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TABLE

SECTION 5

REGIONAL GEOCHEMICAL INTERPRETATIONS

J. Tang

DATA

The regional geochemical synthesis for the Yarrol Province was based on data extracted from the Queensland Exploration Geochemistry and Drill hole database. Terra Search Pty Ltd compiled these data from the open file company exploration reports. A total of 114 514 surface geochemical data points comprising 5206 rock chips, 54 875 stream sediments and 54 433 soils samples (Table 4) were used in this appraisal. The assays for these data points can contain up to 38 separate elements, though the more commonly assayed elements with regional spatial distributions are Ag, As, Au, Cu, Pb and Zn.

Despite the extensive data coverage of the dataset, the collective data cannot be treated as a homogeneous regional population due to their sample and analytical diversity. The possible analytical variations from 26 major sample types, 851 preparation methods, 140 laboratories and 1184 analysis types culminate to 2043 variables. Such data heterogeneity hinders any direct means of comparing or plotting a single geochemical assay/variable for all sample types. Using standard statistical methodologies, each sample type requires an individualised plot to represent respective assays, as the various sample types have little geochemical commonality. Moreover, data types are generally mutually exclusive. For example, stream sediments data occurs primarily within streams whereas rock chips and soil data were collected in areas with exposed rock outcrop.

Table 4: A summary of available data points in the Yarrol Province listed according to map sheets

Sheet No.	Map sheet	No. of Rock Chip samples	No. of Stream Sediment samples	No. of Soil samples
8850	Duaringa	-	2	-
8851	Rookwood	732	3303	1441
8948	Theodore	30	115	-
8949	Banana	-	23	-
8950	Mount Morgan	758	15 377	12 569
8951	Ridgelands	540	4549	3927
9048	Scoria	449	2290	689
9049	Biloela	818	6019	2880
9050	Bajool	460	11 169	14 033
9051	Rockhampton	524	2064	12 547
9148	Monto	487	5146	1202
9149	Calliope	408	4752	5145
9150	Gladstone	-	66	-
TOTAL	**13**	**5206**	**54 875**	**54 433**

Data sourced from the Queensland Exploration Geochemistry and Drill hole database, 2003

METHODOLOGY

A semi-qualitative approach is used (Tang, 2004) to overcome issues such as data heterogeneity, and to identify areas of both known mineralisation and potential mineralisation.

Statistical analyses of assays that have been processed using different analytical methodologies or analyses of different samples types from various geological regions are done using the concept of 'background' and 'anomalous' populations. Using a geochemical anomaly versus background demarcation as the basis for data processing, the heterogeneous Queensland exploration geochemistry data has been recalculated and recombined into a single semi-qualitative dataset.

The purpose of this dataset is to maximise the spatial coverage for an assayed element and identify areas where data is not available. Relevant to the assessment of the mineral potential of the Yarrol Province, it also identifies geochemical anomalies that are related to a geochemical digression from the regional background value.

Data processing involves the following stages.

Subsetting

The Yarrol Province geochemistry was divided on the basis of data types, analytical methods and on different geochemical provinces. For example, the northern section of the Yarrol Province includes ultramafic rocks and serpentinite with vastly different Cu background values to the dominantly subduction-related sediments in the southern section of the Province. Based on this fact, Cu assays for the Province were subsetted into two groups based on geology.

Identifying common variables

The identification of common geochemical variables within a subset enables comparison amongst the different data types. For example, different sample types such as rock chips and stream sediments may share a common assay attribute, 'Au assay'. The 'Au assay' then becomes the common factor for comparison and recombination.

Establishing background and anomalous concentrations

Statistical treatment of a data subset using quantile–quantile (Q–Q) plots establishes the background and anomalous concentrations for an assayed element. The threshold values between background and anomalous populations vary significantly between sample subsets, and such variations highlight intrinsic differences relating to different data types, background levels and/or analytical processes. Irrespective of the numerical threshold values, Q–Q plots are used to identify 'breaks' between regional background and probable mineralisation. The demarcation between the background and anomalous populations can involve significant interpretation, particularly where several breaks have been identified. Problems in the interpretation of the Q–Q plots often arise when there are insufficient or poor quality data (eg below detection limits, low detection levels) or where the absolute geochemical variations are limited. In the latter case, the regional geochemical thresholds are used to allocate the data either to the background or anomalous populations.

The mean, median and standard deviations were calculated and used to highlight the variability amongst the data subsets.

Factorisation

Factorisation or assigning arbitrary numerical factors to individual elements in the anomalous and background populations is used to quantify geochemical variability. Factorisation provides a qualitative means of comparing and combining assay data for all elements in different data subsets into one dataset (eg stream sediments — coarse and fine fractions; pan concentrates; bulk cyanide leach samples; magnetic lags; rock chips and soils).

Nine arbitrary numeric factors were used to split the background population and highlight geochemical variations. The factor '0' is assigned to assay results that are below the analytical detection limits. Factors '1–8' are equal divisions of geochemical concentrations from the detection limit to the anomalous threshold. Commonly, the factors '6–8' represent the change-over range from the background to anomalous levels. The factor '9' is assigned exclusively to the anomalous population in the database. For a small dataset where the background and anomalous populations cannot be discerned, the regional thresholds are used to factorise the data. In the case of the Yarrol Province data, the established thresholds from the South-east Queensland (northern New England Orogen) and Northern Queensland (Georgetown-Ravenswood blocks) have been used to factorise some of the Ba, Bi, Te and W data.

