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SOIL, BEDROCK AND PROFILE GEOCHEMISTRY AT POLICE CREEK, DRUMMOND BASIN, QUEENSLAND

K.M. Scott

CRC LEME OPEN FILE REPORT 127

March 2002

(CSIRO Exploration and Mining Report 323R/CRC LEME Report 25R, 1997. Second impression 2002)

CRC LEME is an unincorporated joint venture between CSIRO-Exploration & Mining, and Land & Water, The Australian National University, Curtin University of Technology, University of Adelaide, University of Canberra, Geoscience Australia, Bureau of Rural Sciences, Primary Industries and Resources SA, NSW Department of Mineral Resources-Geological Survey and Minerals Council of Australia, established and supported under the Australian Government's Cooperative Research Centres Program.

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Headquarters: CRC LEME c/o CSIRO Exploration and Mining, PO Box 1130, Bentley WA 6102, Australia

CSIRO/CRC LEME/AMIRA PROJECT P417
GEOCHEMICAL EXPLORATION IN REGOLITH-DOMINATED TERRAIN, NORTH QUEENSLAND 1994-1997

In 1994, CSIRO commenced a multi-client research project in regolith geology and geochemistry in North Queensland, supported by 11 mining companies, through the Australian Mineral Industries Research Association Limited (AMIRA). This research project, "Geochemical Exploration in Regolith-Dominated Terrain, North Queensland" had the aim of substantially improving geochemical methods of exploring for base metals and gold deposits under cover or obscured by deep weathering in selected areas within (a) the Mt Isa region and (b) the Charters Towers - North Drummond Basin region.

In July 1995, this project was incorporated into the research programs of CRC LEME, which provided an expanded staffing, not only from CSIRO but also from the Australian Geological Survey Organisation, University of Queensland and the Queensland Department of Minerals and Energy. The project, operated from nodes in Perth, Brisbane, Canberra and Sydney, was led by Dr R.R. Anand. It was commenced on 1st April 1994 and concluded in December 1997. The project involved regional mapping (three areas), district scale mapping (seven areas), local scale mapping (six areas), geochemical dispersion studies (fifteen sites) and geochronological studies (eleven sites). It carried the experience gained from the Yilgarn (see CRC LEME Open File Reports 1-75 and 86-112) across the continent and expanded upon it.

Although the confidentiality period of Project P417 expired in mid 2000, the reports have not been released previously. CRC LEME acknowledges the Australian Mineral Industries Research Association and CSIRO Division of Exploration and Mining for authority to publish these reports. It is intended that publication of the reports will be a substantial additional factor in transferring technology to aid the Australian mineral industry.

This report (CRC LEME Open File Report 127) is a second impression (second printing) of CSIRO, Division of Exploration and Mining Restricted Report 323R, first issued in 1997, which formed part of the CSIRO/AMIRA Project P417.

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PREFACE

The principal objective of the P 417 Project is to improve substantially geochemical methods of exploration for base metals and Au in areas obscured by weathering or under cover. The research includes geochemical dispersion studies, regolith characterisation, dating of profiles and investigation of regolith evolution.

Police Creek Au Prospect is covered by soils developed both in residual and transported parent materials. One hundred and eighty samples were collected; 94 of these were soil samples and 86 samples are from four drill holes. Soil samples were collected at 50 m spacing along north and east aligned traverses across the prospect. The soil traverse at 20300 mE is predominantly residual soils whereas that at 20050 mE is mainly of transported soils. Both traverses define the main southern anomaly, especially by using the <75 µm fraction for Au and the coarse (>2000µm) fraction for As and Sb. Both fractions also define a smaller northern anomaly in volcanics adjacent to the Suttor Formation along both traverses. Using the Au in the fine fraction and As in the coarse fraction, the southern anomaly is defined as at least 1600 x 600m and the northern anomaly as having dimensions of at least 400 x 150m.

Study of mineralised and barren profiles through the Silver Hills Volcanics reveal that Au, As and Sb are generally depleted by factors of 2-3 by weathering. Some of the characteristic features of particular alteration zones are potentially mappable in outcrop using PIMA.

An associated report describes regolith-landform evolution of the Police Creek and Mt Coolon region.

R.R.Anand
Project Leader

I.D.M.
Deputy Project Leader

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SUMMARY

Anomalies within residual soils along the 20300E traverse at Police Creek are defined by both the +2 mm and -75 µm fractions. Although Au, As and Sb are anomalous in both soil fractions, Au is preferentially concentrated in the fine fraction and As and Sb in the coarse fraction. Significant Mo may also be present, especially in the coarse fraction in anomalous areas. Gold >40 ppb in the fine fraction and As >100 ppm in the coarse fraction define an anomaly at least 1 km x 600 m (southern anomaly) in alluvium and residual soil. As in the previous survey at 20050E, a second anomaly was found to the north of the major geochemical anomaly and again identified by anomalous Au, As and Sb contents in both soil fractions. Arsenic >100 ppm defines the 400x150 m northern anomaly in residual soil. Comparison of results from residual soils and adjacent outcrop reveals that the fine fraction of the soils concentrate Au with respect to the rock. These features indicate that the soils at Police Creek are a good sample medium whether they are transported or residual.

The effect of weathering on three distinctive profiles have been observed. Highly mineralized samples with illite, adularia and kaolinite associated with arsenical pyrite (up to 7.3% As, 2.3% Sb and 0.4% Hg) weather to illite, kaolinite, jarosite and Fe oxides. In less mineralized samples, chlorite and calcite occur with adularia and illite, with the latter two minerals retained in outcrop with neoformed kaolinite. Areas of argillic alteration contain dickite and pyrophyllite, with the former being retained in outcrop. Such mineralogical and consequent geochemical variation in the feldspar and phyllosilicate stabilities/abundances could be defined by PIMA and radiometric survey of outcrop (or shallow drill spoil) to provide vectors to the most altered areas during exploration.

1. INTRODUCTION

A previous study of transported soils at Police Creek (Scott, 1995) found that using the -75 µm fraction produces a larger Au anomaly than the -180 µm (-80 mesh) fraction, using a 100 ppb Au threshold. Although As and Sb were also anomalous in the fine fraction of the soils, study of other size fractions revealed that these elements were concentrated with Fe in the coarse (+2 mm) fraction of the soils. Despite this divergent behaviour within the soils, the Au in the fine fraction, and As and Sb in the coarse fraction define coincident anomalies at Police Creek. The study also found evidence of second anomaly, (not obvious in the -180 µm survey) in a small area with residual soils and low outcrop/subcrop, to the north of the main anomaly. This anomaly is best defined by anomalous As, Sb and Au in the coarse soil fraction. Thus Scott (1995) recommended analysing both the fine and coarse fractions during exploration.

This study considers a second traverse across the deposit, 250 m east of the initial study, to determine the features of residual (in situ) soils across the main southern anomaly and whether the northern anomaly is significant. It also considers the mineralogical and geochemical variations which occur down profiles above high grade mineralization, low grade mineralization and barren argillic and propylitic alteration.

2. REGOLITH GEOLOGY AND GEOMORPHOLOGY

In the Police Creek area, 6 km northeast of Mount Coolan, quartz latite ignimbrites of the Carboniferous Silver Hills Volcanics host primary gold mineralization (R. Mustard, pers. comm., 1994). During the early Tertiary these rocks were overlain by ~10 m of sandstones (Suttor Formation). (The extent of pre-Tertiary weathering of the volcanics is not known). The Suttor Formation is likely to be Palaeocene in age and stratigraphically equivalent to the Southern Cross Formation in the Charters Towers area (Henderson and Nind, 1994; Henderson, 1996). During the mid to late Tertiary lateritization, which affected the whole Drummond Basin (Wells et al., 1989), surficial ferruginization occured in the Suttor Formation and saprolite was developed in the underlying Silver Hills Volcanics. Subsequently, the lateritic profile has been incised to a depth of 15 to 20 m, exposing the mottled and clay zones of the volcanics prior to their cover by alluvium. This alluvium has been subjected to pedogenic processes leading to some mottling and the formation of Fe nodules. Quartz-rich colluvium up to several metres thick may also be developed in the region, but is generally poorly developed over the prospect area. Recent incision of the alluvium and colluvium by the Quaternary streams has led to several periods of fluvial deposition. Very thin but very obvious colluvial sandy outwash is present at the base of the scarps.

In the Police Creek area, the alluvium occurs ~10 m below the top of the Suttor Formation and ~2 m above the current streams (Figure 1). Within the prospect area, outcropping Silver Hills Volcanics occur either as silicified ridges ~5 m above the general level of the transported alluvium or as very low outcrops that are commonly found after recognising the abundance of float about them. The soils about these areas of outcrop and float are largely residual. Residual soils may also be present at the base of the Suttor Formation scarp (Figure 1).

Regolith Stratigraphy

Youngest

Local colluvium
Fluvial alluvium
? Residual soil
Sheetwash (qtz-rich) - poorly developed in prospect area (not shown below)
Alluvial soil
Suttor Formation

Oldest

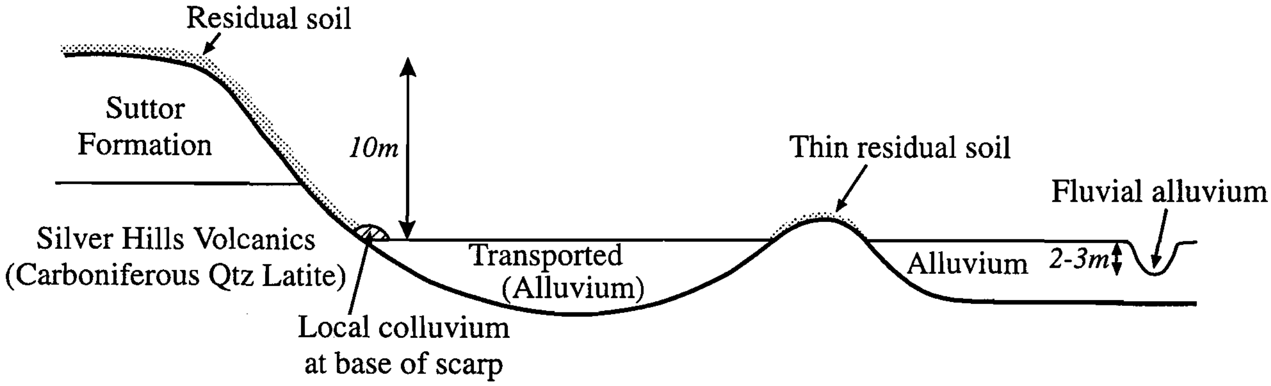


Figure 1 Schematic representation of the landscape and stratigraphy in the Police Creek prospect area

A detailed map of the regolith regimes at Police Creek, done as part of the more regional regolith mapping of the Mt Coolan-Wirralie area, is presented in Figure 2 and emphasizes the residual nature of the soils and relationship to outcropping saprolite.

