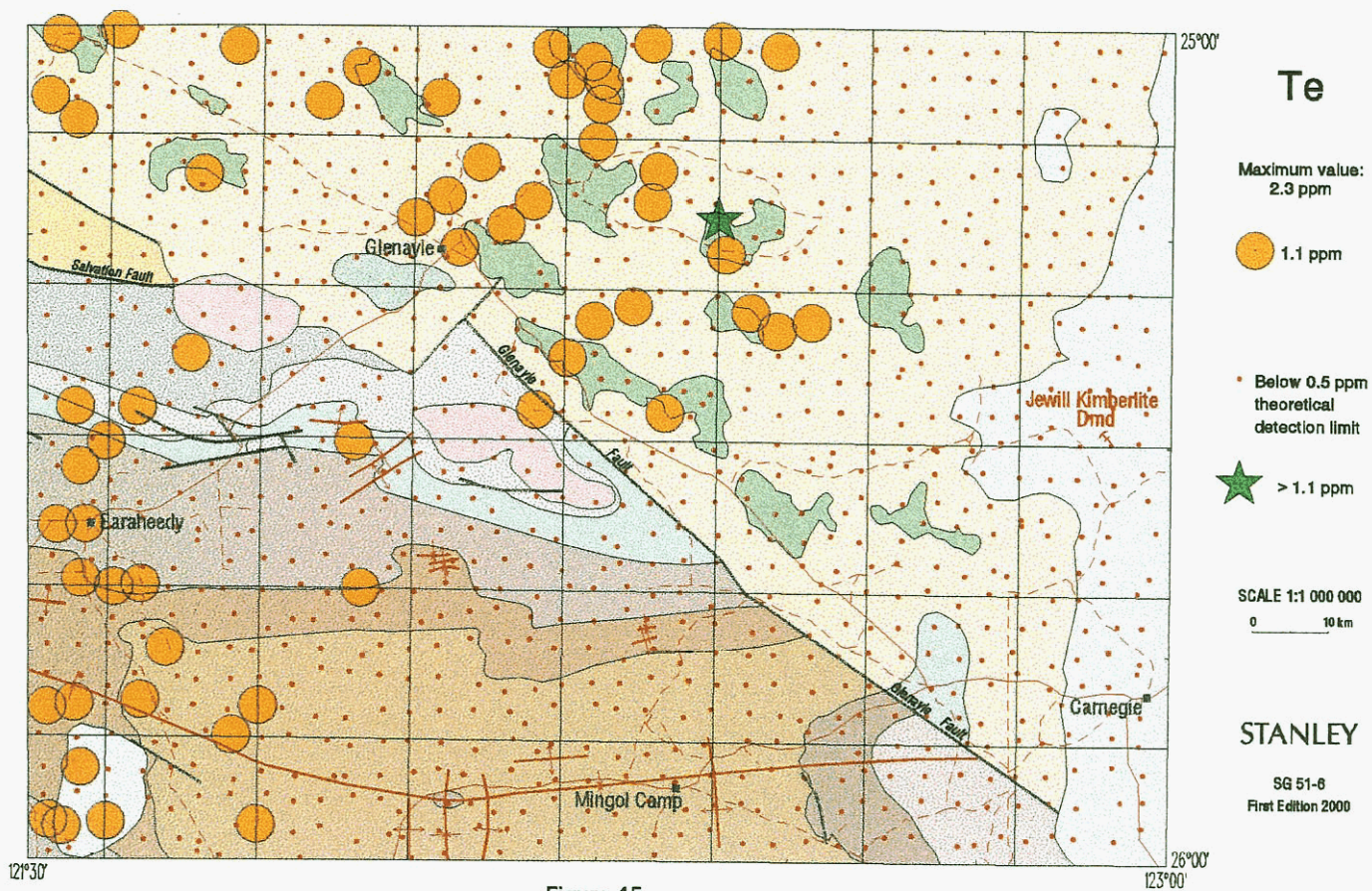


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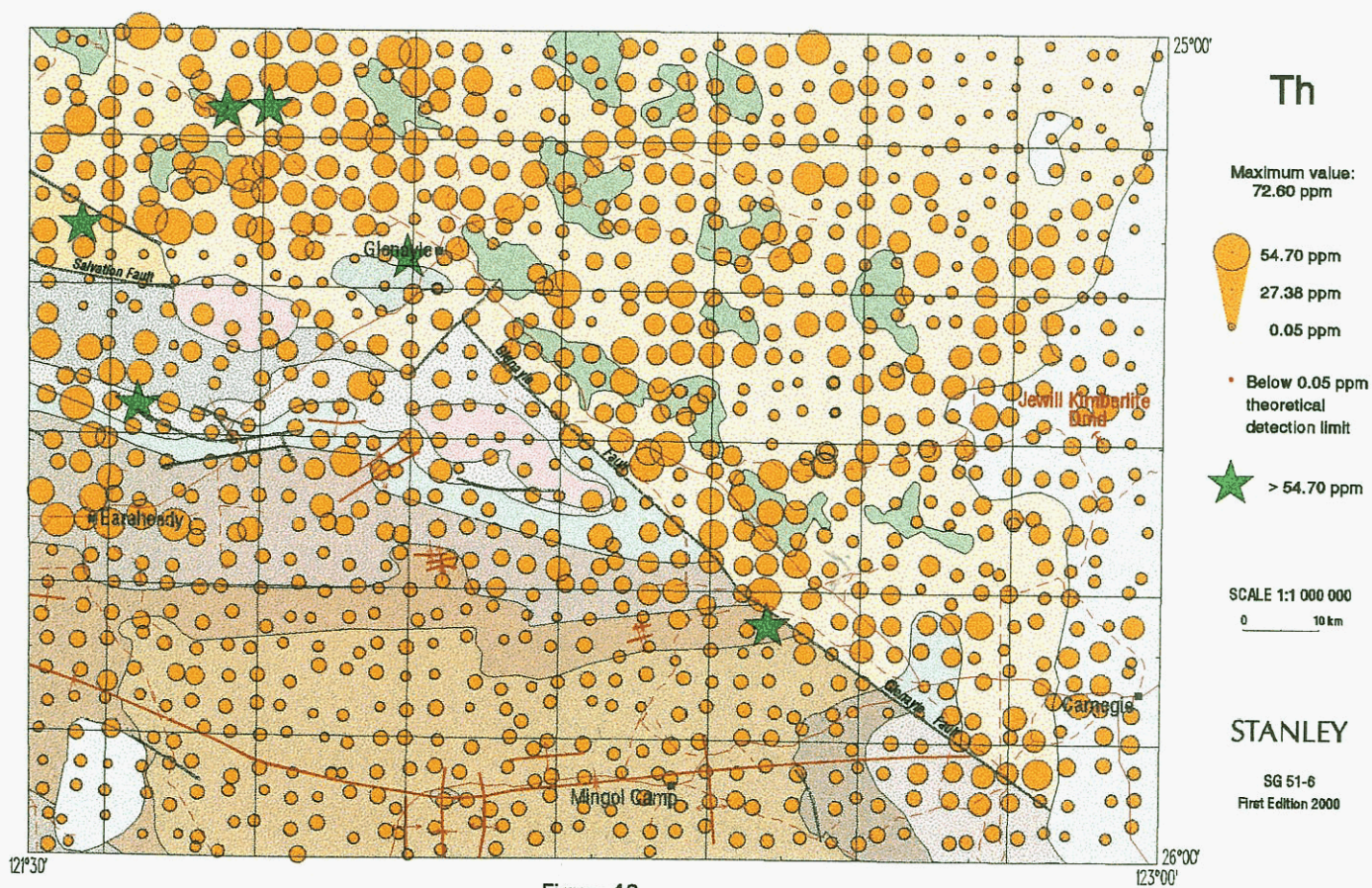


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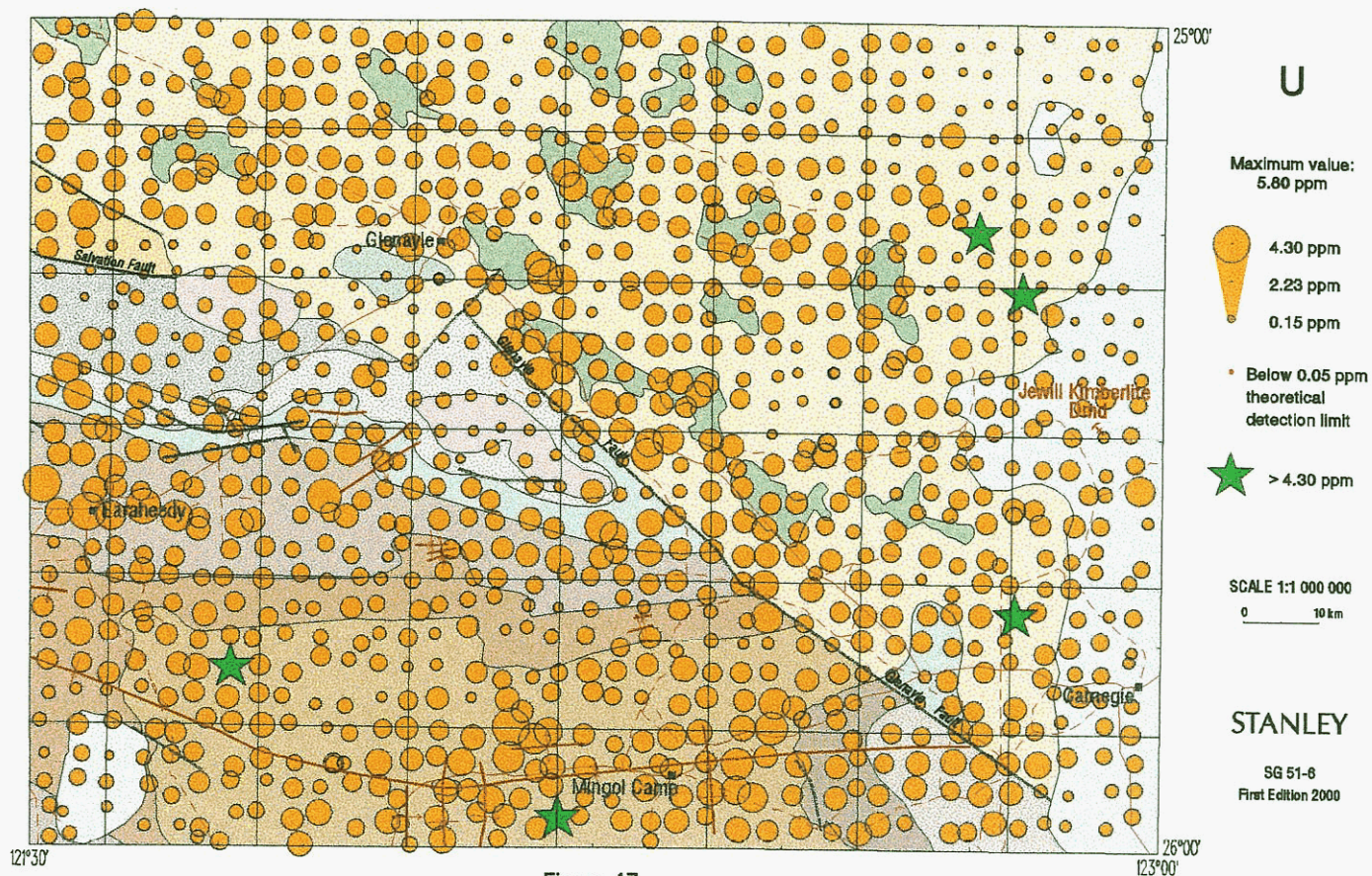