Weighting

The factorised geochemical data is weighted by multiplying the factors with a numerical weight. Weighting is designed to reflect the relative importance of the different data types in generating a geochemical anomaly. In the case of rock chip chemistry, a weighting factor of 1.0 was assigned to reflect the fact that the chemistry has a direct relationship to the geochemical source. Soil geochemistry is assigned a weighting of 0.95 as the chemistry represents the *in situ* dispersion of a geochemical source and is generally close to the source.

Stream sediment geochemistry data are secondary signatures of a geochemical source that has been mobilised, diluted or enriched. Consequently, the chemistry is weighted downwards to 0.90 reducing its importance in defining areas of mineralisation.

Recombination

The factorised and weighted data for a geochemical variable are recombined into a regional database. The recombined data comprises locational attributes (longitude and latitude) and the weighted geochemical factors.

Analysis and Verification

The factorised geochemical data for the Yarrol Province are plotted using ArcScene by the inverse distance weighting method (settings: power= 2, plot radius 0.5°–0.7° and output cell size of 0.01°–0.02°). The plotted data is compared against identified mineral occurrences for data verification.

RESULTS

Geochemical anomalies

Eighteen elements were processed using the above methodology and plotted in the GIS package to highlight regional geochemical anomalies. The density of data for the different elements are highly variable. Gold, silver, copper, lead and zinc have reasonable regional distributions and interpretations made of the resultant plots are considered robust. The limited number of data points for Ba, Bi, Cd, Cr, Fe, Hg, Mn, Mo, Ni, Pt, Sn and W (Table 5) reduce the confidence in the interpretations made for these elements.

Most background-anomalous thresholds used in the data processing were determined from the Q–Q plots of individual data subsets. However, where subsets had insufficient data or where the background and anomalous populations were poorly defined, regional threshold concentrations (eg the South-east Queensland thresholds) were used to demarcate the two populations. A summary of the factorised geochemical data for the Yarrol Province is tabulated in Table 6. Included in the summary are the mean, median and standard deviation of the various sample types.

The following discusses the results of the anomaly analysis for each data subset.

Gold anomalies (Au anomalies)

Au anomalies in the Yarrol Province are primarily associated with Permian–Triassic intrusions. The largest anomaly occurs in the Mount Morgan area. Although spatially significant, the intensity of the Mount Morgan anomaly (factors '3–7') is less pronounced than those associated with the Permian–Triassic intrusions (factors '2–9').

Most of the 695 gold mines known in the Yarrol Province are included within or proximal to the Au anomalies (factors '2–9') identified in this analysis. The high coincidences between the Au occurrences and geochemical anomalies reaffirm the effectiveness of analysis for Au mineralisation. Exceptions do occur however, and include the King Solomon–Queen Sheba, Fig Tree, Last Chance and Southern Cross groups, and workings in the Mount Forest, Golden Spur Creek and Paddy Gully areas — all very small workings. The lack of anomalies in these instances may be due to inadequate sampling or from the absence of geochemical

Table 5: Number of geochemical data points used in the Yarrol Province anomaly analysis

Elements	Number of geochemical data points
Ag	Geochemical anomaly plot from 37 824 data points
As	Geochemical anomaly plot from 24 614 data points
Au	Geochemical anomaly plot from 32 340 data points
Ba	Geochemical anomaly plot from 4 776 data points
Bi	Geochemical anomaly plot from 4 221 data points
Cr	Geochemical anomaly plot from 2 438 data points
Cu	Geochemical anomaly plot from 104 340 data points
Fe	Geochemical anomaly plot from 3 649 data points
Hg	Geochemical anomaly plot from 3 166 data points
Mn	Geochemical anomaly plot from 16 115 data points
Mo	Geochemical anomaly plot from 13 018 data points
Ni	Geochemical anomaly plot from 15 192 data points
Pb	Geochemical anomaly plot from 72 482 data points
Pt	Geochemical anomaly plot from 4 052 data points
Sb	Geochemical anomaly plot from 3 890 data points
Sn	Geochemical anomaly plot from 505 data points
W	Geochemical anomaly plot from 762 data points
Zn	Geochemical anomaly plot from 89 915 data points

signatures around the workings. Geochemical processing also identified numerous Au anomalies in the Province with no associated mines/working, including:

- Mount Morgan map sheet
  12km south-west of Mount Morgan
  4km north of Sugarloaf Mountain

- Bajool map sheet
  South of Goat Hill
  Mount Helen

- Scoria map sheet
  4.5km south-east of Mount Lookerbie

- Ridgelands
  4km north-west of Mount Etna.

Copper anomalies (Cu anomalies)

Cu anomalies are associated with the Silurian to Carboniferous Capella Creek Group and units within the forearc and Permian extensional basins of the Yarrol Province, as well as some small porphyritic stocks.