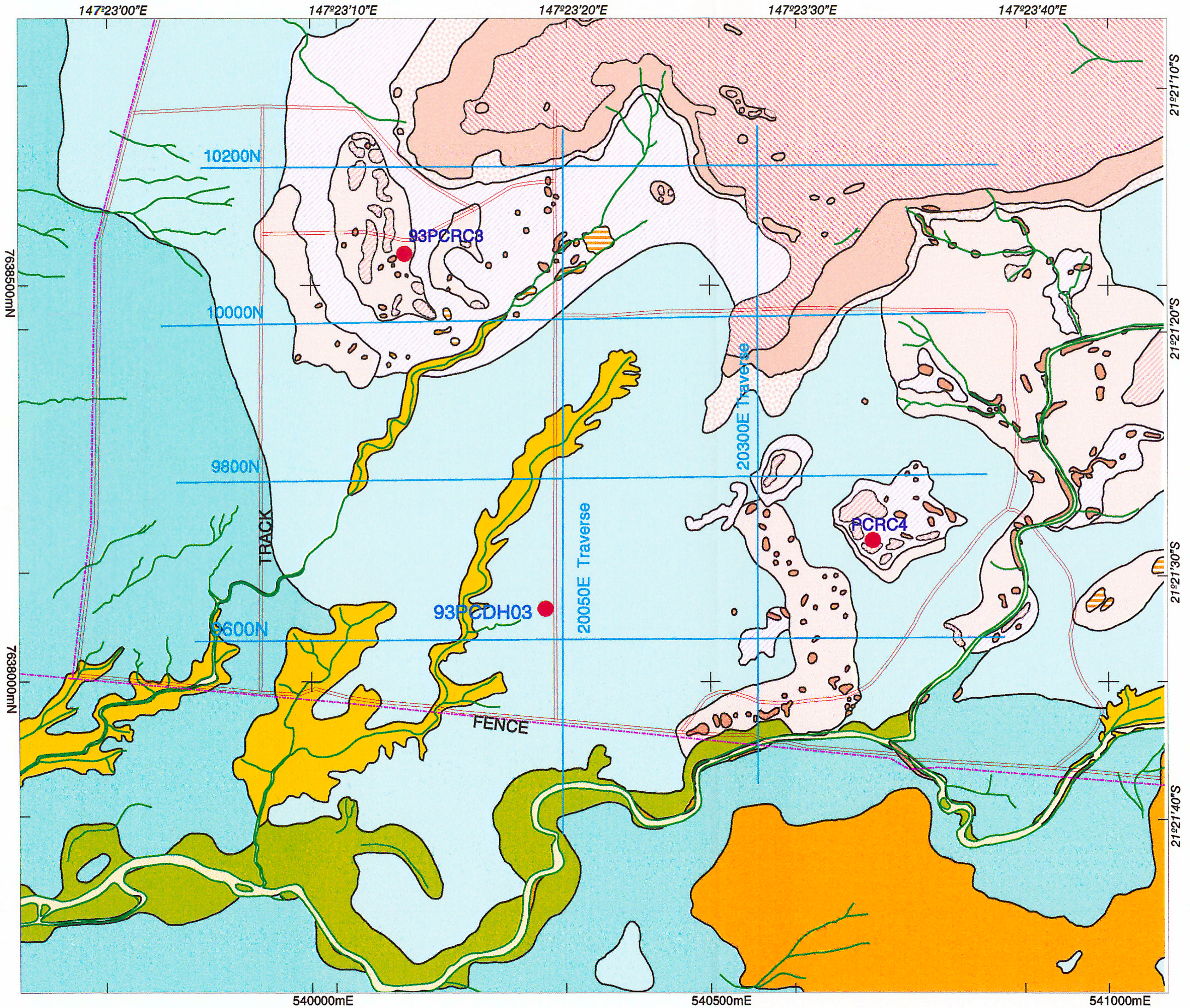
3. SAMPLES

During the period May to October 1995, 180 samples were collected from the Police Creek prospect. Ninety-four of these were soil or outcrop samples collected along lines across the deposit whilst 86 samples are from four drill holes. (Most of the drill hole sampling and some soil sampling was done by Ross Mining NL staff).

Soil samples were obtained at 50 m spacings along North-South or East-West traverses across the deposit. At each sampling site, soil was collected from the top 10 cm and the proximity of outcrop and/or the presence of float was recorded. In contrast to the soils along 20050E which are developed on alluvium, the soils along 20300E are residual (Figure 2) and so this line was selected for detailed study. Some additional soils and outcrop samples mainly from adjacent to or between the two traverses were also studied in detail to determine the size of the northern anomaly and to investigate a possible Zn anomaly in the Cicada East area.

Of the four drill holes sampled, three, 93PCDH03 (through alluvium and then into highly mineralized volcanics), PCRC4 (through outcropping lower grade mineralization at Cicada East) and 93PCRC3 (through altered but barren rocks at Cicada Ridge) were selected for detailed analysis.

REGOLITH-LANDFORM MAP OF THE POLICE CREEK PROSPECT MOUNT COOLON, QUEENSLAND



DURICRUST

Post-Palaeozoic

- Reddish brown lateritic duricrust on Suttor Formation, partly covered with a thin layer of sandy soil; mesa

SAPROLITE

Palaeozoic

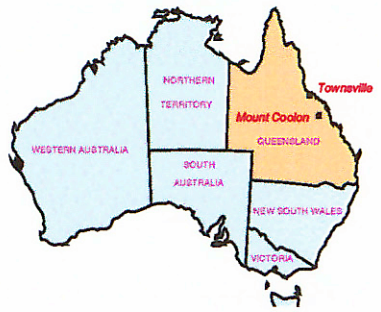
- Ferruginised, and in places bleached, saprolite on volcanics; stream banks and alluvial plain
- Lag of ferruginous fragments of saprolite with thin lithic soil on saprolite; erosional plain
- Saprock of rhyolite and dacite; low rises and small hills

Post-Palaeozoic

- Ferruginous and mottled saprolite on Suttor Formation; bluff of mesa
- Erosional remnants of mottled saprolite on Suttor Formation; alluvial plain

COLLUVIUM / ALLUVIUM

- Thin lithic soil with loose lateritic pisoliths and nodules on Palaeozoic saprolite, mixed with colluvium from Suttor Formation; erosional plain
- Colluvial talus derived from mottled saprolite on the Suttor Formation
- Grey soil on slightly mottled sediments from Suttor Formation mixed with proximal ferruginous saprolite on volcanics; alluvial plain
- Grey soil developed on the mixture of colluvium from saprolite on Suttor Formation with those on volcanics; alluvial plain
- Grey sandy soil developed on alluvium; alluvial plain
- Alluvium from slightly mottled sediments consisting of material from saprolite on Suttor Formation and on Palaeozoic volcanics; gullies
- Grey sandy soil on alluvium; floodplain
- Silicified alluvium; stream bed
- Alluvium in modern stream



N

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0 100 200 300

Compiled by Li Shu (CRC LEME / CSIRO), 1997

It is recommended that this map be referred to as:

Li Shu 1997 - Regolith-landform map of the Police Creek Prospect, Mount Coolon, Queensland (1:5000 map scale). Cooperative Research Centre for Landscape Evolution and Mineral Exploration (CRC LEME), Perth.

This map is based on field observations.

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Figure 2 Regolith-landform map of the Police Creek prospect area (after Shu, 1997).

4. METHODS

Soils were described and then about 700 g sieved into +2 mm, -2 mm +75 μm and -75 μm fractions with additional work done on the coarse and fine fractions (Scott, 1995). The coarse fractions of the soils (and some surficial rocks) were described, before being crushed to -75 μm with a Mn steel mill prior to analysis by neutron activation analysis (NAA) by Becquerel Laboratories, using their Au + 28 analytical package.

The drill hole samples were usually in the form of one metre composites. The coarse fraction of this material was described and, using this information and company-derived Au assays, 50 samples were selected for analysis by NAA. Twenty samples, representative of the major weathering zones within the drill holes were also analysed by X-ray diffraction to determine their mineralogy semi-quantitatively.

Polished blocks were made for three samples through fresh mineralization in 93PCDH03. Detailed compositions of the illite, adularia and pyrite were determined by electron microprobe analysis.

5. RESULTS

5.1 20300E Traverse

Soils along this line are generally thin with abundant float or outcrop nearby. The coarse fragments in soils between 9400 and 10000N are derived from porphyritic volcanics, with the material between 9550 and 9600N being quite silicified. From 10050 to 10250N, the coarser material in the soils consists of aggregates of rounded quartz and probably reflects derivation from Suttor Formation. Ferruginous fragments, including some that are magnetic, are commonly present but no consistent abundance pattern is obvious. However, the volcanic-derived material tends to be brown and buff-brown in colour, whereas the Suttor-derived material has a more grey-brown tone. Results of the analysis of coarse and fine fractions from the soils along 20300E are presented in Tables 1 and 2 with significant features being displayed graphically in Figures 3-9.

Using the fine soil fraction (-75μm), the interval 9500 to 9800N is characterized by As ≥ 100 ppm and, commonly Au ≥ 40 ppb (Figures 3 and 4). Samples with Sb ≥ 5 ppm and isolated values of Mo > 5 ppm also occur within this zone (Figures 5 and 6). Although samples with As > 100 ppm and Sb > 5 ppm occur between 9950 and 10000N, no anomalous Au (>40 ppb) is present in this zone (Figures 3, 4 and 5). Iron contents are low but may show a weak association with the northern anomalous zone (Figure 7). The highest K and Rb contents tend to occur within the southern anomalous zone (Figures 8 and 9) with lower K/Rb ratios being a useful discriminant, provided K_2O > 1% (Table 1).

In the coarse soil material (+2 mm), two anomalies defined by As > 200 ppm occur between 9500 and 9700N and 9950 to 10000N (Figure 4). However Au ≥ 40 ppb occurs only as single spot anomalies in each of the two zones (Figure 3). These two anomalous zones are also characterized by Sb > 10 ppm and Mo > 5 ppm (Figures 5 and 6). Iron contents tend to be variable along the traverse, but high values (Fe_2O_3 > 7%) are recorded in the anomalous zones plus within Suttor-derived material (Figure 7). Potassium and Rb contents attain their maximum contents in the larger southern anomaly but are quite low in the northern anomaly (Figures 8 and 9). K/Rb ratios vary considerably across the traverse but if only values when

K_2O > 1% are considered, lower K/Rb ratios do define the southern anomaly (Table 2). Barium and Cs are unrelated to the K trend (Table 2).

Table 1

Chemical compositions of fine (-75µm) fractions of soils along 20300E Traverse, Police Creek (Major components, wt%; minors, ppm)

Sample No.	128183	128184	128185	128186	128187	128188	128189	128190	128192
Northing	9400	9450	9500	9550	9600	9650	9700	9750	9800
Fe_2O_3	1.26	1.77	1.83	2.14	1.94	2.36	2.26	2.82	3.70
Na_2O	0.35	0.63	0.20	0.10	0.09	0.14	0.24	0.07	0.05
K_2O	0.94	1.54	1.69	2.11	2.47	3.12	2.69	3.06	1.76
As	11	13	110	200	160	190	120	220	100
Au(ppb)	11	12	34	60	70	34	25	110	42
Ba	290	550	390	340	290	390	470	860	600
Br	3	11	8	14	11	17	22	13	14
Ce	56	110	92	77	73	83	82	130	110
Co	3	5	9	2	2	2	2	6	2
Cr	16	10	10	12	12	10	10	9	15
Cs	4	7	6	11	11	14	11	10	8
Mo	<5	<5	<5	6	<5	13	<5	7	<5
Rb	49	71	100	160	190	240	200	220	150
Sb	2	1	5	7	7	7	5	7	2
Sc	7	8	14	13	12	12	13	18	15
Th	14	14	11	12	10	11	10	12	12
U	3	4	2	3	2	<2	2	2	<2
W	3	<2	5	7	9	8	7	5	2
Zn	110	150	110	<100	<100	<100	110	150	<100
K/Rb	159	180	136	111	107	107	111	117	97

Table 1 cont'd

Sample No.	128193	128194	128195	128197	128198	128199	128200	128201	128202
Northing	9850	9900	9950	10000	10050	10100	10150	10200	10250
Fe_2O_3	3.82	3.06	3.80	3.72	2.50	2.20	1.46	1.67	1.27
Na_2O	0.31	0.08	0.04	0.04	0.04	0.04	0.04	0.06	0.07
K_2O	2.18	1.30	<0.25	<0.25	0.28	0.46	0.47	0.69	0.66
As	61	93	120	62	22	7	3	3	3
Au(ppb)	22	10	15	26	9	6	17	23	30
Ba	530	230	150	230	300	260	270	250	230
Br	38	22	9	9	10	8	12	13	11
Ce	100	87	61	74	32	21	28	45	49
Co	6	2	1	2	3	2	2	2	2
Cr	11	12	13	16	13	13	14	18	13
Cs	10	10	10	13	7	7	6	6	5
Mo	<5	<5	<5	<5	<5	<5	<5	<5	<5
Rb	130	76	23	37	40	54	47	62	52
Sb	2	3	7	7	4	2	1	1	1
Sc	16	12	8	9	7	6	6	7	5
Th	14	11	19	21	14	12	17	19	18
U	3	3	3	3	<2	<2	3	4	3
W	6	6	5	5	3	2	2	2	3
Zn	130	<100	<100	<100	<100	<100	<100	<100	<100
K/Rb	137	142	<90	<50	58	70	83	92	106

Table 2
Chemical compositions of coarse (+2 mm) fractions of soils along 20300E Traverse, Police Creek
(Major components, wt%; minors, ppm)

Sample No.	128183	128184	128185	128186	128187	128188	128189	128190	128192
Northing	9400	9450	9500	9550	9600	9650	9700	9750	9800
Fe_2O_3	7.65	3.26	5.08	11.1	4.90	2.59	4.69	2.43	1.70
Na_2O	0.39	0.54	0.08	0.03	0.03	0.04	0.03	0.04	0.02
K_2O	1.49	1.49	1.45	1.64	1.65	3.23	2.36	2.42	0.55
As	110	28	330	1030	560	200	220	160	36
Au(ppb)	6	<5	8	110	26	10	21	13	7
Ba	450	440	280	160	200	300	200	350	290
Br	<2	<2	3	6	4	2	<2	2	<2
Ce	34	34	47	25	32	37	33	40	38
Co	3	2	4	2	1	<1	2	2	1
Cr	19	14	14	19	10	8	9	8	11
Cs	5	5	4	4	5	6	5	5	2
Mo	<5	<5	6	7	6	12	14	12	<5
Rb	70	71	97	110	110	200	170	180	43
Sb	5	2	15	29	18	11	10	8	3
Sc	5	4	8	7	7	9	9	9	7
Th	11	11	8	7	7	9	9	9	7
U	<2	<2	<2	<2	<2	<2	<2	<2	<2
W	6	8	9	5	8	8	5	6	7
Zn	<100	<100	<100	<100	<100	<100	<100	<100	<100
K/Rb	177	175	124	127	123	131	117	115	107