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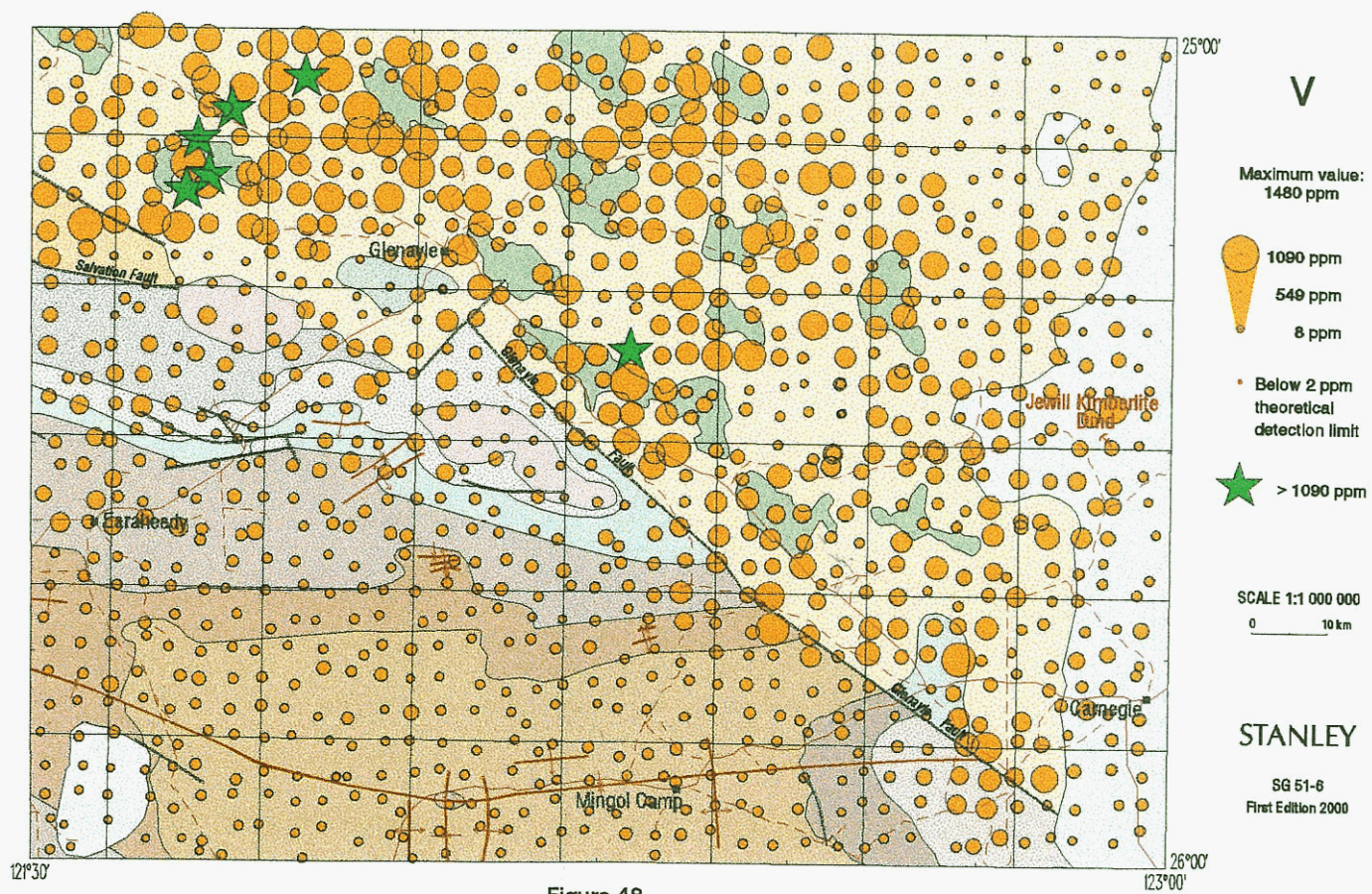
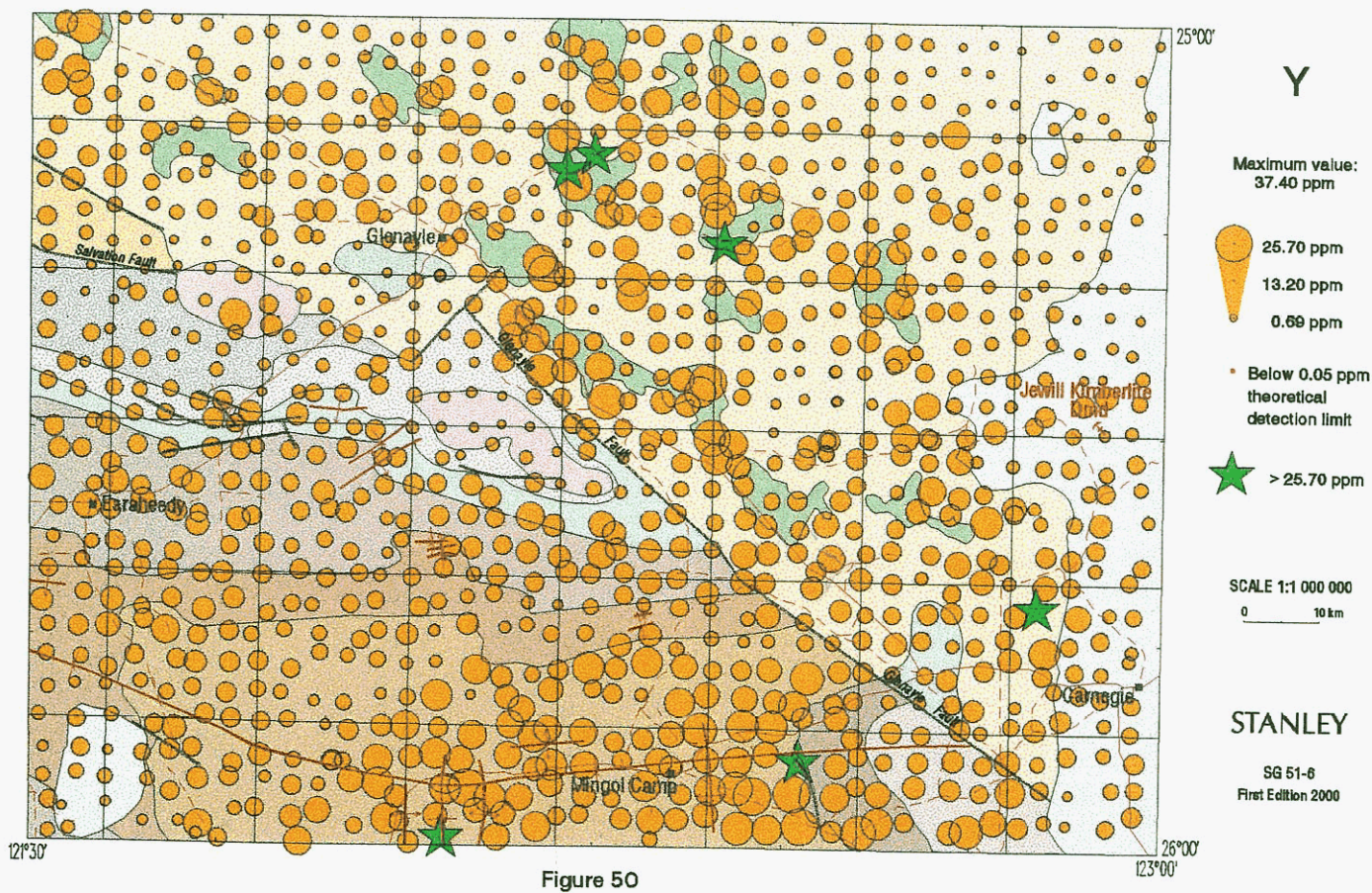
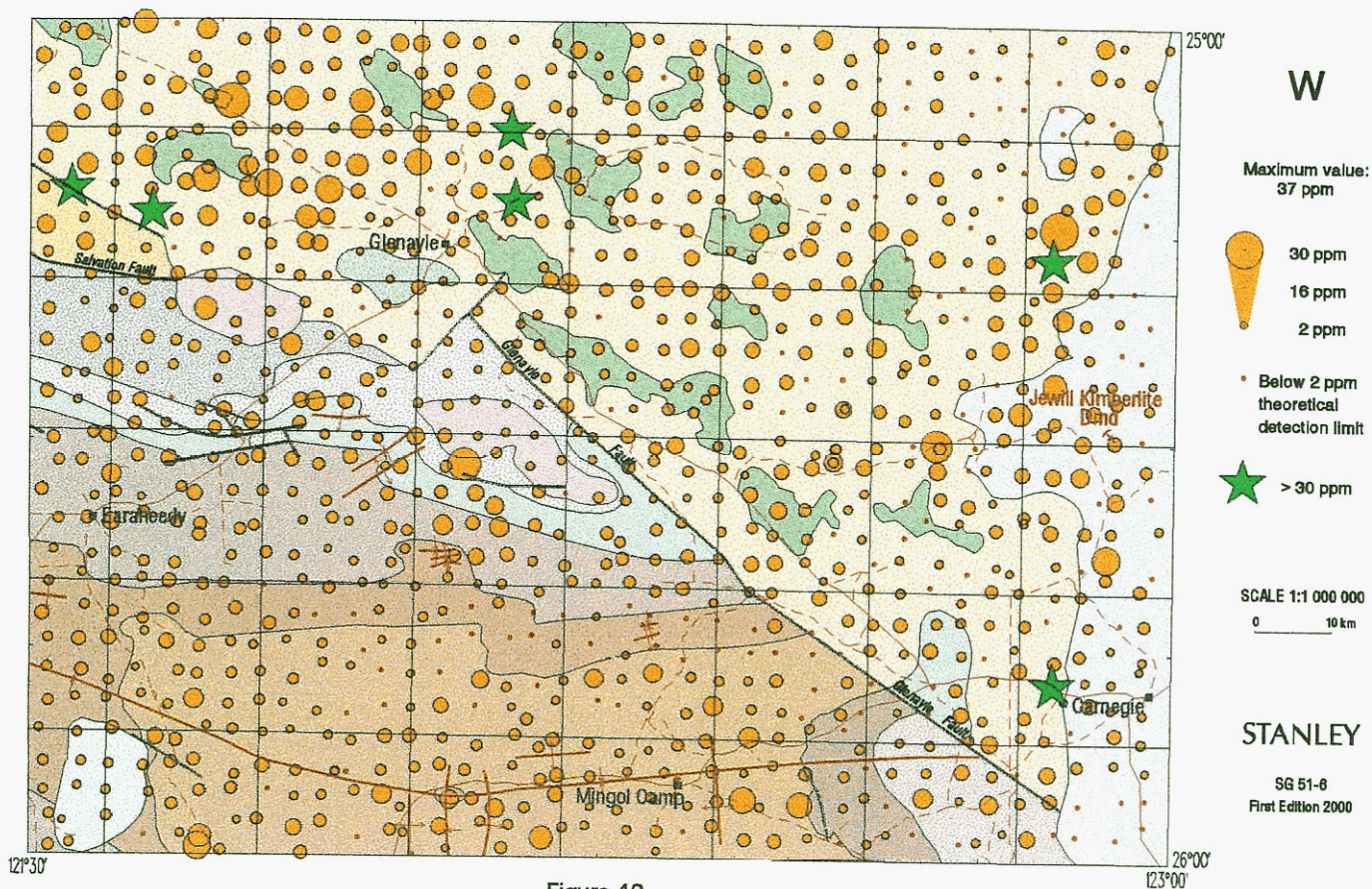