Copper mines in the Province are generally very small and most known mineralisation is linked to weak geochemical anomalies (factors '2–5'). A strong Cu anomaly was identified within the Tertiary basin overlying the Early Permian backarc and extension formations (i.e. the Rookwood Volcanics), located north-west of the Bluff (Mount Morgan map sheet). There is no known mineralisation in this area.

Lead anomalies (Pb anomalies)

Widespread low intensity Pb anomalies (factors '1–3') are associated with Late Devonian deep marine, Early Carboniferous forearc, and early Permian backarc extensional units of the Yarrol Province, as well as along the margins of some Permian-Triassic stocks. The Pb anomalous pattern encompasses all the known mines, with the exception of the Pyrophyllite Hill working. The known Pb occurrences are very small and are linked to weak geochemical anomalies (factors '1–3') except for mines in the Scoria map sheet, which have pronounced anomalies (factor '9').

Zinc anomalies (Zn anomalies)

The regional Zn anomaly pattern is not confined to a single unit or lithologic association. The deep marine to forearc basin sequences of the Yarrol Province, and the adjacent Bowen Basin display extensive Zn anomalies (factor '2–5').

The Yarrol Province is not a major zinc producing region and has only five very small zinc-related mineral occurrences which are associated with mildly anomalous regions (factors '1–2'). Intense anomalies identified in this analysis (factor '7–9') are spatially scattered and are unrelated to any known mineralisation.

Silver anomalies (Ag anomalies)

Ag anomalies are prominent on the Rookwood and Biloela map sheets and are associated with the Mount Hoopbound Formation, Lochenbar Formation and Marble Waterhole beds. Along the coastal fringe in the Rockhampton and

Table 6: Summary of the factorised data for the Yarrol Province showing the range (concentration) for the factors in different elements and data subsets. Also included are the median, mean, standard deviation, and the threshold used to establish the background-anomalous populations.

Elements	Sample types	No.	Max. Value	Median	Mean	Std. Dev.	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Threshold used
Ag (ppm)	RC	2723	9800	0	11.28	224.55	0–1.25	1.25–2.50	2.5–3.75	3.75–5.0	5–6.25	6.25–7.50	7.5–8.75	8.75–10.0	>10.0	Local
Ag (ppm)	Soils	22770	30	0	0.55	0.85	0–0.375	0.38–0.75	0.75–1.13	1.13–1.50	1.50–1.88	1.88–2.25	2.25–2.63	2.63–3.00	>3.00	Local
Ag (ppm)	Soils-BCL	355	0.04	0.00	0.00	0.01	0–0.002	0.002–0.005	0.005–0.007	0.007–0.009	0.009–0.011	0.011–0.014	0.014–0.016	0.016–0.018	>0.018	Local
Ag (ppb)	BCL	440	0.09	0.01	0.01	0.01	0–0.0038	0–0.0075	0.0075–0.0113	0.0113–0.0150	0.01875	0.0225	0.02625	0.03	>0.03	Local
Ag (ppm)	CSS	248	31	0	0.76	2.30	0–0.625	0.625–1.250	1.250–1.875	1.875–2.500	2.500–3.125	3.125–3.750	3.750–4.375	4.375–5.000	>5.000	SEQ
Ag (ppm)	FSS	10838	27.50	0.00	0.34	0.90	0–0.375	0.375–0.750	0.750–1.125	1.125–1.500	1.500–1.875	1.875–2.250	2.250–2.625	2.625–3.000	>3.000	Local
Ag (ppm)	UFSS	347	0	0	0	0.00	-	-	-	-	-	-	-	-	NA	Below detection
Ag (ppm)	PC	103	78.90	0.00	0.94	7.77	0–0.25	0.25–0.50	0.50–0.75	0.75–1.00	1.00–1.25	1.25–1.50	1.50–1.75	1.75–2.00	>2.00	Local
As (ppm)	RC	2137	233000	7	311	5551.61	0–30	30–60	60–90	90–120	120–150	150–180	180–210	210–240	>240	Local
As (ppm)	Soils	11798	10200	7.0	17.7	114.62	0–12.5	12.5–25.0	25.0–37.5	37.5–50.0	50.0–62.5	62.5–75.0	75.0–87.5	87.5–100.0	>100.0	Local
As (ppm)	FSS	10302	750	0	7.4	16.76	0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	>40	Local
As (ppm)	UFSS	344	60	0	3.34	7.36	0–3.125	3.13–6.25	6.25–9.38	9.38–12.50	12.50–15.63	15.63–18.75	18.75–21.88	21.88–25.00	>25.00	Local
As (ppm)	PC	33	115	2	14	26	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	>80	Local
Au (ppm)	RC	3047	147	0	0.94	6.43	0–0.2	0.2–0.4	0.4–0.6	0.6–0.8	0.8–1.0	1.0–1.2	1.2–1.4	1.4–1.6	>1.6	Local
Au (ppb)	Soils	14243	92000	0	18.6	776.2	0–12.5	12.5–25.0	25.0–37.5	37.5–50.0	50.0–62.5	62.5–75.0	75.0–87.5	87.5–100	>100.0	Local
Au (ppb)	Soils-BCL	1107	595	1	4.5	23.6	0–3	3–6	6–9	9–12	12–15	15–18	18–21	21–24	>24	Local
Au (ppb)	Soils-Con	26	2100	0	115.2	245.5	0–125	125–250	250–375	375–500	500–625	525–750	750–875	875–1000	>1000	Local
Au (ppb)	BCL	2059	1560	0.23	2.85	36.74	0–1.25	1.25–2.50	2.50–3.75	3.75–5.00	5.00–6.25	6.25–7.50	7.50–8.75	8.75–10.00	>10.00	Local
Au (ppb)	CSS	190	10222	0	195.3	1038.7	0–52.5	52.5–105.0	105.0–157.5	157.5–210.0	210.0–262.5	262.5–315.0	315.0–367.5	367.5–420.0	>420.0	Local
Au (ppb)	FSS	6872	31200	0	55.65	690.32	0–45	45–90	90–135	135–180	180–225	225–270	270–315	315–360	>360	Local
Au (ppb)	UFSS	4297	1250	10	17.2	31.5	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	>80	Local
Au (ppb)	PC	499	630000	30	4022.5	33773	0–750	750–1500	1500–2250	2250–3000	3000–3750	3750–4500	4500–5250	5250–6000	>6000	Local
Ba (ppm)	RC	293	223000	150	3577	20341	0–250	250–500	500–750	750–1000	1000–1250	1250–1500	1500–1750	1750–2000	>2000	Local
Ba (ppm)	Soils	3522	39000	175	396	1503	0–188	188–375	375–563	563–750	750–938	938–1125	1125–1312	1312–1500	>1500	Local
Ba (ppm)	FSS	961	5000	160	191	219	0–55	55–110	110–165	165–220	220–275	275–330	330–385	385–440	>440	Local
Bi (ppm)	RC	692	510	0	4.5	28.0	0–2.5	2.5–5	5.0–7.5	7.5–10.0	10.0–12.5	12.5–15.0	15.0–17.5	17.5–20.0	>20.0	Local
Bi (ppm)	Soils	1536	25	0	0.8	2.4	0–0.75	0.75–1.50	1.50–2.25	2.25–3.00	3.00–3.75	3.75–4.50	4.50–5.25	5.25–6.00	>6.00	Local
Bi (ppm)	CSS	34	11	0	0.3	1.9	0–0.5	0.5–1.0	1.0–1.5	1.5–2.0	2.0–2.5	2.5–3.0	3.0–3.5	3.5–4	>4.0	Local