Table 2 cont'd

Sample No.	128193	128194	128195	128197	128198	128199	128200	128201	128202
Northing	9850	9900	9950	10000	10050	10100	10150	10200	10250
Fe_2O_3	3.10	3.35	12.0	16.7	7.18	5.66	11.7	5.16	5.74
Na_2O	0.05	0.03	0.03	0.03	0.04	0.05	0.04	0.05	0.04
K_2O	1.02	0.81	0.30	0.39	0.41	0.71	0. 53	0.92	0.65
As	45	110	530	590	150	36	68	26	35
Au(ppb)	6	<5	<5	39	<5	<5	6	8	16
Ba	330	130	140	230	300	280	210	240	260
Br	5	2	5	7	4	3	9	3	3
Ce	34	34	46	42	18	11	20	16	21
Co	3	<1	<1	<1	2	1	2	<1	2
Cr	11	8	18	28	26	16	23	16	18
Cs	3	3	6	6	4	4	3	2	2
Mo	<5	<5	8	<5	<5	<5	<5	<5	<5
Rb	59	42	33	34	29	53	39	52	35
Sb	4	4	18	26	7	1	2	1	1
Sc	6	4	7	6	4	4	4	3	3
Th	7	8	17	15	10	12	23	8	10
U	<2	<2	2	3	<2	<2	3	<2	<2
W	8	6	5	5	16	5	6	7	7
Zn	<100	<100	<100	<100	<100	<100	<100	<100	<100
K/Rb	144	160	76	94	117	111	113	146	154

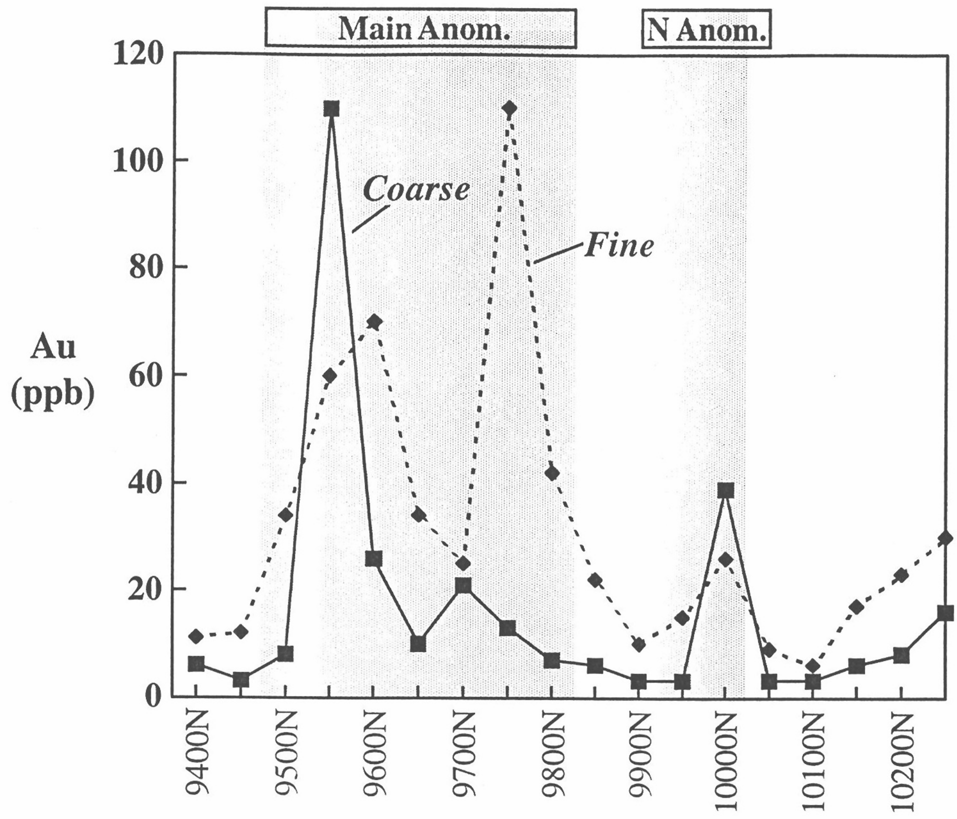

Figure 3 Distribution of Au in fine (-75 μm) and coarse soil (+2 mm) fractions along 20300E traverse.

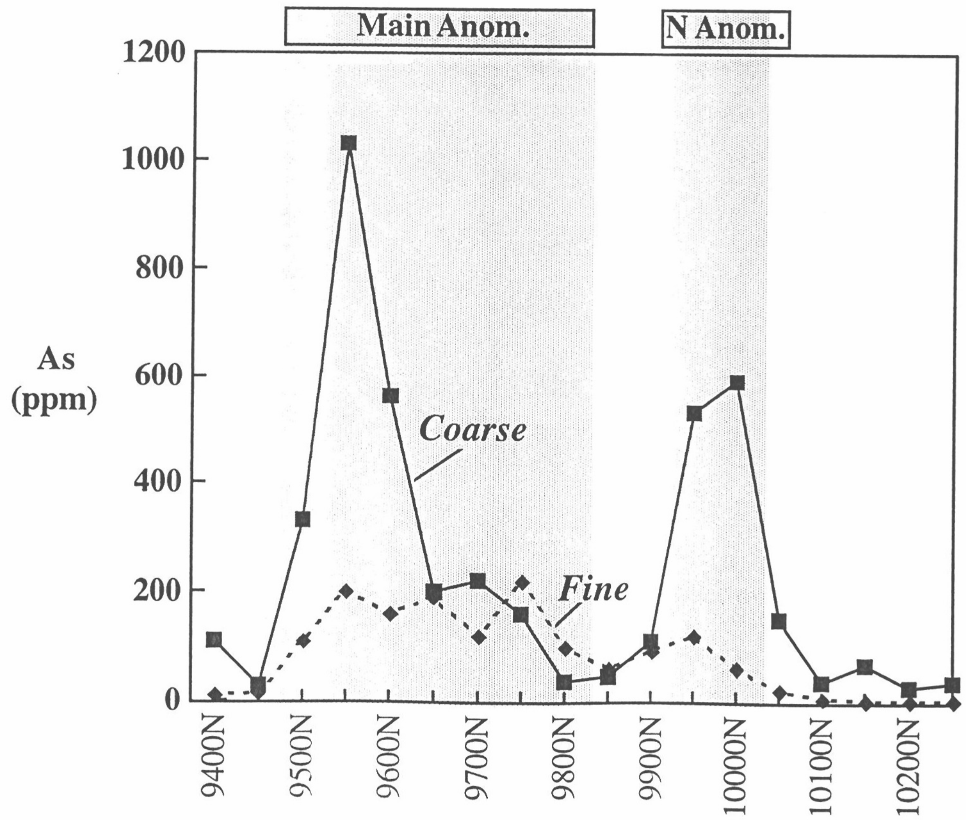

Figure 4 Distribution of As in fine (-75 μm) and coarse soil (+2 mm) fractions along 20300E traverse

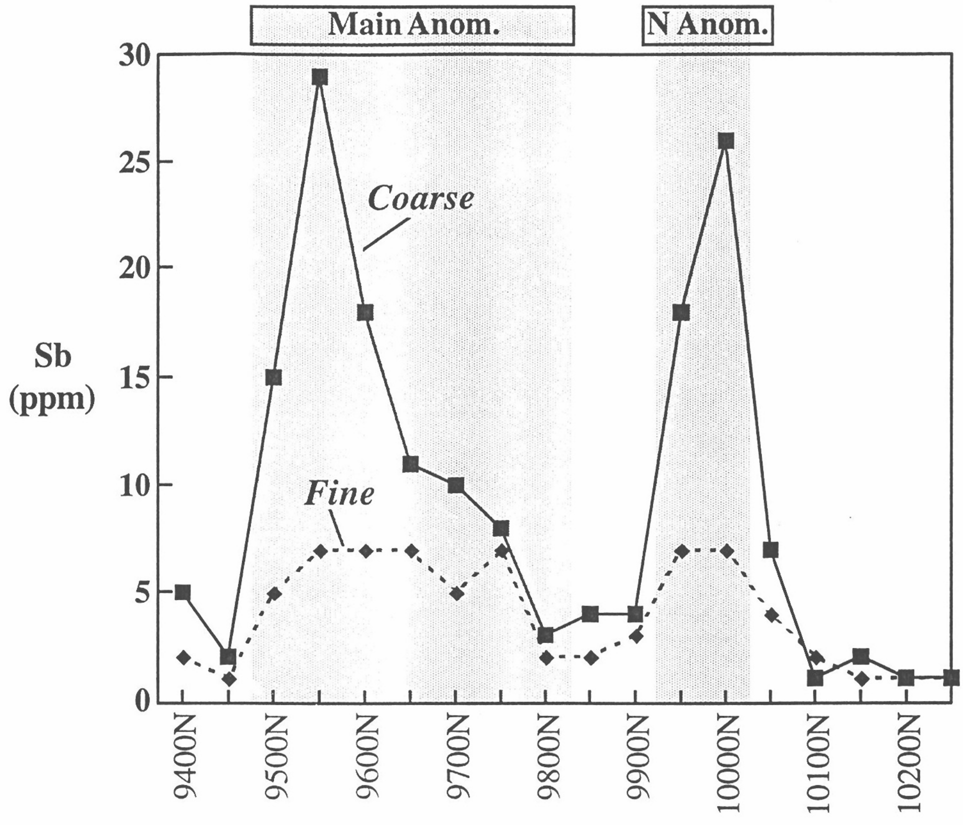

Figure 5 Distribution of Sb in fine (-75 µm) and coarse soil (+2 mm) fractions along 20300E traverse.

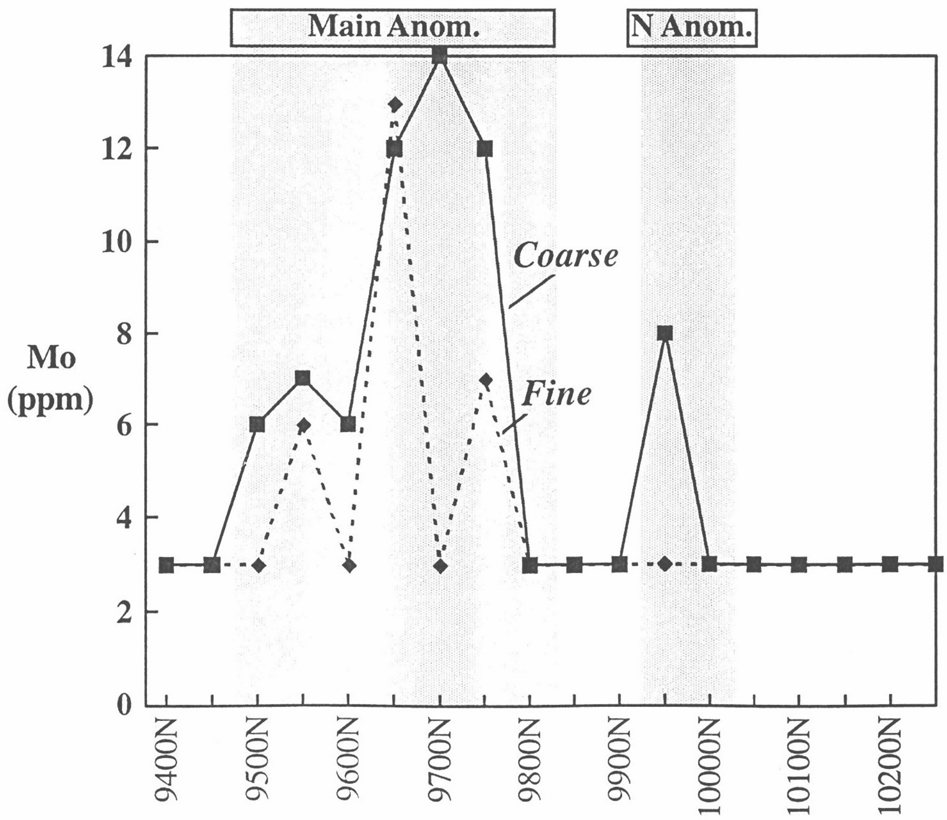

Figure 6 Distribution of Mo in fine (-75 µm) and coarse soil (+2 mm) fractions along 20300E traverse