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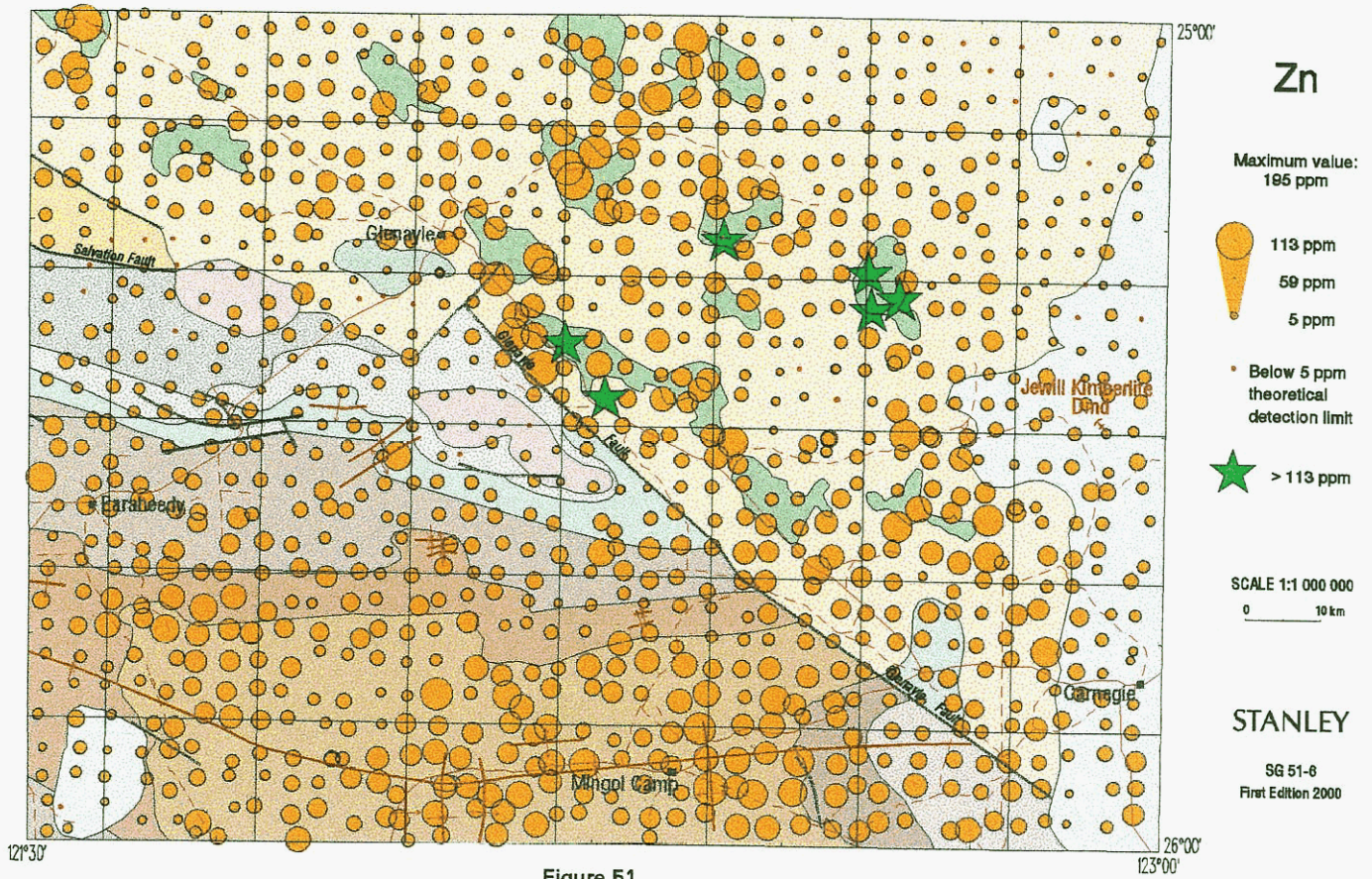


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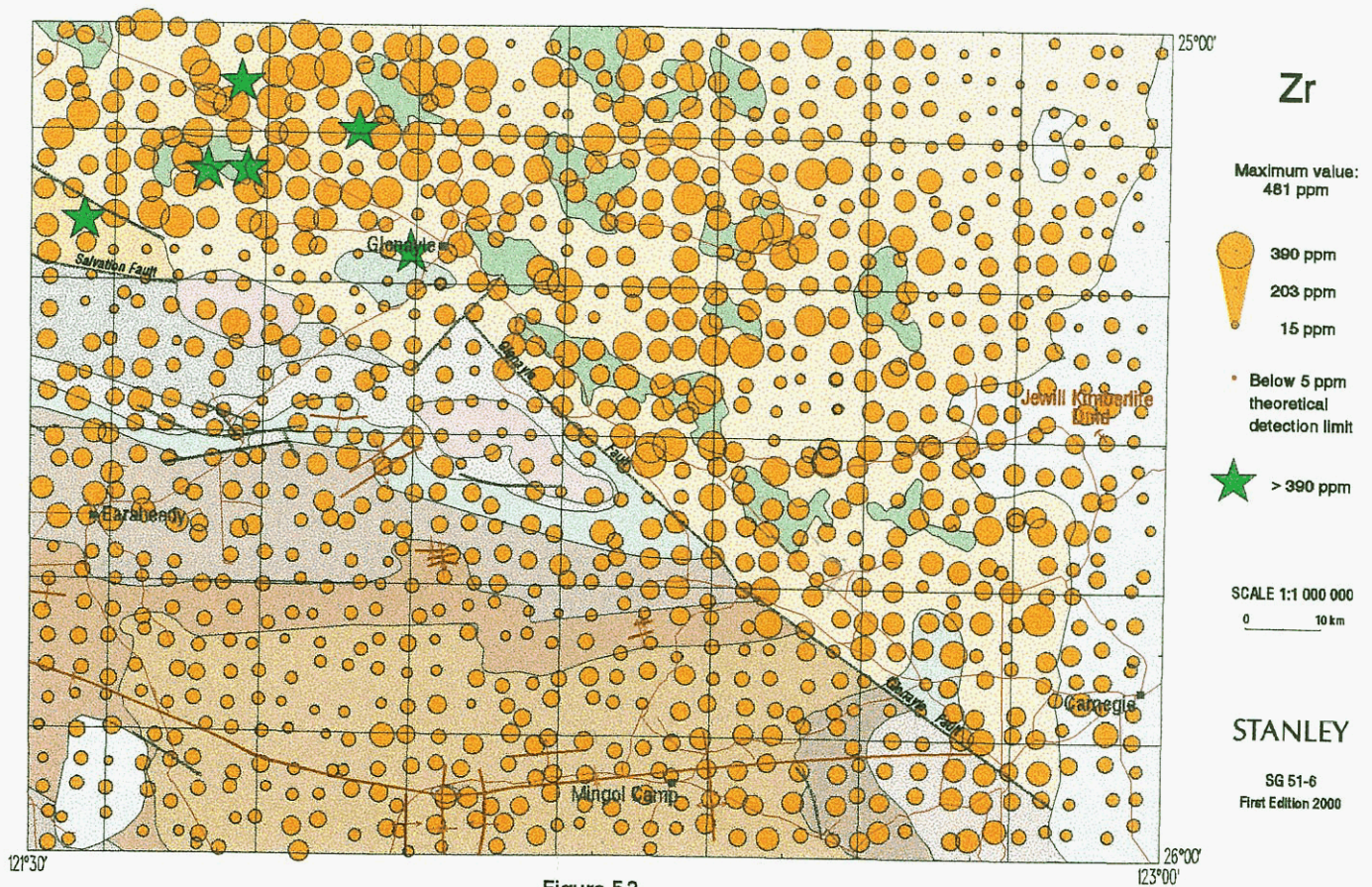
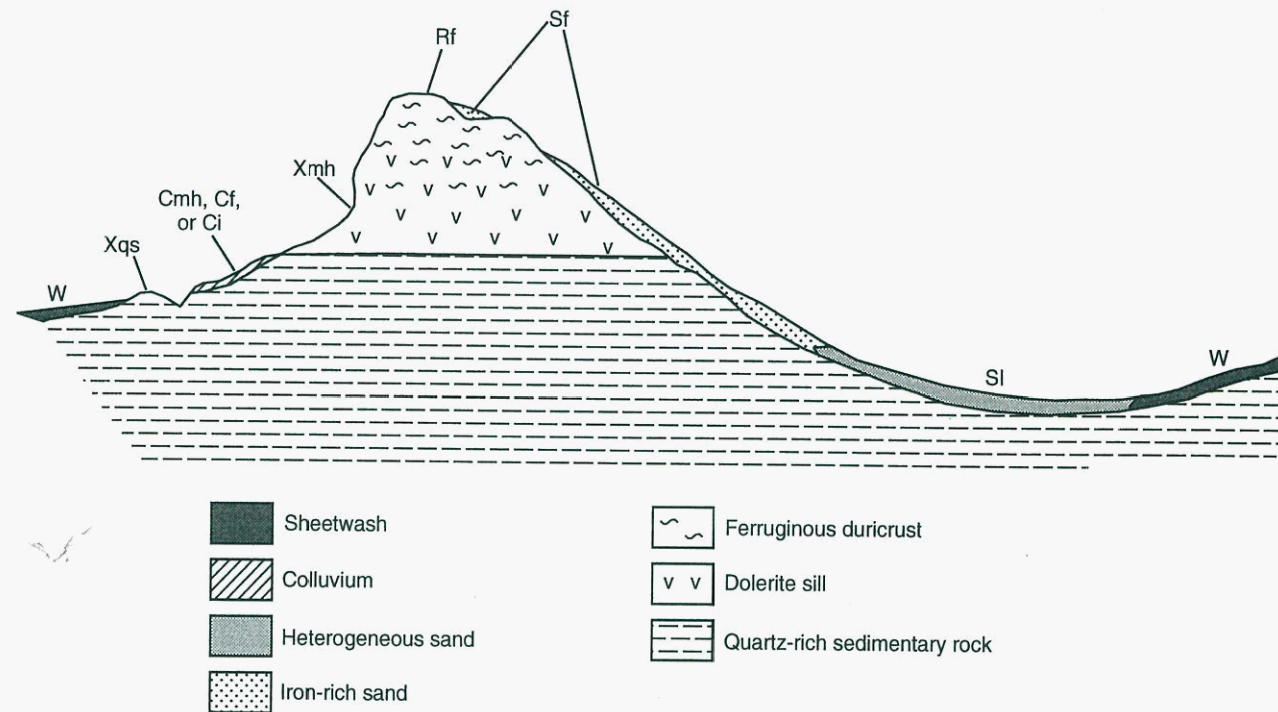