Table 6 (continued)

Elements	Sample types	No.	Max. Value	Median	Mean	Std. Dev.	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Threshold used
Bi (ppm)	FSS	1949	11	0	0.13	0.69	0–0.13	0.13–0.25	0.25–0.38	0.38–0.50	0.50–0.63	0.63–0.75	0.75–0.88	0.88–1.00	>1.00	Local
Bi (ppm)	PC	10	63	0	10.3	20.5	0–22.5	22.5–45.0	45.0–67.5	67.5–90.0	90.0–112.5	112.5–135.0	135.0–157.5	157.5–180.0	>180.0	SEQ
Cr (ppm)	RC	157	429	115	128.7	84.0	0–31.25	31.25–62.50	62.50–93.75	93.75–125.0	125.0–156.3	156.3–187.5	187.5–218.8	218.8–250.0	>250.0	>2 background
Cr (ppm)	Soils	1648	25400	130	328.3	856.5	0–500	500–1000	1000–1500	1500–2000	2000–2500	2500–3000	3000–3500	3500–4000	>4000	>2 backgrounds
Cr (ppm)	CSS	144	111	-	70.7	17.0	0–62.5	62.5–125.0	125.0–187.5	187.5–250.0	250.0–312.5	312.5–375.0	375.0–437.5	437.5–500.0	>500.0	SEQ
Cr (ppm)	FSS	402	38000	175	1852.5	3884.5	0–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000	>8000	>2 backgrounds
Cr (ppm)	PC	87	120000	13300	22665	25459	0–7500	7500–15000	15000–22500	22500–30000	30000–37500	37500–45000	45000–52500	52500–60000	>60000	Local
Cu (ppm)	RC	4939	450000	40	1194	11672	0–400	4000–800	800–1200	1200–1600	1600–2000	1600–2400	2400–2800	2800–3200	>3200	Local
Cu (ppm)	Soils	50235	8500	40	85	205	0–150	150–300	300–450	450–600	600–750	750–900	900–1050	1050–1200	>1200	Local
Cu (ppm)	Soils-auger	1616	9300	440	826.4	1026.9	0–562.5	562.5–1125.0	1125–1687.5	1687.5–2250	2250–2812.5	2812.5–3375	3375–3937.5	3937.5–4500	>4500	Local
Cu (ppb)	BCL	241	2.25	0.26	0.37	0.35	0–0.15	0.15–0.30	0.30–0.45	0.45–0.60	0.60–0.75	0.75–0.90	0.90–1.05	1.05–1.20	>1.20	Local
Cu (ppm)	CSS	932	720	30	41.04	43.09	0–12.5	12.5–25.0	25.0–37.5	37.5–50.0	50.0–62.5	62.5–75.0	75.0–87.5	87.5–100.0	>100.0	Local
Cu (ppm)	FSS	45961	5450	40	55.79	78.30	0–75	75–150	150–225	225–300	300–375	375–450	450–525	525–600	>600	Local
Cu (ppm)	UFSS	347	190	50	57.46	24.75	0–15	15–30	30–45	46–60	60–75	75–90	90–105	105–120	>120	Local
Cu (ppm)	MAG	17	110	50	55.74	23.19	0–25	25–50	50–75	75–100	100–125	125–150	150–175	175–200	>200	Extra-polated threshold
Cu (ppm)	PC	52	320	32.5	45.8	49.3	0–12.5	12.5–25.0	25.0–37.5	37.5–50.0	50.0–62.5	62.5–75.0	75.0–87.5	87.5–100.0	>100.0	Local
Fe %	RC	614	58	3.5	5.7	7.9	0–2.5	2.5–5.0	5.0–7.5	7.5–10.0	10.0–12.5	12.5–15.0	15.0–17.5	17.5–20.0	>20.0	Local
Fe (ppm)	Soils	873	8.9	4.0	4.1	1.5	0–0.94	0.94–1.88	1.88–2.81	2.81–3.75	3.75–4.69	4.69–5.63	5.63–6.56	6.56–7.50	>7.50	Variable
Fe %	Soils-auger	1199	20.3	4.7	4.7	2.5	0–1.25	1.25–2.50	2.50–3.75	3.75–5.00	5.00–6.25	6.25–7.50	7.50–8.75	8.75–10.00	>10.00	Local
Fe %	CSS	25	7.9	3.2	3.6	1.9	0–1.25	1.25–2.50	2.50–3.75	3.75–5.00	5.00–6.25	6.25–7.50	7.50–8.75	8.75–10.00	>10.00	SEQ
Fe (ppm)	FSS	938	22.8	3.7	4.4	2.7	0–1.5	1.5–3.0	3.0–4.5	4.5–6.0	6.0–7.5	7.5 – 9.0	9.0–10.5	10.5–12.0	>12.0	Variable
Hg (ppm)	RC	567	5	0.00	0.07	0.35	0–0.075	0.075–0.150	0.150–0.225	0.225–0.300	0.300–0.375	0.375–0.450	0.425–0.525	0.525–0.600	>0.600	Local
Hg (ppb)	Soils	2293	2100	0.00	50.25	137.35	0–25	25–50	50–75	75–100	100–125	125–150	150–175	175–200	>200	Local
Hg (ppb)	FSS	303	1350	0.00	46.37	97.49	0–25	25–50	50–75	75–100	100–125	125–150	150–175	175–200	>200	Local
Hg (ppm)	PC	3	50	50.00	50.00	0.00	-	-	-	-	-	-	-	-	NA	Insufficient data