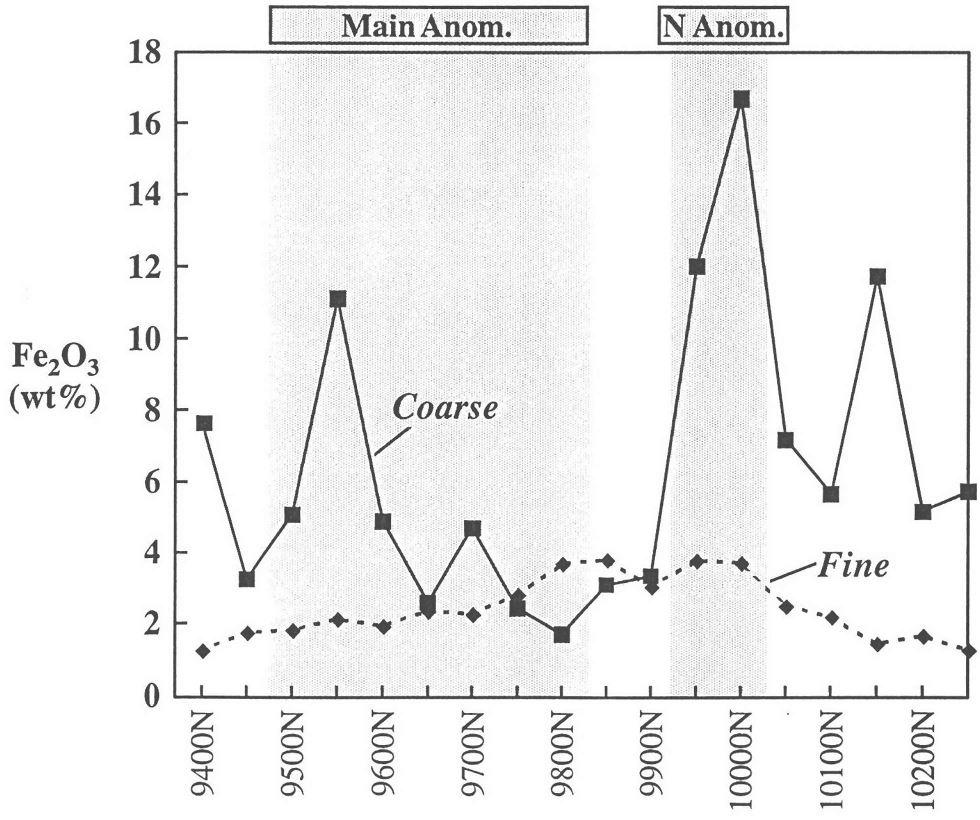

Figure 7 Distribution of Fe_2O_3 in fine (-75 μm) and coarse soil (+2 mm) fractions along 20300E traverse.

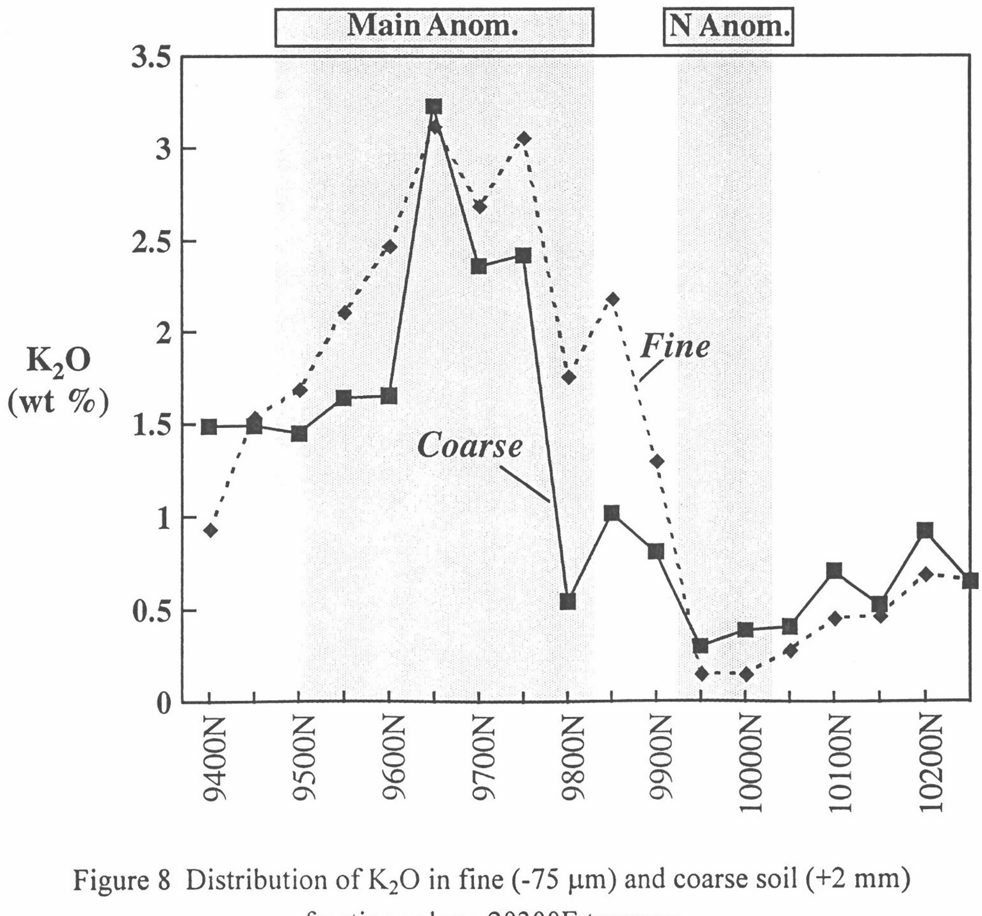

Figure 8 Distribution of K_2O in fine (-75 μm) and coarse soil (+2 mm) fractions along 20300E traverse

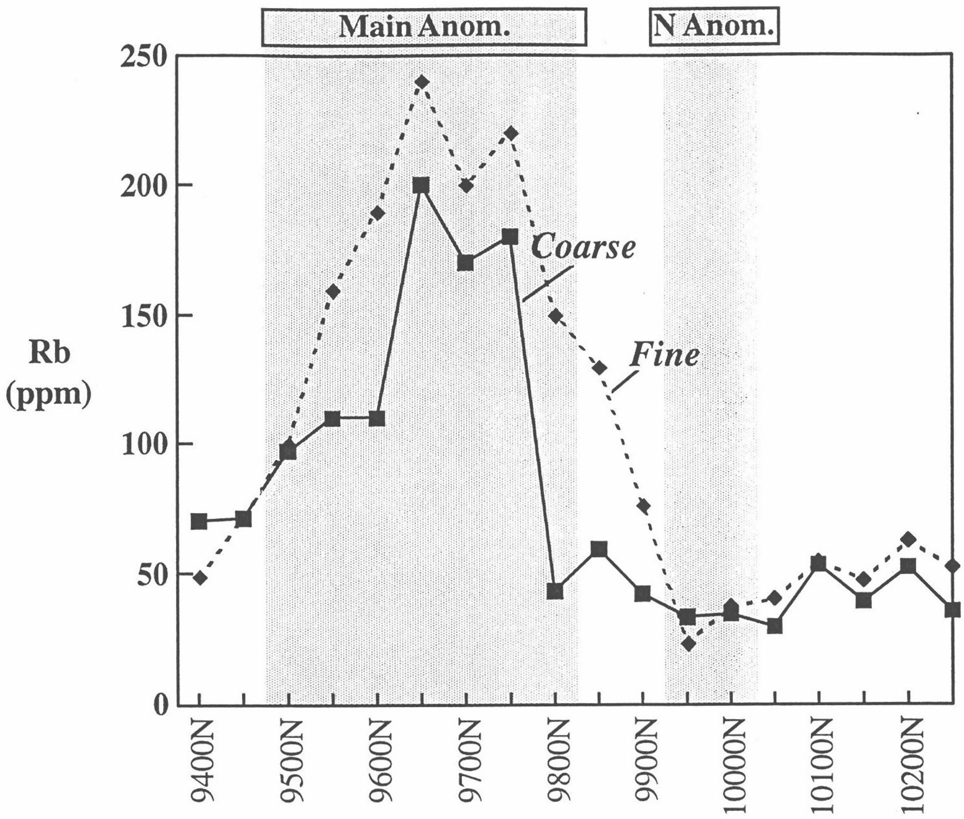

Figure 9 Distribution of Rb in fine (-75 µm) and coarse (+2 mm) soil fractions along 20300E traverse

5.2 Bedrock samples, northern anomaly

Outcropping and subcropping volcanics and Suttor Formation sandstones from the northern anomalous area (outlined by the 20050E and 20300E traverses) have been analysed to establish whether they have features that distinguish them from barren volcanics and/or Suttor Formation material. Results are presented in Tables 3 and 4.

Gossanous material is present in the volcanics and is enriched in Fe, As, Au, Cr and Sb relative to adjacent mottled bedrock (Table 4). However both types of weathered volcanic bedrock from the anomalous zone are very much enriched in these elements plus K, Na, Cs, Rb, Sc and Th relative to "barren" volcanics 200 m to the east, from the top of drill hole 93PCRC3 (Table 4). The significant level of Sb in the "barren" volcanic sample may however reflect the presence of alteration in this sample (Section 5.5).

Suttor Formation sandstone tends to be variably ferruginized but material from the northern anomalous zone tends to be enriched in Fe, As, Au, Cs, Sb and Sc relative to barren material (Table 4). The association of Fe, As, Au and Sb was also found in the coarse fragments of the soils in the northern anomaly (Table 2, Section 5.1). The presence of this suite of elements in Suttor Formation may be related to incorporation of mineralized volcanic material into it or to hydromorphic dispersion from underlying weathering volcanics (see Discussion).

Table 3
Chemical composition of rocks, northern anomaly area, Police Creek
(major components, wt%; minors, ppm)

Sample	128170	128171	128172	128173	128196	128246	128255
Northing	10090		10250		9950	10100	10150
Easting	20050		20000		20300	20100	20200
Lithology	Volc.		Suttor			Volc.	Suttor
Fe_2O_3	1.67	29.0	3.12	0.87	2.85	24.6	5.50
Na_2O	0.08	0.16	0.05	0.05	0.03	0.04	0.03
K_2O	0.49	0.47	0.51	0.49	0.27	<0.25	0.34
As	66	650	9	1	97	920	120
Au(ppb)	29	58	<5	<5	21	21	6
Ba	410	1350	470	1030	200	840	1280
Br	3	11	<2	<2	<2	5	<2
Ce	82	100	18	21	50	16	72
Co	<1	<1	<1	<1	1	3	2
Cr	8	24	10	10	9	16	10
Cs	12	9	3	4	7	6	14
Mo	<5	<5	<5	<5	<5	<5	<5
Rb	31	64	45	38	21	25	46
Sb	20	30	0.6	0.5	8	23	13
Sc	10	12	3	4	6	7	8
Th	12	14	14	12	16	20	14
U	<2	3	<2	<2	2	4	<2
W	5	<2	4	4	4	<2	5
Zn	<100	<100	<100	<100	<100	<100	<100

Table 4
Summary of compositions of Silver Hills Volcanics and Suttor Formation rocks, Police Creek (Major components wt%, minors, ppm)

Lithology	Silver Hills Volcanics			Suttor Formation	
	Mineralized		"Barren"	Mineralized	Barren
	Gossanous	Mottled	(93 PCRC3)		
No of Samples	2	1	1	2	2
Fe_2O_3	26.8	1.67	0.39	4.18	2.00
Na_2O	(0.10)	0.08	<0.01	0.03	0.05
K_2O	(0.30)	0.49	<0.25	0.31	0.50
As	790	66	10	110	5
Au(ppb)	40	29	<5	14	<5
Ba	1100	410	420	(740)	(750)
Br	8	3	<2	<2	<2
Ce	(58)	82	70	61	20
Co	2	<1	<1	2	<1
Cr	20	8	<5	10	10
Cs	8	12	2	11	4
Rb	45	31	<20	34	42
Sb	27	20	12	11	0.6
Sc	10	10	5	7	4
Th	17	12	6	15	13
U	4	<2	<2	<2	<2
W	<2	5	7	5	4

Note: Mo <5 ppm, Zn < 100 ppm
Values in parentheses represent average of two disperate values.

The background levels for As and Au are quite similar for barren volcanics and Suttor Formation sandstones (Table 4). Because the high Sb in the "barren" volcanic probably reflects alteration effects (Section 5.5) the background level for Sb in volcanics is not known. (It would be suspected to be similar to the levels in barren Suttor Formation). Higher Ce and perhaps, lower Th, may discriminate the barren volcanics from sandstones (Table 4).