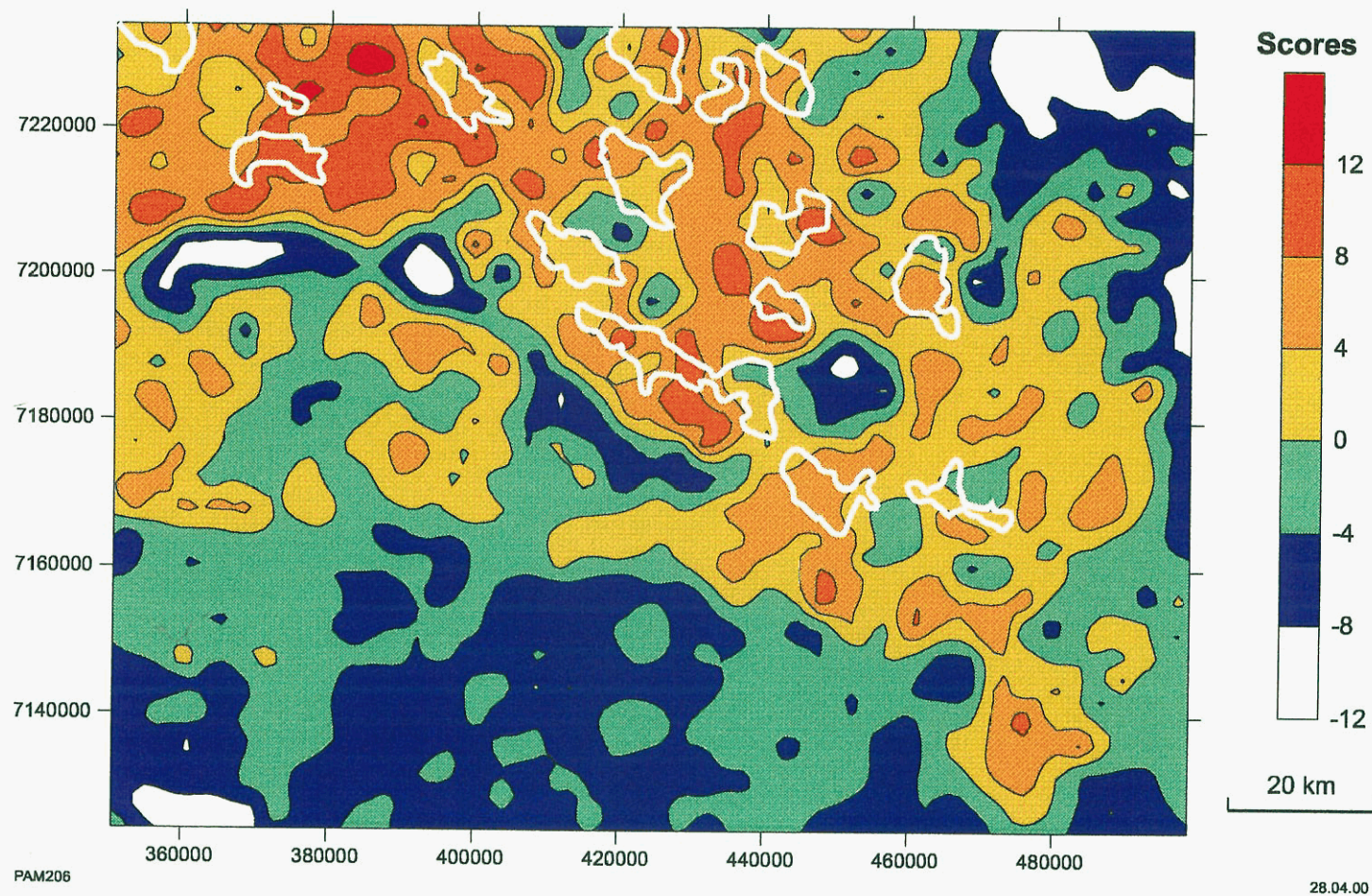
Figure 52



PAM201

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Figure 53. Schematic cross section showing bedrock-regolith relationships for northern STANLEY



**Figure 54. Contoured dolerite additive-index scores (Fe+Ti+Cr+Sc+V+In).
White outlined areas are mapped areas of dolerite (see Figure 3)**

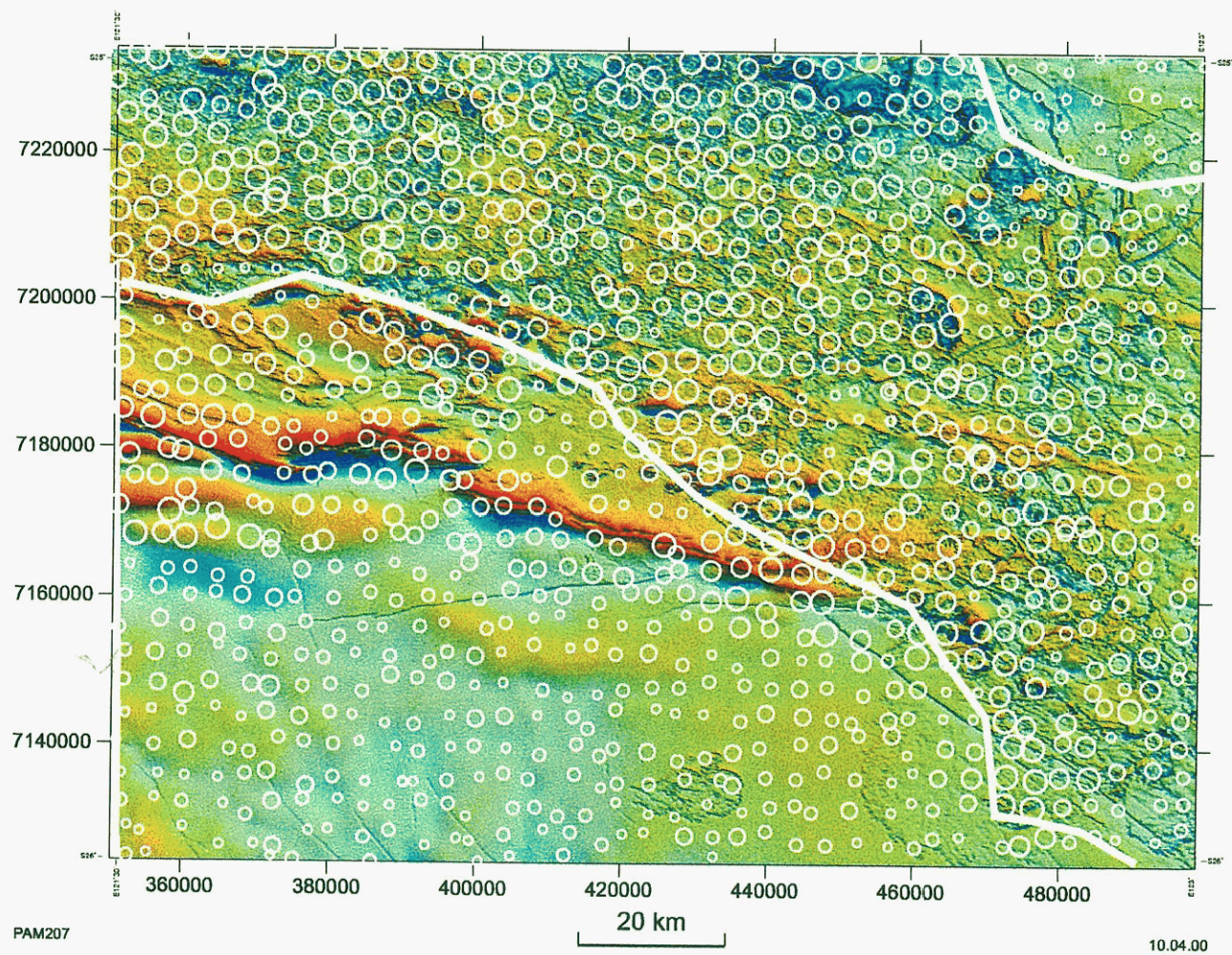


Figure 55. Dolerite index (white circles) and total magnetic intensity. The area between the white lines is the likely extent of dolerite (deduced from magnetic data)