Elements	Sample types	No.	Max. Value	Median	Mean	Std. Dev.	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Threshold used
Mn (ppm)	RC	430	240000	360	3103	19661.55	0–1650	1650–3300	3300–4950	4950–6600	6600–8250	8250–9900	9900–11550	11550–13200	>13200	Local
Mn (ppm)	Soils	13909	29000	500	960	1598.60	0–625	625–1250	1250–1875	1875–2500	2500–3125	3125–3750	3750–4375	4375–5000	>5000	SEQ
Mn (ppm)	CSS	154	3400	530	599	364.52	0–250	250–500	500–750	750–1000	1000–1250	1250–1500	1500–1750	1750–2000	>2000	Local
Mn (ppm)	FSS	1622	19800	627.5	756	941.93	0–200	200–400	400–600	600–800	800–1000	1000–1200	1200–1400	1400–1600	>1600	Local
Mo (ppm)	RC	1133	1060	1.00	11.70	59.90	0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	>40	Local
Mo (ppm)	Soils	6019	200	0.00	2.89	7.30	0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	>40	Local
Mo (ppm)	Soils-auger	1613	320	12.00	20.52	28.65	0–14	14–28	28–42	42–56	56–70	70–84	84–98	98–112	>112	Local
Mo (ppm)	CSS	34	1.2	0.0	0.14	0.38	0–0.175	0.175–0.350	0.350–0.525	0.525–0.700	0.700–0.875	0.875–1.050	1.050–1.225	1.225–1.400	>1.400	SEQ
Mo (ppm)	FSS	4212	180	0.0	1.71	6.99	0–1.25	1.25–2.50	2.50–3.75	3.75–5.00	5.00–6.25	6.25–7.50	7.50–8.75	8.75–10.00	>100	Poor detection
Mo (ppm)	PC	7	7	0.0	1.86	3.18	0–1.25	1.25–2.50	2.50–3.75	3.75–5.00	5.00–6.25	6.25–7.50	7.50–8.75	8.75–10.00	>10	SEQ
Ni (ppm)	RC	866	7200	100	336	752	0–450	450–900	900–1350	1350–1800	1800–2250	2250–2700	2700–3150	3150–3600	>3600	>2 back-grounds
Ni (ppm)	Soils	5057	3200	40	81	211	0–30	30–60	60–90	90–120	120–150	150–180	180–210	210–240	>240	Local
Ni (ppm)	CSS	747	1200	38	50	91	0–20	20–40	40–60	60–80	80–100	100–120	120–140	140 0 160	>160	Local
Ni (ppm)	FSS	8504	7050	20	158	547	0–330	330–660	660–990	990–1320	1320–1650	1650–1980	1980–2310	2310–2640	>2640	Used 98 percentile
Ni (ppm)	PC	18	2700	470	832	891	0–500	500–1000	1000–1500	1500–2000	2000–2500	2500–3000	3000–3500	3500–4000	>4000	Local
Pb (ppm)	RC	3396	160000	15	178	3035	0–40	40–80	80–120	120–160	160–200	200–240	240–280	280 0 320	>320	Local
Pb (ppm)	Soils	42921	14600	20	36	168	0–62.5	62.5–125.0	120.0–187.5	187.5–250.0	250.0–312.5	312.5–375.0	375.0–437.5	437.5–500.0	>500	Local
Pb (ppm)	CSS	932	114	40	39	18	0–15	15–30	30–45	45–60	60–75	75–90	90–105	105–120	>120	SEQ
Pb (ppm)	FSS	24855	10000	20	25	73	0–20	20–40	40–60	60–80	80–100	100–120	120–140	140–160	>160	Local
Pb (ppm)	UFSS	347	35	0	5.5	7.7	0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	>40	Local
Pb (ppm)	PC	31	76	15	21.4	14.8	0–6.25	6.25–12.50	12.50–18.75	18.75–25.00	25.00–31.25	31.25–37.50	37.50–43.75	43.75–50.00	>50.00	Local
Pt (ppm)	RC	53	0.005	0.00	0.00	0.00	0–0.001	0.001–0.002	0.002–0.003	0.003–0.004	0.004–0.005	0.005–0.006	0.006–0.007	0.007–0.008	>0.008	SEQ
Pt (ppm)	BCL	8	0.00	0.00	0.00	0.00	-	-	-	-	-	-	-	-	NA	Below detection
Pt (ppm)	CSS	25	40	0.00	6.40	11.14	0–2.5	2.5 – 5.0	5.0–7.5	7.5–10.0	10.0–12.5	12.5–15.0	15.0–17.5	17.5–20	>20	Local
Pt (ppm)	FSS	24	20	0.00	2.92	6.90	0–1.875	1.875–3.750	3.750–5.625	5.625–7.500	7.500–9.375	9.375–11.250	11.25–13.125	13.125–15.00	>15.000	Local
Pt (ppm)	UFSS	3913	95	0.00	0.21	1.93	0–0.5	0.05–1.0	1.0–1.5	1.5–2.0	2.0–2.5	2.5–3.0	3.0–3.5	3.5–4.0	>4.0	Local
Pt (ppm)	PC	29	860	5.00	36.34	158.88	0–162.5	162.5–325.0	325.0–487.5	487.5–650.0	650.0–812.5	812.5–975.0	975.0–1137.5	1137.5–1300	>1300	SEQ
Sb (ppm)	RC	572	1300	0.00	5.23	55.61	0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16	>16	Local
Sb (ppm)	Soils	3908	68	0.00	0.75	1.98	0–0.75	0.75–1.5	1.5–2.25	2.25–3.0	3.0–3.75	3.75–4.5	4.5–5.25	5.25–6.0	>6.0	Local