5.3 Diamond drill hole 93PCDH03 (main anomaly)

This diamond drill hole is collared at 20022E/9650N (i.e. within the major southern anomaly at Police Creek) and was drilled at 60° along the grid east bearing, with 1 m percussion composites retained over the first 21 m prior to diamond coring. Logging of the core by Ross Mining NL reveals soil to 3 m and weathering to 40 m (R. Mustard, pers. comm., 1995). Samples of the percussion material and six small sections of drill core were collected for study.

Soils in the top 3 m are pale brown-grey with some jarosite staining on volcanic fragments in the basal metre. Between 3 to 5 m, weathered volanics are pink-grey and strongly kaolinitic. From 5 to 21 m, kaolinitic and siliceous fragments, commonly with jarosite and/or Fe staining, occur. The samples between 25 and 27 are Fe stained and kaolinized, but with residual feldspar. Fresh volcanics below 40 m consist of grey silicified volcanics, with disseminated pyrite and pyrite veins.

The composition of selected samples from the drill hole are reported in Appendix 1 and summarized in Table 5 within five groupings down the profile. (It should be noted that the use of the drill core for other purposes precluded sampling between 37 to 39 m where good Au grades occur about the base of oxidation).

As would be expected from the previous study (Scott, 1995), the soils are relatively Fe-rich (Fe_2O_3 ~4.7%) and have anomalous As, Au and Sb contents. The strongly weathered material between 3 and 5 m is relatively Fe-poor (Fe_2O_3 ~1.8%) and hence lower As than the soils, but still contains significant Au. Both these zones (soil and top 2 m of the weathered volcanics) contain elevated Cr relative to deeper samples. Weathered volcanics between 5 and 21 m have lower Au relative to samples higher in the profile, but As and Sb are quite anomalous. Below 21 m the presence of feldspar is reflected by the K contents and indicates that weathering is less intense, as does the retention of Zn (Table 5). Although As and Sb are anomalous, the Au grades are low, although there are some unsampled intervals of >1 g/t Au in the zone 21-40 m. Fresh material contains significant Au and associated As, Sb, Co, W and Zn. With the exception of the strongly kaolinized interval, the As/Sb ratio is 20-30 in the rocks of this profile.

Electron microprobe analysis of pyrite from the unweathered volcanics reveals there to be several pyrite generations (Figure 10) and that, although the As contents of the pyrite averages >2%, As contents are quite variable within samples (e.g. As = 0.8-7.30% in pyrite from 112367). Variable Sb (up to 2.4%) and Hg (up to 0.4%) are present in pyrite, with Ag (up to 3.2%) also found in the Sb-rich samples. As/Sb ratios vary between 10 and 60 but average 40. The Cu, Co, Pb and Mn contents of the pyrites are generally low (<0.1%). Illite from these samples is relatively Mg-rich (i.e. showing some tendency toward celadonite) and may also be V-rich (Table 6). Arsenic-rich pyrite and celadonitic micas are also reported at Wirralie, 40 km to the north (Fellows and Hammond, 1990). Adularia usually contains 1.4 mol % albite but one analysis records 1500 ppm Ba. Similar albitic components in adularia are reported for other Queensland epithermal deposits (Dong and Morrison, 1995).

Table 5
Average composition of zones in 93PCDH03 (main anomaly) profile, Police Creek (Major components, wt%; minors ppm)

Zone	Soil	Kaolinitic	Kaol/Fe	Partially weathered	Fresh
Depth (m)	0-3	3-5	5-21	21-40	40-55
No of analyses	3	2	6	2	3
Fe_2O_3	4.68	1.76	4.29	2.60	3.90
Na_2O	0.24	0.33	0.17	0.22	0.11
K_2O	1.24	0.90	1.79	5.59	6.98
As	290	75	450	410	1050
Au(ppb)	230	410	90	24	620
Ba	480	310	390	460	390
Br	5	7	6	3	4
Ce	65	100	100	(68)	(86)
Co	6	5	2	2	21
Cr	20	13	<5	<5	8
Cs	8	12	9	12	(32)
Rb	120	140	210	380	410
Sb	15	14	18	20	54
Sc	10	11	14	11	10
Th	10	11	11	11	10
U	<2	<2	2	<2	7
W	6	3	4	6	17
Zn	<100	<100	<100	170	300
As/Sb	19	7	30	21	21
K/Rb	84	53	72	120	140

Note: Average in parenthesis includes one anomalously high analysis
Mo < 5 ppm

Table 6
Average illite compositions, fresh rocks 93PCDH03 (main anomaly)
Based on Structural formula with 22 O*

Sample No.	128367	128363	128369
Depth (m)	42.4	45.8	55.2
No of analyses	7	6	3
K	1.37	1.39	1.37
Na	0.01	0.01	0.01
Ca	0	0.01	0
Ba	0	0	0.01
ΣX	1.38	1.41	1.39
Al	3.44	3.50	3.48
Mg	0.47	0.46	0.45
Fe	0.14	0.09	0.13
Ti	0.01	0.	0.01
V	0.01	0.02	0.03
ΣY	4.07	4.07	4.10
Si	7.03	6.91	6.82
Al	0.97	1.09	1.18
ΣZ	8.00	8.00	8.00
OH	3.97	3.94	3.94
F	0.05	0.05	0.04
Cl	0	0	0.01

*Formula for illite = $X_{1\text{-}1.5}\ Y_4\ Z_8\ O_{20}\ (OH, F)_4$
X = large ions
Y = octahedrally coordinated ions
Z = tetrahedrally coordinated ions

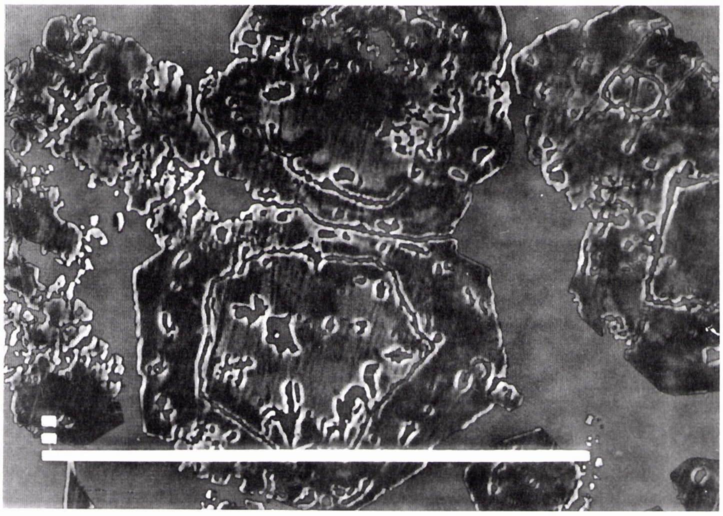

Figure 10a Pyrite with brighter areas reflecting higher As contents (up to 2.9%). Back scattered electron image (Sample 128367 : 93PCDH03 : 42.4 m) Scale bar ≡ 100 μm.

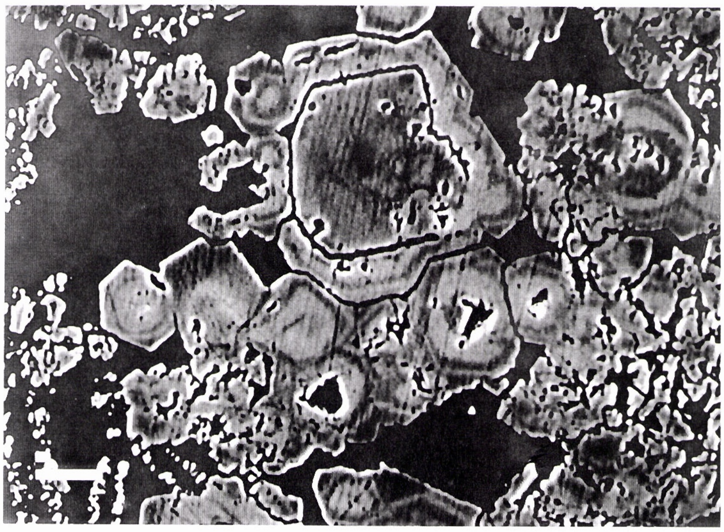

Figure 10b Pyrite with brighter areas reflecting higher As (up to 5.3%) and Sb (up to 0.5%) contents. Back scattered electron image. (Sample 128367 : 93PCDH03 : 42.4 m). Scale bar ≡ 10 μm.

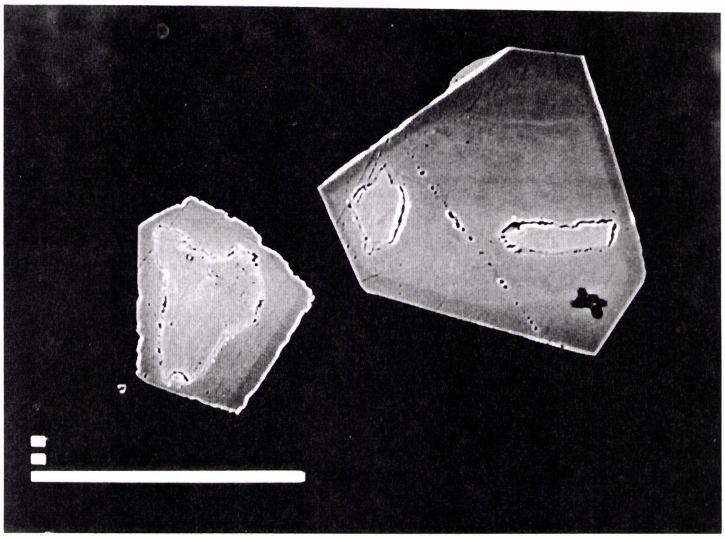

Figure 10c Euhedral pyrite grains with core of more As-rich material (up to 4.7% As). Back scattered electron image. (Sample 128369 : 93 PCDH03 : 55.2 m). Scale bar ≡ 100 μm.

Alluvial and clay zone material from the top 5 m of drill hole 93PCDH03 was separated into coarse (+2 mm) and fine (-75 μm) fractions (Table 7). Coarse fractions from the soils have higher Fe, As, Mo and Sb but lower K, Au and Sc than the clay-rich fine fraction, as generally found by the previous studies (e.g. Scott, 1995). However, once the rock is encountered in the drill hole, Fe, As and Sb levels are relatively similar for coarse and fine fractions but Au contents may be elevated in the coarse fraction, possibly reflecting its presence within quartz veins. The lower abundances of lithophile elements, K, Cs, Rb, Sc and Th, in the coarse fraction of sample 128284 is compatible with the preferential concentration of quartz-rich fragments into the coarse fraction of the sample.

5.4 Drill Hole PCRC4 (Cicada East)

This drill hole was collared at 20450E/9725N and drilled at 60°W, i.e. at Cicada East in an area of outcrop where soils are very thin. Metre composite samples from the top 40 m were collected. Weathering extends to 34 m, although disseminated pyrite is observed well above that level.

The top 4 m of the profile consists of pink-purple highly weathered volcanics whereas the 4-21 m interval is more obviously siliceous in appearance and often has jarositic staining on fragments. Between 21 and 31 m, the porphyritic texture of the volcanics is well preserved and jarosite staining and/or pyrite is present. Iron oxides are strongly developed between 31 and 34 m, i.e. at the base of weathering. Below 34 m, the volcanics are fresh, with disseminated pyrite and carbonate present in some samples.

Examination of the geochemistry reveals high K contents (K_2O >4%) through the profile (Table 8, Appendix 2). Iron is also comparatively high throughout, although there is some relative depletion between 4 and 21 m. Arsenic decreases from the high values (840 ppm) in fresh rock but is still anomalous throughout the profile. Gold is >60 ppb throughout the hole except in the top 4 m. Other features of the profile are the high Mo contents in the upper two zones (in the interval 0-14 m; Appendix 2) and the presence of low level Zn below 29 m (Appendix 2). Antimony contents are low (≤ 8 ppm) relative to the more highly mineralized profile, 93PCDH03, especially in fresh samples (cf. Table 5).

The fine and coarse fractions of four soils in this general area were also analysed because company data suggested they might be Zn rich. However the results (Table 9) do not reveal significant Zn contents. As observed in other soil samples, the coarse fractions show enrichment in Fe, As and Sb relative to the finer fractions (Table 9). Molybdenum is also concentrated in the coarse fractions as often found along 20300E but not so often along the 20050E traverse (see Discussion).

5.5 Drill Hole 93PCRC3 (Cicada Ridge)

This hole, drilled at 60°E at 19866E/10100N, provides a profile through altered but barren material. White silicified volcanics occur around the collar of the drill hole and weathering, reflected by Fe staining, is significant to 34 m.