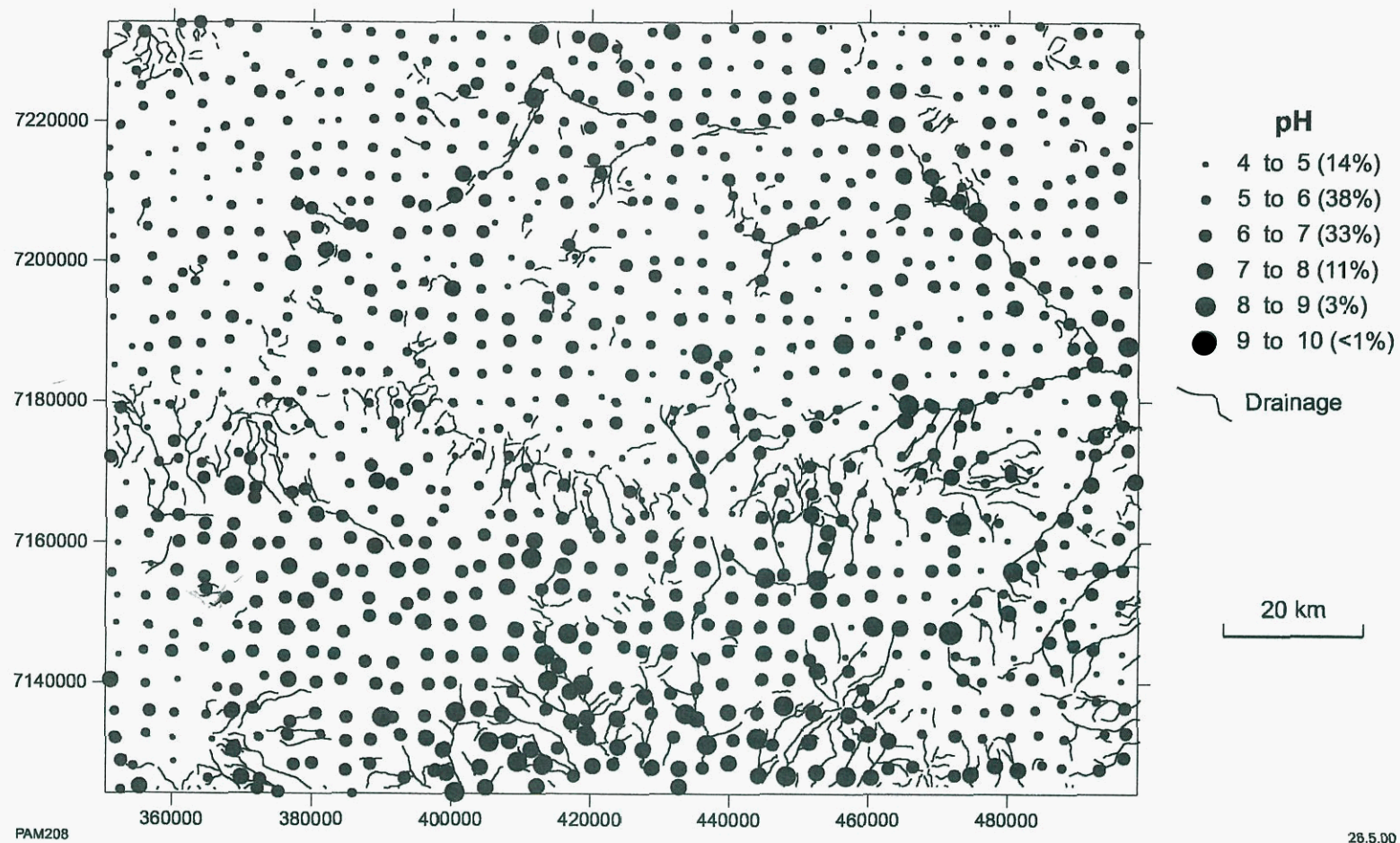


Figure 56. pH of regolith

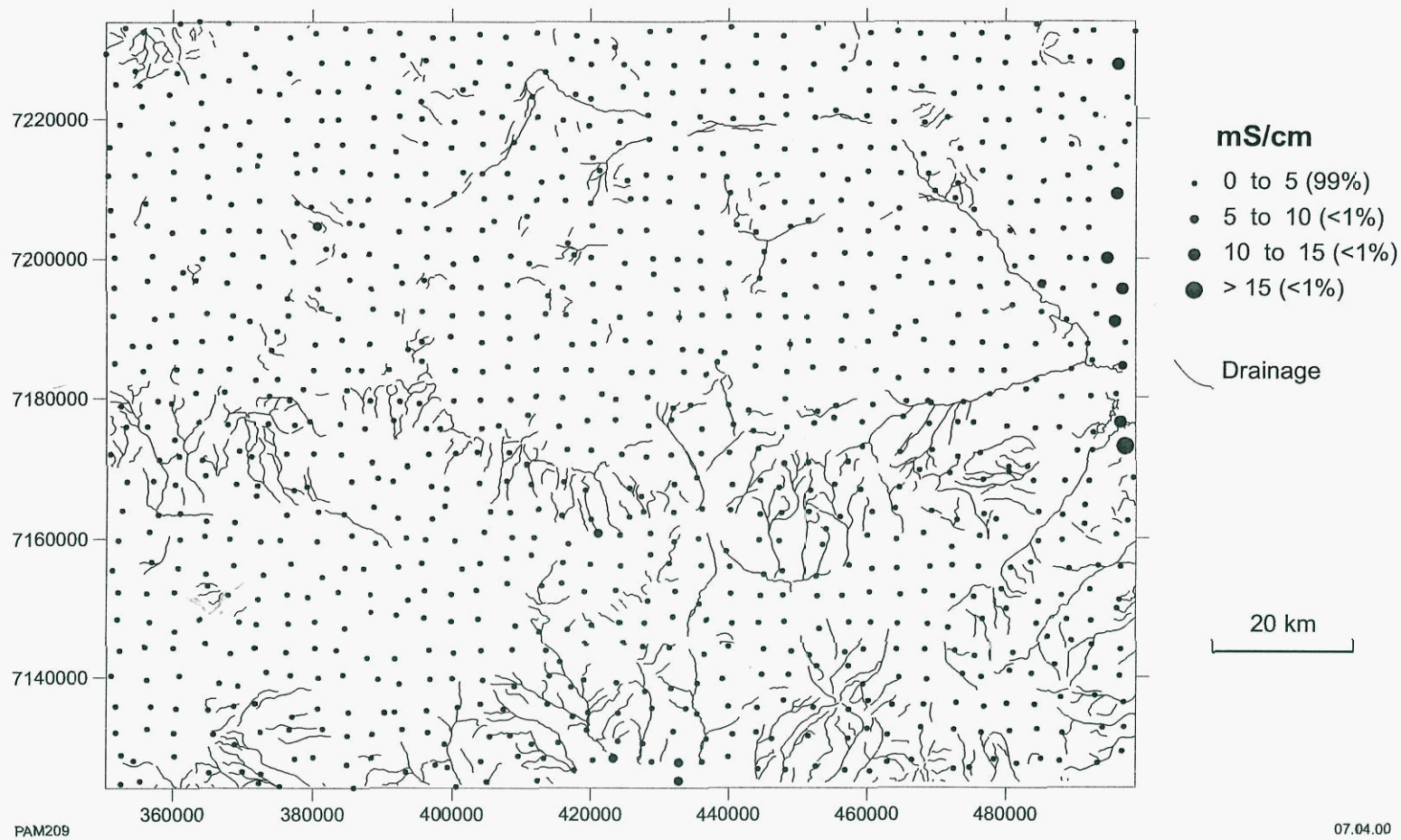
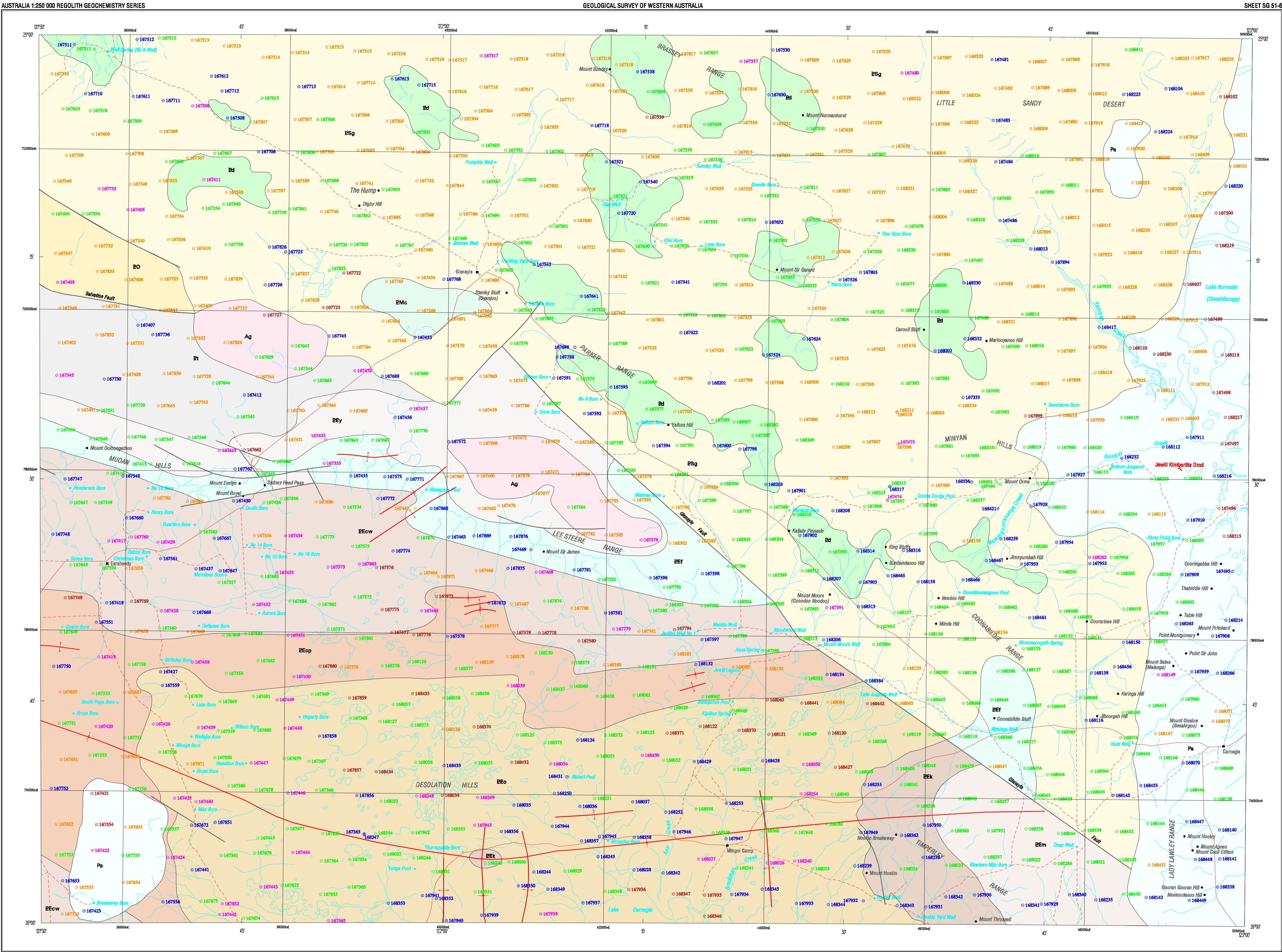


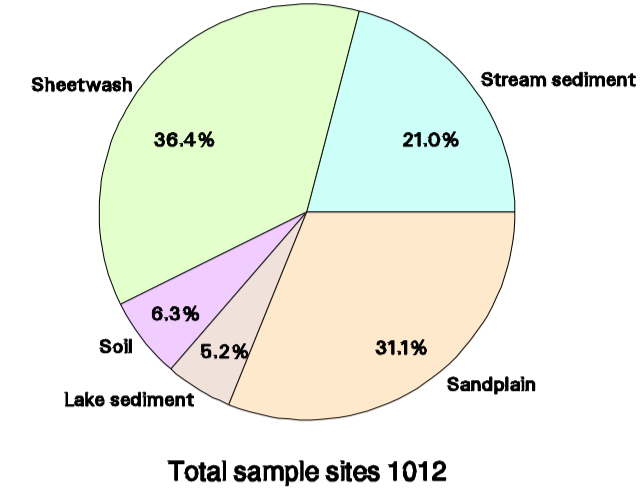
Figure 57. Conductivity of regolith (mS/cm)