Table 6 (continued)

Elements	Sample types	No.	Max. Value	Median	Mean	Std. Dev.	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Threshold used
Sb (ppm)	CSS	34	67	0.00	3.94	12.15	0–1.75	1.75–3.50	3.50–5.25	5.25–7.00	7.00–8.75	8.75–10.50	10.50–12.25	12.25–14.00	>14.00	SEQ
Sb (ppm)	FSS	1337	10	0.00	0.17	0.60	0–0.2	0.2–0.4	0.4–0.6	0.6–0.8	0.8–1	1.0–1.2	1.2–1.4	1.4–1.6	>1.6	Local
Sb (ppm)	UFSS	29	1	0.00	0.07	0.26	-	-	-	-	-	-	-	-	NA	Insuffic-ient data
Sb (ppm)	PC	10	252	13.50	37.70	76.46	0–15.63	15.63–31.25	31.25–46.88	46.88–62.50	62.50–78.13	78.13–93.75	93.75–109.38	109.38–125.0	>125.0	SEQ
Sn (ppm)	RC	46	10	0.00	0.67	2.06	0–1.75	1.75–3.50	3.50–5.25	5.25–7.00	7.00–8.75	8.75–10.50	10.50–12.25	12.25–14.00	>14.00	SEQ
Sn (ppm)	Soils	238	50	4.00	5.05	5.70	0–2.25	2.25–4.50	4.50–6.75	6.75–9.00	9.00–11.25	11.25–13.50	13.50–15.75	15.75–18.00	>18	Local
Sn (ppm)	CSS	14	0	0.00	0.00	0.00	-	-	-	-	-	-	-	-	NA	Below DL
Sn (ppm)	FSS	186	0	0.00	0.00	0.00	-	-	-	-	-	-	-	-	NA	Below DL
Sn (ppm)	PC	21	0	0.00	0.00	0.00	-	-	-	-	-	-	-	-	NA	Below DL
W (ppm)	RC	242	1080	4.00	21.66	93.97	0–6.25	6.25–12.50	12.50–18.75	18.75–25.00	25.00–31.25	31.25–37.50	37.50–43.75	43.75–50.00	>50	Local
W (ppm)	Soils	138	50	0.00	1.38	5.36	0–1.25	1.25–2.50	2.50–3.75	3.75–5.00	5.00–6.25	6.25–7.50	7.50–8.75	8.75–10.0	>10	Poor detection
W (ppm)	CSS	14	9	0.00	1.71	3.43	0–6.25	6.25–12.50	12.50–18.75	18.75–25.00	25.00–31.25	31.25–37.50	37.50–43.75	43.75–50.00	>50	SEQ
W (ppm)	FSS	278	15	0.00	0.29	1.73	0–6.25	6.25–12.50	12.50–18.75	18.75–25.00	25.00–31.25	31.25–37.50	37.50–43.75	43.75–50.00	>50	SEQ
W (ppm)	PC	90	20	0.00	1.33	4.02	0–200	200–400	400–600	600–800	800–1000	1000–1200	1200–1400	1400–1600	>1600	NEQ
Zn (ppm)	RC	3387	290000	55	284	5004	0–150	150–300	300–450	450–600	600–750	750–900	900–1050	1050–1200	>1200	Local
Zn (ppm)	Soils	46277	13500	60	116	300	0–125	125–250	250–375	375–500	500–625	625–750	750–875	875–1000	>1000	Local
Zn (ppm)	CSS	921	530	60	66	37	0–20	20–40	40–60	60–80	80–100	100–120	120–140	140–160	>160	Local
Zn (ppm)	FSS	39107	9000	59	66	94	0–40	40–80	80–120	120–160	160–200	200–240	240–280	280–320	>320	Local
Zn (ppm)	UFSS	192	2000	45	139	287	0–125	125–250	250–375	375–500	500–625	625–750	750–875	875–1000	>1000	>2 back-grounds
Zn (ppm)	PC	31	205	50	65	34	0–15	15–30	30–45	45–60	60–75	75–90	90–105	105–120	>120	Local