The top 8 m are characterized by argillized and silicified volcanics with traces of jarosite/Fe oxide staining. From 8 to 21 m, white argillized volcanics with significant Fe staining occurs. Between 21 and 33 m, the volcanics are white to grey in colour with strong Fe oxide development in the basal portion, especially around 29 m. X-ray diffraction and PIMA analysis shows that dickite and pyrophyllite occur from surface

Table 7
Chemical composition of fine and coarse fractions of samples from top 5 m of the 93PCDH03 profile, Police Creek (Major components, wt%; minors, ppm)

Fraction	FINE					COARSE				
Sample No	128280	128281	128282	128283	128284	128280	128281	128282	128283	128284
Depth	0-1	1-2	2-3	3-4	4-5	0-1	1-2	2-3	3-4	4-5
Fe_2O_3	2.22	1.56	1.32	1.63	0.70	13.5	7.72	10.5	2.02	0.63
Na_2O	0.15	0.17	0.19	0.18	0.14	0.05	0.11	0.08	0.08	0.05
K_2O	1.69	1.24	0.92	1.17	1.10	1.53	1.02	1.25	0.40	0.57
As	100	68	66	83	48	990	740	1300	190	36
Au(ppb)	890	150	89	230	220	130	52	100	230	2400
Ba	410	600	500	420	320	330	690	820	430	160
Ce	97	64	55	68	110	38	75	120	34	58
Co	8	6	8	9	2	4	11	19	2	<1
Cr	16	18	17	13	9	22	19	17	12	8
Cs	10	7	6	9	8	5	5	5	5	4
Mo	<5	<5	<5	<5	<5	13	6	<5	<5	<5
Rb	150	91	73	95	84	100	91	92	69	40
Sb	7	7	8	12	20	41	40	41	19	28
Sc	15	9	8	10	12	8	7	7	7	4
Th	12	11	10	10	10	8	8	11	6	5
U	3	<2	<2	2	<2	<2	<2	<2	<2	<2
W	7	5	4	5	7	5	6	6	9	7
Zn	130	<100	<100	<100	<100	<100	<100	<100	<100	<100

Table 8
Average composition of zones in PCRC4 (Cicada East) Police Creek
(Major components, wt%, minors, ppm)

Zone	Highly weath.	Silic	Partially weath.	Base of weath.	Fresh
Depth (m)	0-4	4-21	21-31	31-34	34-40
No of Analyses	2	5	3	2	3
Fe_2O_3	3.94	2.59	3.26	4.70	6.04
Na_2O	0.11	0.09	0.11	0.09	0.08
K_2O	5.55	4.26	5.07	4.34	4.05
As	270	250	200	400	840
Au(ppb)	21	120	84	110	130
Ba	470	460	480	520	350
Br	2	2	<2	<2	2
Ce	74	57	57	56	57
Co	<1	<1	7	11	9
Cr	6	6	6	<5	<5
Cs	7	8	8	12	11
Mo	46	12	<5	<5	10
Rb	430	390	400	390	340
Sb	7	8	6	4	6
Sc	11	11	10	11	10
Th	9	10	9	9	9
U	<2	<2	<2	<2	<2
W	5	6	6	9	7
Zn	<100	<100	<100	140	120
As/Sb	43	32	40	100	130
K/Rb	110	110	106	93	99

Table 9
Chemical composition of fine and coarse fractions of soils, Cicada East area, Police Creek
(Major components, wt%; minors, ppm)

Fraction	FINE				COARSE			
Sample No	128256	128257	128258	128259	128256	128257	128258	128259
Northing	9500	9700	9750	9750	9500	9700	9750	9750
Easting	20350	20450	20200	20400	20350	20450	20200	20400
Fe_2O_3	2.83	2.54	2.53	2.06	3.85	8.45	3.59	2.92
Na_2O	0.32	0.08	0.10	0.11	0.11	0.06	0.05	0.06
K_2O	2.92	3.05	2.17	3.19	1.29	3.76	1.35	4.01
As	450	220	270	160	510	620	340	230
Au(ppb)	160	360	32	270	20	71	12	370
Ba	610	310	610	460	330	440	330	440
Br	43	16	17	15	5	5	3	<2
Ce	130	68	99	68	64	42	45	44
Co	6	2	3	2	4	4	2	<1
Cr	6	13	10	12	8	9	10	8
Cs	15	9	8	8	5	10	4	5
Mo	<5	24	<5	11	14	41	17	21
Rb	190	230	130	230	76	230	100	240
Sb	12	9	26	4	27	14	56	7
Sc	19	13	19	11	10	10	9	9
Th	11	11	11	9	8	10	8	9
U	5	3	5	<2	3	3	<2	<2
W	3	7	5	6	14	5	11	7
Zn	130	<100	110	<100	<100	110	<100	<100

to at least 22 m. Below 33 m, the volcanics are fresh with plagioclase, chlorite and calcite ± disseminated pyrite present.

Down the profile Fe, Na and K all increase from very low surficial levels (Table 10, Appendix 3). Gold contents are <5 ppb throughout the profile but, although As is <60 ppm in the fresh samples, some As>80ppm is present in the weathered zone between 8 and 33 m (Table 10). Antimony contents are also elevated (>20 ppm) in that interval, attaining levels even greater than those in the highly mineralized profile 93PCDH03 (cf. Table 5). As/Sb ratios are thus quite low in this profile (Table 10). Zinc is elevated in the fresher samples from the basal part of the profile but Mo is low throughout and W decreases in fresh samples (Table 10).

6. DISCUSSION

6.1 Soils

Two zones, 300 m and 100 m long respectively, defined by As>100 ppm and Sb>5 ppm in the fine (-75µm) fractions of the soils, occur along the 20300E traverse. The larger southern area generally has Au>40 ppb and sometimes has Mo > 5 ppm as well. A smaller zone but with higher As and Sb (>200 and >10 ppm respectively), more consistent Mo values >5 ppm but only intermittent Au > 40 ppb are defined within the anomalous areas by the coarse (+2 mm) fraction of the soils (Figure 11).

These thresholds are somewhat lower than previously used to define the anomalies along 20050E (Scott, 1995) but their use allows the two anomalous areas to be seen in both coarse and fine soil fractions along 20050E (Figure 11). The southern anomaly is best defined by Au in the fine fraction and Fe, As and Sb in the coarse fraction, and the northern anomaly by Fe, Au, As and Sb in the coarse fraction (Figure 11).

Comparison of the As contents in the fine fractions within the southern anomaly reveals As to be higher along 20300E, whereas Au contents are lower than those attained along 20050E. However, the As contents of the coarse soil fractions are higher along 20050E (Figure 11). This difference reflects the difference in the samples - soils within the anomaly along 20050E are developed in alluvium with As highly concentrated into the coarse fraction (which generally contains ferruginous concretions which may have formed within the soil profile) whereas along 20300E soils are largely residual and do not display such large differences between fine and coarse fractions. Coarse fractions along 20300E are composed of lithic fragments and are mostly not highly ferruginous (Section 5.1) and the total coarse fraction is much greater than along 20050E (Figure 11). This difference in the soils is readily reflected by the presence of float and low outcrop along the 20300E traverse.

The presence of the northern anomaly along both traverses suggests that it may be significant even though it was not obvious in the original -180 µm soil sampling. Indeed, the outcropping/subcropping volcanics of this area do bear anomalous As, Au and Sb, especially when they are gossanous or ferruginous (Tables 3 and 4), suggesting that alteration/mineralization does occur in this area. However, because of its location close to remnants of Suttor Formation, it is possible that the anomaly could be at least, in part, derived from colluvial outwash of mechanically-transported gold-bearing sediments from the base of the Suttor

Table 10
Average composition of zones in 93PCRC3 (Cicada Ridge), Police Creek
(Major components, wt%; minors, ppm)

Zone	Highly weath.	Dickite/Fe	Partially Weath.	Fresh
Depth (m)	0-8	8-21	21-33	33-62
No of Analyses	4	4	3	8
Fe_2O_3	0.45	1.91	(5.69)	4.55
Na_2O	0.01	0.08	0.23	0.97
K_2O	<0.25	0.31	1.21	1.38
As	18	120	180	57
Au(ppb)	<5	<5	<5	<5
Ba	330	240	340	630
Br	<2	<2	<2	<2
Ce	81	81	98	62
Co	<1	<1	7	7
Cr	5	7	7	7
Cs	1	2	16	17
Rb	<20	<20	120	160
Sb	15	28	21	13
Sc	6	15	16	11
Th	9	8	14	10
U	<2	3	<2	<2
W	7	9	9	3
Zn	<100	<100	(210)	110
As/Sb	1	5	7	5
K/Rb	-	(110)	95	70

Note: Averages in parenthesis include one anomalously high analysis
Mo < 5 ppm

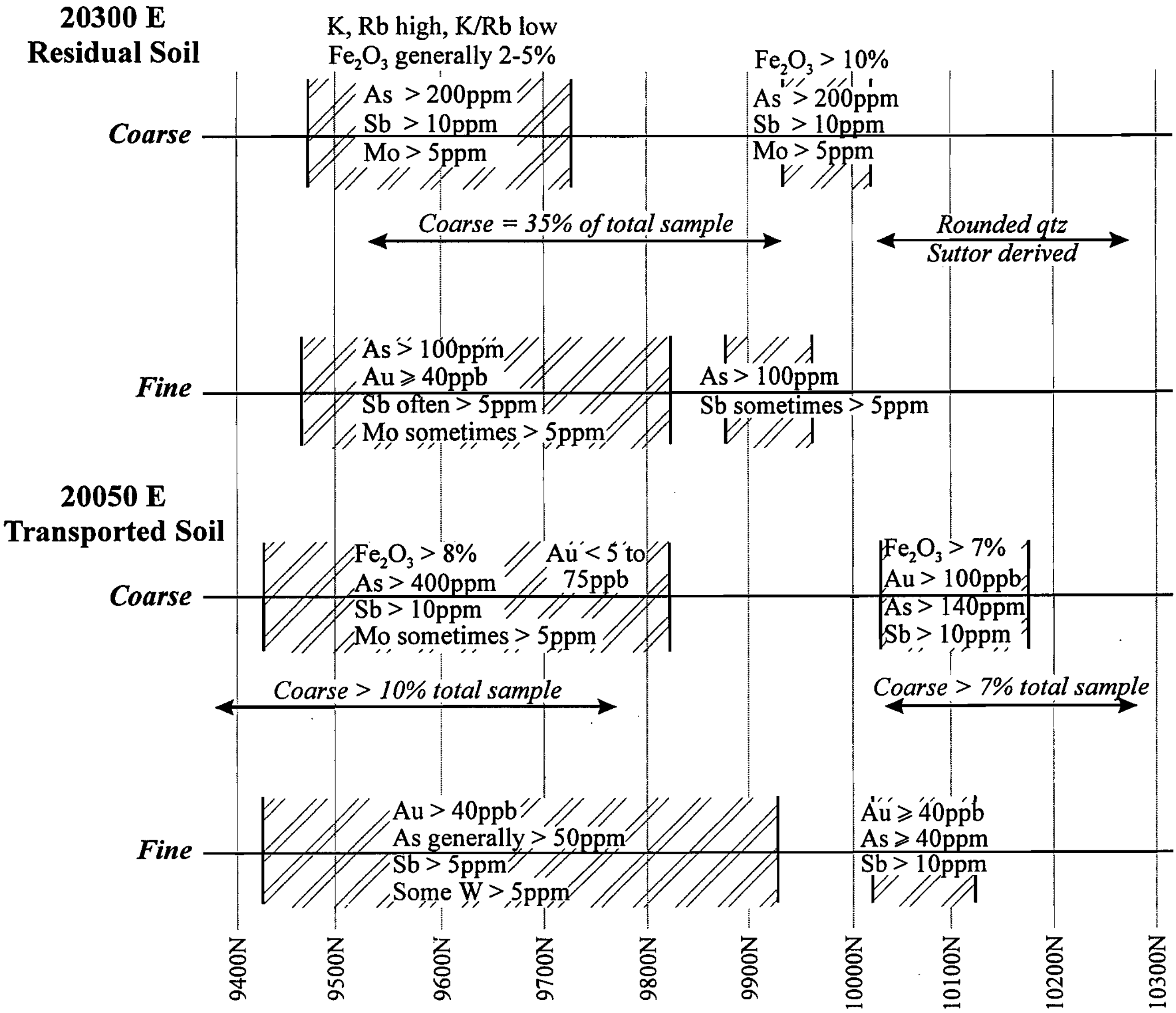

Figure 11 Summary of soil characteristics within the main and northern anomalies, 20050E and 20300E, Police Creek

Formation. Indeed, two samples of outcropping Suttor Formation from this general area are enriched in Au, As and Sb relative to other Suttor Formation samples (Tables 3 and 4). It is also possible that the Au, As and Sb within these two samples could represent recent hydromorphic dispersion into remnant thin Suttor Formation from underlying altered/mineralized volcanics, i.e. mineralization may extend under the Suttor Formation. In this case, the presence of adjacent outcropping and subcropping volcanics with alteration or mineralization features clearly establishes the significance of the anomaly, but such rocks may not always be present. Thus, a way to distinguish between recent hydromorphic dispersion into the Suttor Formation (probably occurring at the same time as As, Au and Sb were dispersed into the alluvial soils in the main Police Creek anomaly) and incorporation of detrital Au-bearing material into the base of the Suttor Formation is needed. Because some Au within the Suttor Formation is clearly associated with epithermal quartz in the Police Creek area (R. Mustard, pers. comm., 1994) and at Wirralie (Fellows and Hammond, 1990), all Au anomalies from the Suttor Formation must be treated very cautiously. Preliminary work at Wirralie suggests that, although Au associated with ferruginous clasts has associated As and Sb, the Au with quartz does not show an As-Sb association (Scott et al., 1996). Thus, further documentation of samples containing known mechanically transported Au is needed to confirm whether such material is separated from its pathfinder elements, As and Sb, during mechanical transport and whether other detrital grains, e.g. anatase, can give indications of an original epithermal association.