SAMPLE LOCATIONS

Sample point reference

- 168336 Stream sediment
- 168020 Sheetwash
- 167474 Soil
- 167496 Lake sediment
- 167400 Sandplain



GEOLOGICAL INTERPRETATION

- PALEOZOIC**
- PERMIAN**
 - Pa PATTERSON FORMATION: fluvial and fluvio-glacial sandstone, conglomerate, and siltstone
 - Bd Dolerite
 - Sunbeam Group**
 - ESg Sandstone, siltstone, conglomerate, shale, mudstone, dolomite, and evaporite
 - Collier Group**
 - EMc Sandstone with minor shale and siltstone
 - Scorpion Group**
 - BO Sandstone, shale, conglomerate, and dolomite
 - Enderby Group**
 - Bt Metamorphosed shale and sandstone; minor chert
 - BEin MULGARIPA SANDSTONE: quartz sandstone; with minor shale and limestone
 - BEK KULELE Limestone: stromatolitic limestone, calcarenite, and mudstone; minor sandstone
 - BEo WONGAWOL FORMATION: very fine-grained sandstone, shale, and minor carbonate-rich rocks
 - BEcp CHALL FORMATION: Phosporus Range Member: quartz arenite and minor siltstone
 - BEow Windward Member: sandstone, siltstone, and shale; locally glauconitic basal conglomerate
 - BEf FREIRE FORMATION: granular iron-formation, hematitic shale, chert, and siltstone
 - BEy YELMA FORMATION: sandstone and shale; minor chert and stromatolitic carbonate
- PROTEROZOIC**
- ARCHAEOAN**
- Ag Granitoid rock

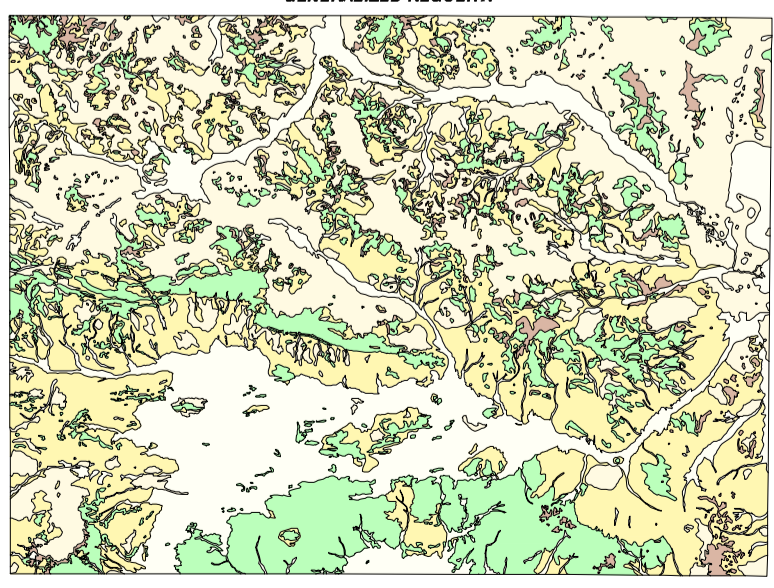
- Geological boundary
- Anticline
- Fault
- Syncline

SYMBOLS

- Formed road
- Track
- Watercourse
- Lake
- Pool, spring, bore, well
- Enderby Homestead
- Mount Royal Locality
- Jewell Kimberlite Prospect
- Dmd Diamond

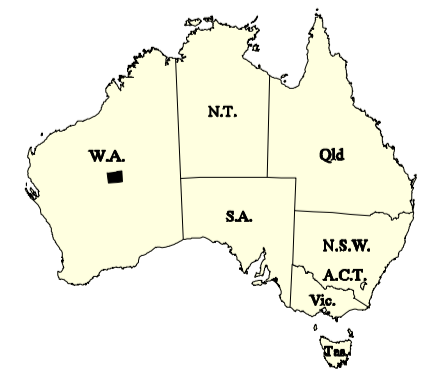
Edited by M. Tetlow, K. Greenberg, and G. Loan
Cartography by M. Vento
Topography from Australian Surveying and Land Information Group, and Department of Land Administration Sheet SG 51 - 6
This map was compiled and produced using a Geographic Information System (ArcInfo), and the data are available in digital form
Published by the Geological Survey of Western Australia. Copies of this map, or extracts of the data, are available from the Information Centre, Department of Minerals and Energy, 100 Plain Street, East Perth, W. A., 6004. Phone (08) 9222 9459, Fax (08) 9222 3444

Compiled by J. Coker 1998
Sampling by: S. A. McGuinness and J. Downing (GSWA), and A. Wey, J. Moore, S. Boncompagni, J. Henson, and S. Blackmore
Total sample sites: 1012; 212 stream sediment, 368 sheetwash, 84 soil, 53 lake sediment, and 915 sandplain
Analyte: Analabs Pty. Ltd.
Minimum sample size: 1.5 kg
Fraction of sample analysed: > 0.45mm < 2mm
Geological interpretation after Myers and Hocking (1998), Pijpers (1998), and Jones et al. (2000)
The recommended references for this publication are:
COKER, J., 2000. Sample locations, Stanley, W.A. Sheet SG 51 - 6, in Geochemical mapping of the Stanley 1:250 000 sheet by P. A. MORRIS, S. A. MCGUINNESS, A. J. SANDERS, and J. COKER. Western Australia Geological Survey, 1:250 000 Regolith Geochemistry Series Explanatory Notes, Plate 1



SCALE 1:250 000

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM
Grid lines indicate 20 000 metre interval of the Map Grid Australia, Zone 51
The Map Grid Australia (MGA) is based on the Geocentric Datum of Australia 1994 (GDA94)
GDA94 positions are compatible within one metre of the datum WGS84 positions

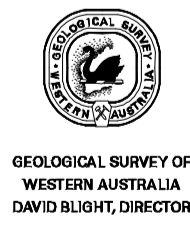


SHEET INDEX

STANLEY SG 51-1	STANLEY SG 51-2	STANLEY SG 51-3
STANLEY SG 51-4	STANLEY SG 51-5	STANLEY SG 51-6
STANLEY SG 51-7	STANLEY SG 51-8	STANLEY SG 51-9

INDEX TO 1:100 000 MAP SHEETS

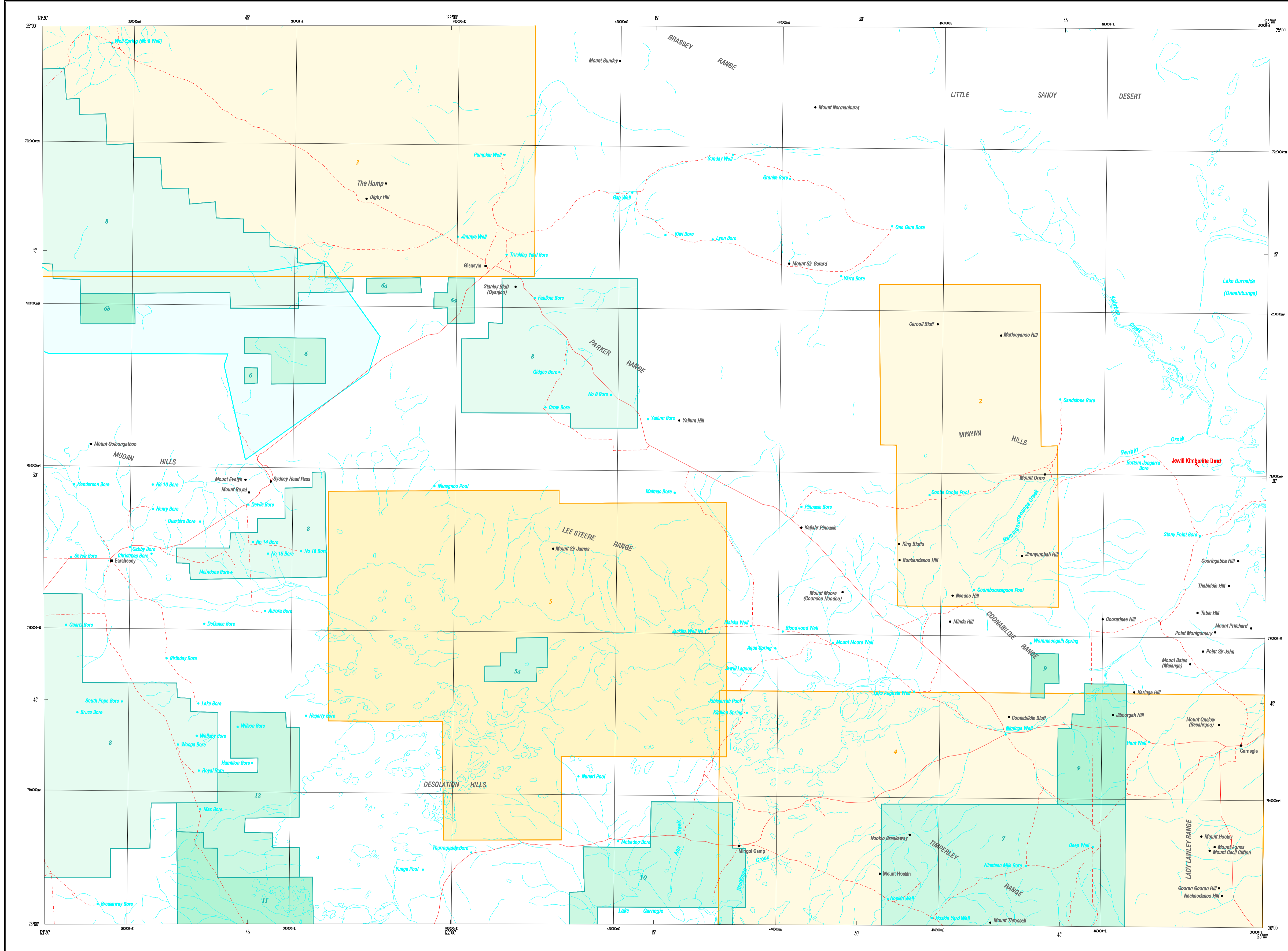
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STANLEY SG 51-4	STANLEY SG 51-5	STANLEY SG 51-6
STANLEY SG 51-7	STANLEY SG 51-8	STANLEY SG 51-9



SAMPLE LOCATIONS

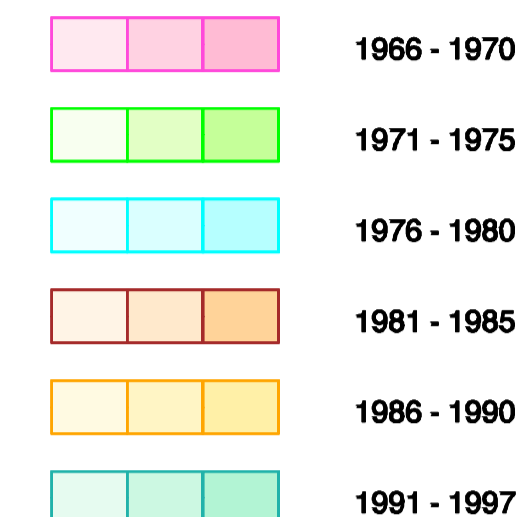
REGOLITH GEOCHEMISTRY SERIES
STANLEY
SHEET SG 51-6
FIRST EDITION 2000
© Western Australia 2000