Abbreviations: RC= rock chip sample; BCL= bulk cyanide leaching, Con= concentrate; CSS= coarse fraction of the stream sediment samples (> 60#), FSS= fine fraction of the stream sediment samples (<60#); UFSS= ultra fine fraction of the stream sediment samples (<200#); PC= panned concentrate, SEQ= South-east Queensland regional threshold, NEQ= North-east Queensland regional threshold, DL= detection limit, NA= not available

Calliope map sheets, Ag anomalies are associated with the Carboniferous to Permian transitional arc/extensional volcanic sequences of the Yarrol Province. Despite the prominent geochemical anomalies (factor '4–7'), no known silver mines occur in or around these anomalies. Known silver occurrences are either within Early Permian backarc units (eg Chalmers Formation) or along the margins of Permian–Triassic granitoids (eg Munholme Quartz Diorite). Geochemical signatures around these intrusive related silver occurrences (eg Silver Star, Rossmore Silver mine) are weaker than expected (factors '2–4').

Arsenic anomalies (As anomalies)

As anomalies are patchy and almost always associated with Permian–Triassic granitoids (eg Mount Seaview Igneous Complex, Castletower Granite). A strong arsenic anomaly in the Scoria map sheet is located at the margin of the Hirrami Igneous Complex, which intrudes the Early Permian backarc volcanics and extensional basinal sequences. Significant As anomalies also occur west of the Mount Morgan mine and may be linked to the presence of arsenopyrite within the Mount Morgan mineralised system (Cornelius, 1969; Golding & others, 1993). The anomaly west of Mount Morgan also coincides with the thermal aureole of the Permian Kyle Mohr Igneous Complex.

Bismuth anomalies (Bi anomalies)

In the Mount Morgan map sheet, a strong Bi anomaly is associated with the middle Devonian Mount Morgan Trondhjemite and coincides with the Mount Morgan and Bouldercombe mineralised areas. On the Bajool, Monto and Scoria map sheets, anomalies are associated with middle Devonian granitoids intruding the Devonian volcanic arc rocks.

Molybdenum anomalies (Mo anomalies)

Mo anomalies in the Yarrol Province are poorly constrained due to data and localised distribution. The majority of the Mo anomalies identified are located within 5 km of the margins of Permian–Triassic plutonic bodies, with most of these located within the contact aureoles. There are only three very small known Mo occurrences within the Yarrol Province and these are located at the margins of Permian–Triassic plutons. All three occurrences are not associated with significant geochemical signatures and this is attributed to the lack of systematic sampling in and around the mine areas. The presence of Mo mineral occurrences around intrusive bodies is consistent with their predicted locations from this analysis.

Antimony anomalies (Sb anomalies)

Sb anomalies are erratic and are not confined to a specific unit or lithology although the Neoproterozoic serpentine (eg the Princhester Serpentinite) and the Craigilee beds generally contain higher Sb concentrations than the surrounding rocks. Most of the anomalies identified are located proximal to Permian–Triassic intrusive contacts (eg Mount Seaview Igneous Complex, Bocoolima Granodiorite). Within the Yarrol Province there is only one Sb working which is hosted by the Wandilla Formation in close proximity to the Late Permian–Early Triassic Castletower Granite. Although there is no geochemical sampling at the mine site, the geochemical anomaly distal from this working has an anomaly factor of '9'.