The southern anomaly at Police Creek is approximately 1 km long and up to 600 m wide, using an Au cutoff of 50 ppb in the -180 µm (-80 mesh) soil samples (Figure 12). Comparison with the extent of the >40 ppb Au anomaly in the -75 µm soil fraction along the two lines studied suggests that use of the finer fraction is likely to increase it significantly, especially along Line 20300E (Figure 11), i.e. in residual soil. However, the Au in the finer fraction does not reveal the northern anomaly in residual soil along Line 20300E (Figure 11). Here the As content of the coarse (+2mm) soil material defines a zone at least 400 m long and about 150 m wide (Figure 12). The As content of the coarse fraction of the soils also appears to reflect substantial enrichment that defines the southern anomaly (Figures 11 and 12). Thus, the As content of the coarse fraction of the soils may well represent the most robust exploration parameter when the origin of the soils is unknown.

Study of the profiles reveals that ~300 ppm Zn is present in highly mineralized rocks (Table 5), probably as a minor sulfide component and ~100 ppm is present in lesser mineralized and propylitic samples (Tables 8 and 10), where it is probably associated with calcite and/or chlorite. Weathering in each case results in depletion of Zn above 20 m in the profiles (Tables 5, 8 and 10), but some Zn is present in the fine fraction of some soils along 20300E (Appendix 1).

Scott (1995) previously suggested that Zn in soils may reflect the presence of carbonate which may in turn be associated with Au. However, the Zn-bearing soils along 20300E do not contain anomalous Au and soils from the Cicada East area (collected because of suspected high Zn contents) do not contain significant Zn (Table 9). Thus the possible association between Au, Zn and carbonate could not be verified at Police Creek.

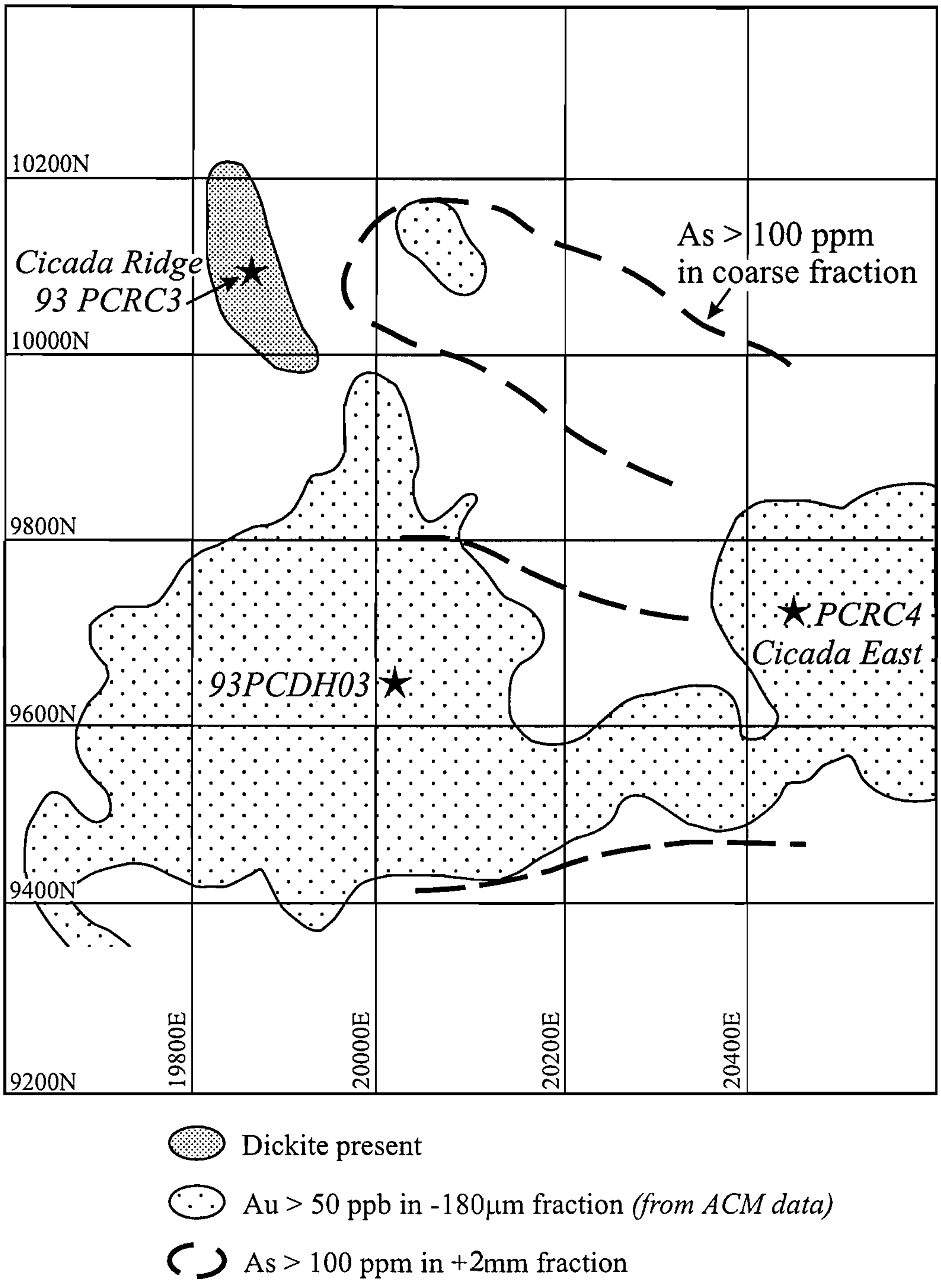

Figure 12 Extent of southern and northern anomalies in soils, Police Creek.

6.2 Profiles in the Silver Hills Volcanics

6.2.1 Weathering effects on different alteration assemblages

Weathering of highly mineralized assemblages of quartz, adularia, pyrite, illite and kaolinite at 20022E/9650N (93PCDH03) is characterized by the destruction of adularia and pyrite to form additional kaolinite, jarosite and Fe oxides. As indicated above (Section 5.3), K, As, Au, Co, Rb, Sb, W and Zn are leached during such weathering. Gold itself is concentrated in the near-surface kaolinitic samples (and in the overlying alluvial soil) with As and Sb still abundant enough in the near-surface samples to be useful as gold pathfinders. Arsenic is particularly well concentrated in the overlying soil relative to the rock below.

The occurrence of up to 0.4% Hg in pyrite at depth (Section 5.3) suggests that Hg may also be a possible pathfinder. Similarly, the presence of up to several thousand ppm V in illite could make V a useful lithogeochemical indicator. The potential of these two elements should be tested further.

At Cicada East (PCRC4), low grade mineralization is associated with quartz, adularia, illite, pyrite, chlorite ± calcite. The presence of the latter two minerals suggests that this alteration is more propylitic, i.e. lower grade than in 93PCDH03. Weathering of the chlorite and calcite leads to the formation of kaolinite, whereas pyrite weathers to jarosite (although some residual pyrite is still present up to 7-8 m). Chemically, weathering results in the loss of As, Au, Co and Zn, but K and Rb are retained because adularia persists through the weathering profile. The persistence of pyrite and retention of adularia to high levels in the profile suggests that it is less strongly weathered than the more mineralized rocks in 93PCDH03. The effects of substantial silicification may well have minimized weathering effects at Cicada East. Relative to As, Sb is low at this less mineralized site. Molybedenum contents are high in this area as indicated by Mo≥15 ppm in the coarse fractions of soil samples about Cicada East (Table 9) and close to the surface in PCRC4 (Table 8).

Fresh rock at Cicada Ridge (93PCRC3) consists of quartz, plagioclase, calcite, chlorite, illite and mixed layer/smectitic clays, i.e. a propylitic assemblage. The Au content is very low (<5 ppb) but Sb is enriched relative to As (As/Sb = 5). In outcrop and the top 33m of this drill hole, quartz, dickite ± alunite ± pyrophyllite ± illite occur. Pyrophyllite is a relatively uncommon alteration mineral in N.E. Queensland, but it is found with high temperature minerals, like topaz, at Truncheon, 30 km south of Charters Towers (Berry et al., 1992). Dickite is also regarded as an alteration mineral (e.g. at Pajingo; Porter, 1990; Cornwell and Treddinnik, 1995). Thus, it is probable that the abrupt change from chlorite- and calcite-bearing assemblages to dickite ± pyrophyllite represents an alteration change (from propylitic to argillic alteration) rather than a weathering change. The abrupt increase in As and Sb contents above 33 m is consistent with such an interpretation. If the top 33 m represents a profile through argillic alteration, it would appear that the only weathering effects on such alteration are some loss of As and Sb and the possible loss of pyrophyllite above 7 m. Dickite appears to be quite stable to weathering and thus potentially useful as an indicator of argillic alteration in outcrop/subcrop. Indeed, dickite has been found in outcrop along the 200 m length of Cicada Ridge, where silicification probably helps preserve it. If this drill hole passes through barren argillic and then propylitic alteration in an eastwards direction (as argued above), any more intense alteration in this area is likely to be to the west and the argillic alteration in this drill hole is unlikely to be related to the northern anomaly alteration observed along the 20050E and 20300E traverses.

6.2.2 Primary genetic implications

Because As and Sb are hosted by pyrite (Section 5.3), whole rock As/Sb ratios may reflect temperatures of formation of the host pyrite (cf. Scott, 1986). Thus high As/Sb values at Cicada East may reflect higher temperatures there relative to the pyrite formation at Cicada Ridge and the major alteration (at 93PCDH03). High Mo contents at Cicada East are consistent with higher temperatures than at the other locations (cf. Korobeynikov and Pshenickkin, 1985). Molybdenum is also elevated at deeper levels of the Wirralie mine (M.L. Fellows, pers. comm., 1994) and is associated with the early higher temperature alteration at Mount Leyshon (Paull et al., 1990). The very strong development of adularia relative to illite at Cicada Ridge may also reflect the formation deeper in the hydrothermal system. However the development of adularia as a pre-main mineralization event at Pajingo (Bobis et al., 1995) suggest that additional textural and structural information on the feldspar should be sought (cf. Dong and Morrison, 1995). Although pyrophyllite usually forms at temperatures >275°C (Deer et al., 1962), the presence of some alunite with the pyrophyllite and dickite suggest a formation from an acidic silica-supersaturated fluid below 260°C (White and Hedenquist, 1990). Such temperatures may still be close to the 300°C upper limit for formation for epithermal gold deposits (Hayba et al.,1986; White and Hedenquist, 1990). However the low As/Sb ratios suggest lower temperatures than at Cicada East. To determine whether the pyrophyllite and pyrite represent different events (i.e. telescoping of alteration assemblages has occurred) requires more detailed textural work.

Because many of the epithermal alteration minerals at Police Creek appear to be retained in outcrop, additional work to firmly establish their paragenetic relationships is recommended. Such work is probably beyond the scope of this AMIRA project but would allow features seen in surficial samples to be used to maximum advantage during exploration.

6.3 Effects of weathering

During the Tertiary period, the Silver Hills Volcanics of the Police Creek area were unconformably overlain by the sandstones of the Suttor Formation. Lateritization of the Suttor Formation and the underlying volcanics occurred during the mid to late Tertiary (Wells et al., 1989) resulting in some surficial ferruginization of the Suttor Formation and mottling and clay development in the volcanics (Scott, 1995). Incision of the landscape exposed the mottled and clay weathered zones of the Silver Hills Volcanics prior to the more recent deposition of the alluvium and colluvium. Company studies (R. Mustard, pers. comm., 1994) and a previous report (Scott, 1995) have documented dispersion of As, Au, Sb and Fe into such material from the underlying kaolinitic rock, with pedogenic processes probably being responsible for the association of As and Sb with Fe concretions. The effects of mechanical reworking of mineralized fragments of volcanic-material cannot be discounted either.