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

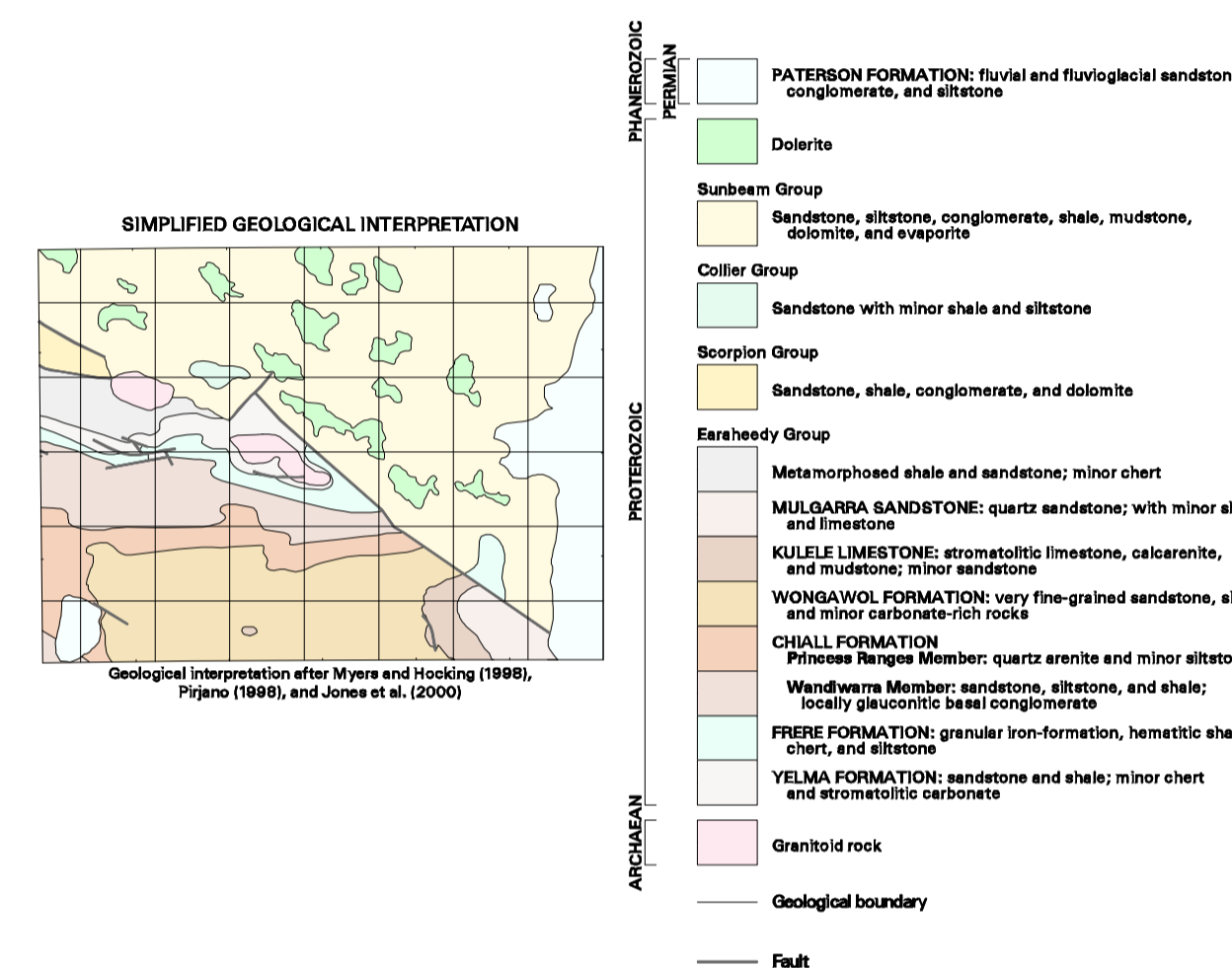


**COMPANY PROJECTS WITH SURFACE
GEOCHEMISTRY DATA IN OPEN-FILE
REPORTS (at June 1999)**

Project period reported within
(Various colour shades used for ease of project identification)



Number within project area is a database ID number (see Appendix 2 of the Explanatory Notes)



SYMBOLS



Edited by N. Tetlaw, K. Greenberg, and G. Loan

Cartography by M. Vicentic

Topography from Australian Surveying and Land Information Group, and Department of Land Administration Sheet SG 51 - 6

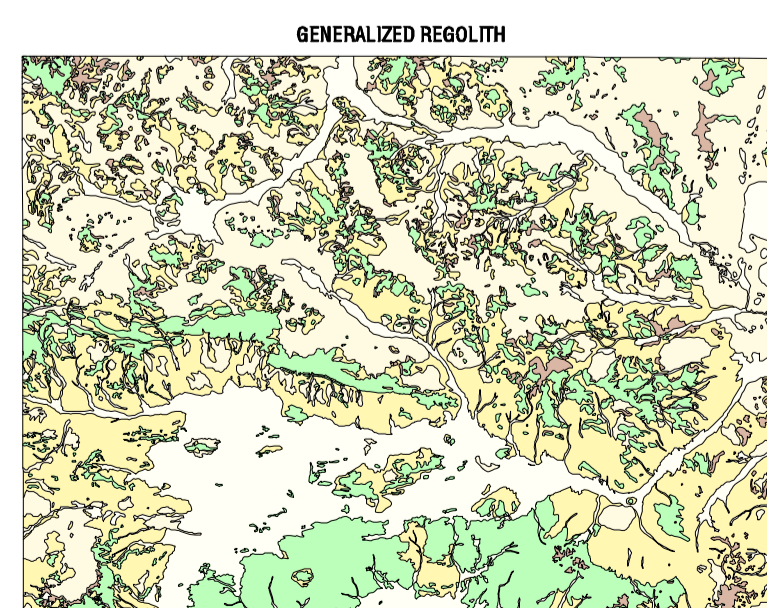
This map was compiled and produced using a Geographic Information System (ArcInfo), and the data are available in digital form.

Published by the Geological Survey of Western Australia. Copies of this map, or extracts of the data, are available from the Information Centre, Department of Minerals and Energy, 100 Plain Street, East Perth, W. A. 6004. Phone (08) 9222 3459, Fax (08) 9222 3444

Compiled by S. A. McGuinness 1999

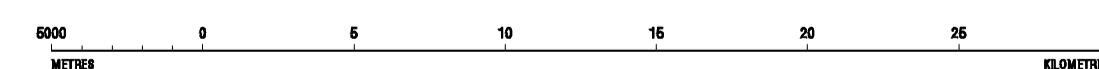
Compiled from open-file mineral exploration reports held by
the Geological Survey of Western Australia

The recommended reference for this map is:
McGUINNNESS, S. A., 2000, Company projects with surface geochemistry data in open-file reports (at June 1999), *Stanley, WA*, Sheet S6 51 - 6, in *Geochemical mapping of the Stanley 1:250 000 sheet by P. A. MORRIS, S. A. McGUINNNESS, A. J. SANDERS, and J. COKER*: Western Australia Geological Survey, 1:250 000 *Regolith Geochemistry Series Explanatory Notes*, Plate 2



SCALE 1:1 500 000

SCALE 1:250 000

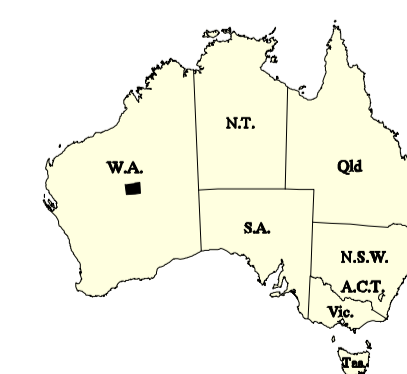


UNIVERSAL TRANSVERSE MERCATOR PROJECTION

HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994

Grid lines indicate 20 000 metre interval of the Map Grid Australia, Zone 5

GDA The Map Grid Australia (MGA) is based on the Geocentric Datum of Australia 1994 (GDA94). GDA94 positions are compatible within one metre of the datum WGS84 positions.

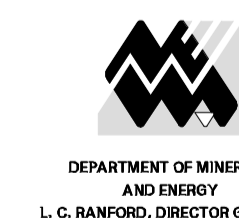


SHEET INDEX

BULLEN SG 51-1	TRAIWOR SG 51-2	MADLEY SG 51-3
NABERU SG 51-5	STANLEY SG 51-8	HERBER SG 51-7
WILLINA SG 51-9	KINGSTON SG 51-10	ROBER SG 51-11

INDEX TO 1:100 000 MAP SHEETS

MUDAN 3247	GLENAYLE 3347	KAHRBAN 3447
EARAHEEDY 3248	LEE STEERE 3348	COONABILD 3448



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



GEOLOGICAL SURVEY OF
WESTERN AUSTRALIA
DAVID BLIGHT, DIRECTOR

**COMPANY PROJECTS WITH SURFACE
GEOCHEMISTRY DATA IN OPEN-FILE
REPORTS (at June 1999)**

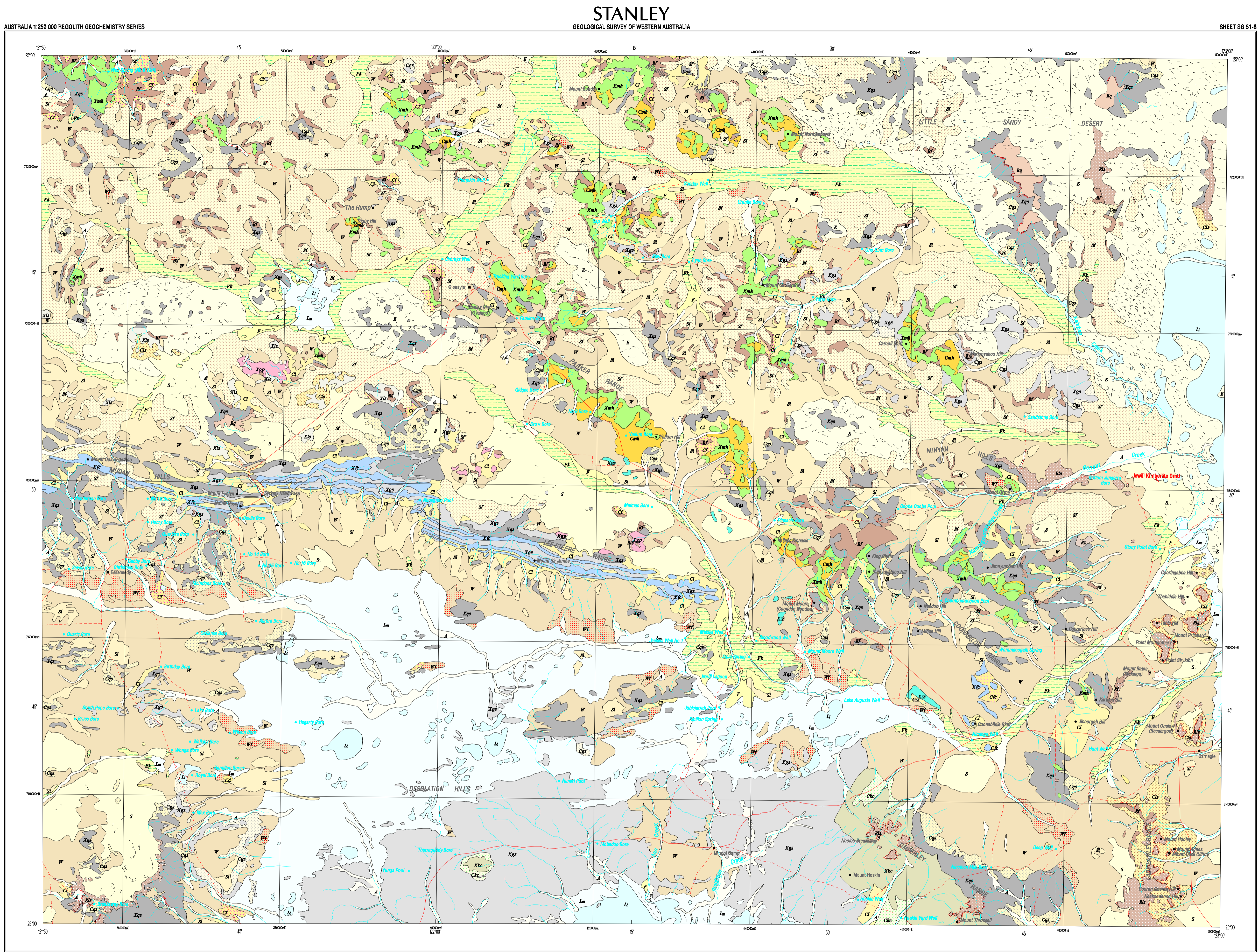
REGOLITH GEOCHEMISTRY SERIES

STANLEY

SHEET SG 51-6

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REGOLITH MATERIALS

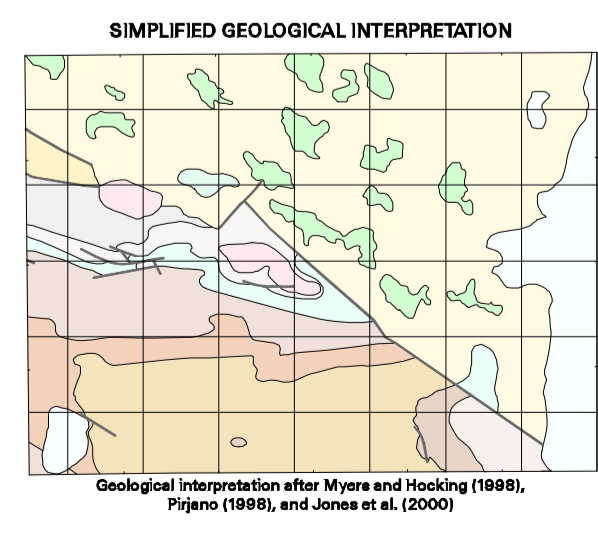
REFERENCE

- RESIDUAL (X) -** Residual sand, duricrust, and proximal reworked material derived by weathering in situ
- Rf** comprising mainly iron-rich material (ferrosite)
 - Rls** derived from mixed sedimentary rock (Paterson Formation); locally silicified
 - Rq** comprising mainly quartz-rich material
 - Rz** comprising mainly silica-rich material (silicite)
- EXPOSED (X) -** Outcrop of bedrock, subcrop, and apron with locally derived sand, silt, clay, and rubble
- Xf** derived from iron-rich chemical sedimentary rock (pelletal and banded iron-formation, hematitic shale, and chert)
 - Xgp** derived from quartzofeldspathic plutonic rock (granitoid rock)
 - Xgs** derived from quartzofeldspathic siliciclastic sedimentary rock (sandstone, siltstone, and shale)
 - Xlc** derived from carbonate-rich biochemical sedimentary rock (limestone, calcarenite, and dolomite)
 - Xls** derived from mixed metamorphosed sedimentary rock
 - Xmh** derived from ferromagnesian hypabyssal rock (dolerite and metadolerite)
 - Xqs** derived from quartz-rich siliciclastic sedimentary rock (sandstone and mudstone)
 - Xsa** derived from silica-rich sedimentary rock
- COLLUVIAL (C) -** Unconsolidated and semi-consolidated silt, sand, gravel, and rubble; small rock outcrops may be present
- Cd** undivided
 - Cf** comprising iron-rich material
 - Cfb** derived mainly from iron-rich chemical sedimentary rock (pelletal and banded iron-formation, hematitic shale, and chert)
 - Cgs** derived mainly from quartzofeldspathic sedimentary rock (sandstone, siltstone, and shale)
 - Ckc** derived mainly from carbonate-rich biochemical sedimentary rock (limestone, calcarenite, and dolomite)
 - Ct** derived from mixed parentage
 - Cls** derived mainly from mixed sedimentary rock
 - Cmh** derived mainly from ferromagnesian hypabyssal rock (dolerite)
 - Cqs** derived mainly from quartz-rich siliciclastic sedimentary rock (sandstone and mudstone)
 - Csa** derived mainly from silica-rich sedimentary rock
- DISTAL SHEETWASH (W)**
- W** Sand- and clay-dominated colluvium or sheetwash
 - WT** Sand- and clay-dominated colluvium or sheetwash with abundant iron-rich material
- ALLUVIAL (A)**
- A** Cobbles, gravel, sand, silt, and clay in alluvial channels
- FLOODPLAIN (F)**
- F** Overbank deposits; sand- or clay-rich alluvium and colluvium on floodplains
 - FE** Overbank deposits; sand- or clay-rich alluvium and colluvium on floodplains containing carbonate-rich material (valley caliche)
- LACUSTRINE (L)**
- L** Clay, silt, sand, and evaporitic material; locally saline and gypiferous
 - Ls** in playas and claypans
 - Lm** in mixed dune and playa terrain proximal to lakes
- SANDPLAIN (S)**
- S** Residual and eolian sand; dominated by undulating sandplain and eolian dunes
 - Sf** Colluvial and residual sand with abundant iron-rich material; locally eolian
 - Sr** Sandplain with clay-rich colluvium and sheetwash; minor eolian reworking
- EOLIAN (E)**
- E** Dominantly eolian sand; extensive dunes

SYMBOLS

- Regolith boundary
- Breakaway
- Sand dune
- Formed road
- Track
- Watercourse
- Pool, spring, bore, well
- Eartheddy
- Mount Royal
- Jewell Kimberlite
- Dmd
- Homestead
- Locality
- Prospect
- Diamond

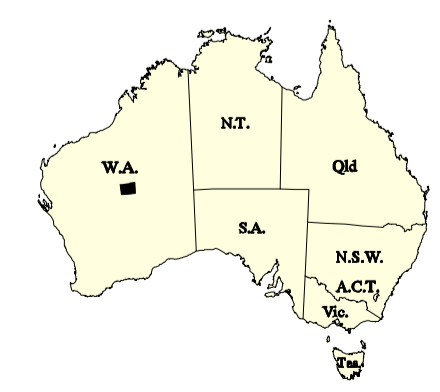
Edited by M. Tetlow, K. Greenberg, and G. Loen
Cartography by M. Vicente
Topography from Australian Surveying and Land Information Group, and Department of Land Administration Sheet SG 51-6
This map was compiled and produced using a Geographic Information System (ArcInfo), and the data are available in digital form
Published by the Geological Survey of Western Australia. Copies of this map, or extracts of the data, are available from the Information Centre, Department of Minerals and Energy, 100 Plain Street, East Perth, W.A., 6004. Phone (08) 9222 5459, Fax (08) 9222 3444
Compiled by S. A. McGuinness and A. J. Sanders 2000
Field observations 1989 by S. A. McGuinness and J. Downing (GSWA), and A. Way, J. Moore, S. Bonaparte, J. Hannon, and S. Blackmore
Compiled using Landsat TM images (1985 data), 1986 black and white, and 1987 color aerial photography, published Geological Survey of Western Australia Geological Series maps, and field observations 1989
The recommended reference for this map is:
McGUINNESS S. A. and SANDERS A. J. 2000. Regolith Materials, Stanley, W.A. Sheet SG 51-6 in Geological mapping of the Stanley 1:250 000 sheet by P. A. MORRIS, S. A. McGuinness, A. J. SANDERS, and J. COKER. Western Australia Geological Survey, 1:250 000 Regolith Geochemistry Series Explanatory Notes, Plate 3



- PHANEROZOIC**
- PERMIAN**
 - PATERSON FORMATION: fluvial and fluvio-glacial sandstone, conglomerate, and siltstone
 - Dolerite
 - Sunbeam Group**
 - Sandstone, siltstone, conglomerate, shale, mudstone, and evaporite
 - Collair Group**
 - Sandstone with minor shale and siltstone
 - Scorpion Group**
 - Sandstone, shale, conglomerate, and dolomite
 - Sarsheedy Group**
 - Metamorphosed shale and sandstone; minor chert
- PROTEROZOIC**
- MILBARRA SANDSTONE**: quartz sandstone; with minor shale and limestone
 - KULELE LIMESTONE**: stromatolitic limestone, calcarenite, and mudstone; minor sandstone
 - WONGAWOL FORMATION**: very fine-grained sandstone, shale, and minor carbonate-rich rocks
 - CHALL FORMATION**
 - Princess Ranges Member: quartz arenite and minor siltstone
 - Wardlaw Member: sandstone, siltstone, and shale; locally glauconitic basal conglomerate
 - FRIERE FORMATION**: granular iron-formation, hematitic shale, chert, and siltstone
 - YELMA FORMATION**: sandstone and shale; minor chert and stromatolitic carbonate
- ARCHAIC**
- Granitoid rock
 - Geological boundary
 - Fault

SCALE 1:250 000

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM
Grid lines indicate 20 000 metre interval of the Map Grid Australia, Zone 51
The Map Grid Australia (MGA) is based on the Geocentric Datum of Australia 1994 (GDA94)
GDA94 positions are compatible within one metre of the datum WGS84 positions



SHEET INDEX

BULLER SG 51-1	THORPE SG 51-2	MALBY SG 51-3
NARBUND SG 51-4	STANLEY SG 51-5	HERRERT SG 51-6
WILUNA SG 51-7	KIMBERLEY SG 51-8	ROBERT SG 51-9

INDEX TO 1:100 000 MAP SHEETS

MUDAN 3447	OLENAYLE 3447	KARIBAN 3447
EARHEEDY 3448	LEE STEERE 3448	COONABIDIE 3448



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