Where the Silver Hills Volcanics crop out, Au, As and Sb are lost up the profile (Table 8). Comparison of the compositions of the fine soil fraction with adjacent outcrop suggests that As and Sb are generally lost during pedogenesis, whereas Au may be enriched (Table 11). The minerals of argillic alteration assemblages at Cicada Ridge are not severely affected by weathering, probably due to associated (? hydrothermal) silicification, but As and Sb are depleted close to the surface (Table 10). These features suggest that soils are enriched in Au, As and Sb relative to outcropping volcanics. Such mobilization of Au and As and Sb into the soils is similar to the process occurring in the midst of the main southern Police Creek anomaly, i.e. pedogenic mobilization occurs in both residual soils and those developed on transported material. Silicification of the outcrop may also contribute to the apparent depletion of Au and its pathfinders in outcropping volcanics.

Table 11
Compositions of rock and adjacent soil at Police Creek

Location	9950N/20300E		10100N/19900E		10100N/20100E		10150N/20200E		9700N/20450E	
Sample No.	128195F	128196	128242F	128243	128245F	128246	128254F	128255	128257F	128260
Sample Type	-75 µm soil	rock	-75 µm soil	rock	-75 µm soil	rock	-75 µm soil	rock	-75 µm soil	rock
Fe_2O_3%	3.80	2.85	4.02	7.73	1.90	24.6	1.87	5.50	2.54	3.32
As (ppm)	120	97	61	220	45	920	8	120	220	220
Au (ppb)	15	21	<5	<5	35	21	19	6	360	20
Sb (ppm)	7	8	11	18	9	23	3	13	9	6

How much redistribution of Au and its pathfinders occurred during the mid to late Tertiary lateritization event and how much during the much more recent events, including surficial silicification, is not known. Nevertheless, the concentration of Au, As and Sb into specific soil fractions suggests that soils may be the best exploration medium in the Police Creek area.

7. CONCLUSIONS

The Silver Hills Volcanics have probably undergone several periods of weathering. The initial period during mid to late Tertiary lateritization (when the volcanics were capped by Suttor Formation) resulted in mottling and clay development in the volcanics. Subsequent weathering has occurred after the Tertiary cover was removed. Mobilization of Au and its pathfinder elements (As and Sb) probably occurred during both periods, with dispersion into soils occurring during the latter (? still continuing) event.

The soil traverse at 20300E occurs across predominantly residual (in situ) soils whereas that at 20050E is mainly across an alluvial area. Nevertheless, both traverses define the main southern anomaly well, especially by using the -75 µm fraction for Au and the coarse (+2 mm) fraction for Fe, As and Sb. These two fractions also define a smaller northern anomaly in volcanics adjacent to the Suttor Formation along both traverses. Using the Au in the fine fraction and As in the coarse fraction, the southern anomaly is defined as at least 1 km long and 600 m wide and the northern anomaly as having dimensions of at least 400 x 150 m. This latter anomaly was not obvious in the original -180 µm soil survey over the area and it may extend underneath the Suttor Formation. If so, it may have contributed to hydromorphic dispersion into the basal portion of the Suttor Formation. However, the widespread occurrence of mechanically transported Au in such a position makes the accurate assessment of the significance of anomalies in basal Suttor Formation sequences difficult.

Study of highly mineralized, mineralized and barren profiles through the Silver Hills Volcanics reveal that Au, As and Sb are generally depleted by factors of 2 to 3 during weathering processes. Such processes alter adularia + illite + kaolinite + pyrite assemblages to illite + kaolinite + jarosite + Fe oxides in highly mineralized volcanics. Lower grade mineralization is associated with adularia + illite + chlorite + pyrite at depth and adularia + illite + kaolinite + jarosite + Fe oxides in surficial assemblages, i.e. adularia and illite is retained. Argillic alteration is barren and consists of dickite + pyrophyllite + illite at depth and dickite + alunite in outcrop. Propylitic assemblages (plagioclase + illite + calcite + chlorite and smectitic clays) have not been studied in outcrop. Some of the characteristic features of particular alteration zones are potentially mappable in outcrop, e.g. using techniques like PIMA and radiometric surveys.

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APPENDICES

Appendix 1
Compositions of samples in 93PCDH03 (main anomaly) profile, Police Creek
(Major components; wt%, minors, pp,)

Sample No.	128280	128281	128282	128283	128284	128285	128287	127288
Depth (m)	0-1	1-2	2-3	3-4	4-5	5-6	7-8	9-10
Fe_2O_3	7.26	3.57	3.20	2.42	1.10	1.67	6.20	5.12
Na_2O	0.11	0.29	0.33	0.41	0.24	0.22	0.19	0.16
K_2O	1.29	1.23	1.19	0.92	0.88	1.67	1.96	1.82
As	470	220	170	93	56	100	740	460
Au(ppb)	350	150	190	220	600	100	110	97
Ba	430	640	380	270	350	150	420	270
Br	5	5	5	8	6	8	10	5
Ce	59	62	75	75	130	91	130	54
Co	6	6	7	7	3	2	5	3
Cr	18	18	23	15	10	10	<5	<5
Cs	6	7	10	12	12	13	10	9
Rb	120	120	130	140	140	190	180	210
Sb	25	11	9	10	18	25	26	9
Sc	11	9	11	11	11	13	14	13
Th	10	9	10	11	11	11	9	10
U	3	<2	<2	2	<2	<2	3	2
W	6	8	4	4	<2	4	4	5
Zn	<100	<100	<100	<100	<100	<100	<100	<100
As/Sb	19	20	19	10	3	4	30	48
K/Rb	88	89	76	53	53	75	91	71

Appendix 1 cont'd

Sample No.	128290	129293	128295	128364	128365	128367	128368	128369
Depth (m)	12-13	16-17	20-21	25.6	27.2	42.4	45.8	55.2
Fe_2O_3	4.17	5.03	3.53	2.72	2.63	5.13	3.49	3.07
Na_2O	0.21	0.09	0.15	0.28	0.15	0.13	0.07	0.13
K_2O	1.95	1.28	2.05	5.02	6.16	6.84	4.99	9.12
As	400	680	330	400	410	1270	1390	490
Au(ppb)	110	11	110	32	16	1060	410	390
Ba	410	570	490	300	620	490	300	370
Br	6	3	4	3	3	5	5	2
Ce	130	150	150	15	120	180	24	54
Co	<1	2	2	2	2	41	7	16
Cr	8	<5	<5	6	<5	8	9	6
Cs	10	6	8	12	12	85	5	7
Rb	250	190	240	380	380	470	260	500
Sb	9	22	17	17	22	75	69	19
Sc	14	15	14	11	10	14	5	10
Th	10	12	11	9	12	15	4	10
U	<2	4	3	<2	<2	17	2	3
W	<2	5	7	6	5	15	26	11
Zn	<100	<100	<100	180	160	570	110	220
As/Sb	47	31	20	23	19	17	20	26
K/Rb	65	57	71	110	135	120	159	153

Appendix 2

Compositions of samples in PCRC4 (Cicada East) profile, Police Creek

(Major components, wt%; minors, ppm)

Sample No.	128260	128261	128262	128263	128264	128266	128268	128270
Depth (m)	1-2	3-4	5-6	7-8	9-10	13-14	17-18	21-22
Fe_2O_3	3.32	4.56	2.42	2.87	2.16	2.70	2.80	3.63
Na_2O	0.11	0.11	0.09	0.07	0.11	0.12	0.12	0.11
K_2O	5.72	5.37	4.90	5.09	5.02	4.96	5.57	5.19
As	220	320	210	260	210	390	200	240
Au(ppb)	20	21	230	61	82	120	100	87
Ba	440	500	410	350	520	450	560	530
Br	<2	3	2	3	<2	<2	2	<2
Ce	77	71	62	74	57	43	47	55
Co	1	<1	1	<1	<1	<1	2	6
Cr	10	<5	10	<5	7	<5	9	7
Cs	6	7	8	12	8	5	6	8
Mo	45	46	12	20	10	16	<5	<5
Rb	450	400	410	400	370	360	390	410
Sb	6	7	6	7	7	13	7	6
Sc	10	11	13	13	10	9	9	10
Th	9	9	11	12	9	8	9	9
U	<2	<2	<2	2	<2	2	<2	<2
W	4	5	5	4	5	8	8	6
Zn	<100	<100	<100	<100	<100	<100	<100	<100
As/Sb	41	44	36	35	31	30	28	38
K/Rb	107	112	99	105	112	115	119	105

Appendix 2 cont'd

Sample No.	128272	128274	128275	128276	128277	128278	128279
Depth (m)	25-26	29-30	31-32	33-34	35-36	37-38	39-40
Fe_2O_3	2.33	3.83	4.70	4.70	5.49	7.63	5.00
Na_2O	0.12	0.11	0.09	0.09	0.07	0.07	0.09
K_2O	5.02	5.01	4.49	4.19	3.72	3.70	4.72
As	170	190	280	510	780	1170	560
Au(ppb)	81	83	86	140	100	150	130
Ba	420	480	490	550	350	250	460
Br	<2	<2	<2	<2	<2	3	2
Ce	56	60	57	55	60	55	56
Co	3	12	14	8	7	12	7
Cr	<5	8	<5	<5	<5	9	<5
Cs	8	9	12	11	11	11	10
Mo	<5	<5	<5	<5	<5	24	<5
Rb	400	390	370	410	330	340	350
Sb	8	3	3	4	6	8	5
Sc	10	11	11	10	10	10	10
Th	9	10	10	8	10	9	9
U	<2	2	2	<2	2	<2	<2
W	6	7	10	8	6	6	9
Zn	<100	160	150	130	110	140	110
As/Sb	21	61	90	120	136	150	104
K/Rb	106	107	101	85	93	90	114

Appendix 3

Compositions of samples in 93PRRC3 (Cicada Ridge) profile, Police Creek (Major components, wt%; minors ppm)

Sample No.	128296	128298	128300	128320	128304	128305	128307	128309	128311
Depth (m)	0-1	2-3	4-5	6-7	8-9	9-10	13-14	17-18	21-22
Fe_2O_3	0.39	0.39	0.61	0.40	1.97	2.14	1.62	1.90	0.59
Na_2O	<0.01	0.01	0.02	0.01	0.04	0.04	0.12	0.11	0.25
K_2O	<0.25	<0.25	<0.25	<0.25	0.41	<0.25	0.35	0.35	1.24
As	10	17	26	18	75	95	110	200	67
Au(ppb)	<5	<5	<5	<5	<5	<5	<5	<5	<5
Ba	420	220	400	270	250	380	200	120	<100
Ce	70	73	72	110	79	110	97	37	140
Co	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cr	<5	5	7	6	10	<5	<5	11	11
Cs	2	1	<1	1	<1	1	3	4	10
Rb	<20	<20	<20	<20	<20	<20	<20	26	73
Sb	12	17	17	14	29	33	29	21	16
Sc	5	5	5	7	14	9	23	14	24
Th	6	8	7	13	8	11	9	4	23
U	<2	<2	<2	<2	4	2	3	3	3
W	7	6	7	6	10	7	11	7	9
Zn	<100	<100	<100	<100	<100	<100	<100	<100	100
As/Sb	1	1	1	1	3	3	4	10	4
K/Rb	-	-	-	-	-	-	-	114	141

Note: Br <2 ppm, Mo <5 ppm

Appendix 3 cont'd

Sample No.	128313	128315	128317	128319	128321	128322	128324	128326	128329	128331
Depth (m)	25-26	29-30	33-34	37-38	41-42	43-44	47-48	51-52	57-58	61-62
Fe_2O_3	4.37	12.1	4.33	5.15	4.23	4.37	3.96	4.09	5.88	442
Na_2O	0.22	0.21	0.90	0.87	1.05	1.56	0.90	0.73	0.12	1.59
K_2O	1.39	1.00	0.69	2.10	1.33	1.26	1.22	0.96	1.92	1.61
As	370	90	25	95	34	6	96	37	130	34
Au(ppb)	<5	<5	<5	<5	<5	<5	10	<5	<5	<5
Ba	560	410	730	740	960	1060	360	360	450	400
Ce	77	76	56	68	56	64	60	70	60	58
Co	2	21	9	7	7	7	7	7	9	6
Cr	<5	7	7	8	6	8	6	9	<5	7
Cs	9	28	17	23	19	19	14	13	16	16
Rb	120	170	98	220	170	180	140	140	180	170
Sb	33	14	8	11	12	13	23	13	13	8
Sc	14	10	10	12	11	12	11	11	12	12
Th	11	9	9	11	10	11	9	10	10	10
U	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
W	7	11	<2	<2	6	3	4	<2	3	<2
Zn	<100	470	110	130	100	130	<100	130	160	<100
As/Sb	11	6	3	9	3	0.4	4	3	10	5
K/Rb	94	49	58	79	66	58	73	59	91	78