Tin and tungsten anomalies (Sn and W anomalies)

The only Sn anomaly (factors '3–7') in the Province occurs within a Mesozoic basin located 20km north-east of Rockhampton. Sn is not a known mineral commodity in the Yarrol Province, though a reported occurrence in the Mundubbera map sheet was associated with an unnamed Triassic (?) granite. W anomalies are well constrained to margins of Permian–Triassic intrusives in the Yarrol Province. There are four notable anomalies, which occur adjacent to or within intrusive bodies. On the Biloela map sheet, a strong W anomaly (factors '2–9') is apparent around the Late Permian–Early Triassic Bocoolima Granodiorite. Another prominent W anomaly (factors '3–6') occurs on the Calliope map sheet, and is linked to the Triassic Littlemore Granodiorite. Weaker anomalies (factors '2–4') occur around an unnamed late Permian–Early Triassic diorite on the Ridgelands map sheet, and on Mount Morgan map sheet in the Mount Morgan Trondhjemite.

The Littlemore Scheelite is the only W mine known in the Yarrol Province. It is located within the Triassic Littlemore Granodiorite. Though no geochemical sampling was conducted around the mine, a strong geochemical halo (factors '3–6') is present north-west of this old working.

Manganese and Nickel anomalies (Mn and Ni anomalies)

Mn and Ni geochemical patterns form as strata-related anomalies. The geochemical pattern for the Yarrol Province is patchy and discontinuous due to limited and inconsistent sampling. No geochemical sampling has been conducted around the 16 known Mn mineral occurrences for the Yarrol Province, which occur exclusively within the Wandilla Formation. The patchy Mn anomalies from available samples highlight higher Mn concentrations in the Neoproterozoic serpentinites and in the deep marine, forearc and backarc formations of the Yarrol Province.

The Ni anomalies are associated with Neoproterozoic serpentinites (Princhester Serpentinite), mafic volcanics (Camboon Volcanics) and a mafic pluton (Bucknalla Gabbro). All seven Ni mines in the Yarrol Province are hosted in the Princhester Serpentinite, and most are included within or proximal to Ni anomalies (factors >'4').

Trace elements: Mercury and Platinum anomalies (Hg and Pt anomalies)

Hg anomalies are associated with small Permian–Triassic stocks. Pt anomalies occur in the Late Devonian–Early Carboniferous volcanic arcs units (eg Balaclava Formation, Mount Hoopbound Formation) and are localised along intrusive contacts.

DISCUSSION

The geochemical anomalies identified in the foregoing analyses provide a useful exploration tool for the identification of mineralisation in the Yarrol Province. Data processing on this regional scale utilised broad subdivisions or data subsets, which can be refined when working at local scales.

Results indicated that Au, Ag, As, Mo, Sb, Bi, Sn, W and Hg anomalies in the Yarrol Province are intimately associated with Permian–Triassic granitoids. Sn, W and As anomalies were specifically associated with granitic bodies, whereas Ag, Bi and Sb anomalies tended to be located in metamorphic aureole around igneous bodies. The close association of the variety of mineralisation with Permian–Triassic granitoids suggests a genetic relationship to magmatism.

Numerous low-level Pb and Zn anomalies are associated with metasediments and metavolcanics of the Province. These anomalies intensify towards the margins of Permian-to-Triassic plutons, suggesting that the volcanogenic sediments are the likely sources for the Pb and Zn, and the magmatic bodies enrich or reconcentrate these elements to form mineralisation at the periphery of the plutons.

Most Cu anomalies were identified within the Capella Creek Group. Two popular models for copper mineralisation in the Yarrol Province are the volcanic-hosted massive sulphide (VHMS) (Taube, 1986, 1990a,b; Golding & others, 1993), and structurally controlled replacement deposit related to pluton emplacement (Arnold & Sillitoe, 1989). A close relationship between volcanic units, plutonic bodies and Cu anomalies has been identified in these analyses.

Elevated Mn and Ni concentrations are associated with the Neoproterozoic serpentinite (eg Princhester Serpentinite) and basic volcanics. The associated geochemical anomalies are the result of higher background levels in these rocks, which may also locally attain economic grades.

The Mount Morgan deposit was the biggest mine in the Yarrol Province, producing a total of 248.8t of gold and 360 000t of copper. The three proposed mineralisation models for the Mount Morgan mine are the replacement type, the volcanic-hosted massive sulphide (VMS) and the porphyry type (eg Cornelius, 1969; Taube, 1986; Horton, 1987, Taube & McLeod, 1987; Arnold & Sillitoe, 1989; Large, 1992). Golding & others (1994) suggested that the mineralisation had a mixed source with contributions from both magmatic and metamorphic sources.

In the regional geochemical analysis the Mount Morgan mineralising system was found to have a strong geochemical association between Au, As, Ba, Bi, Cu, Mn, Ni and S. Deep marine hydrothermal vent systems typically have the association of Ba-Mn-Au-Cu + As (Plank & Langmuir, 1998; Gao & others, 1998). The presence of Bi, As and Ba in the Mount Morgan regional geochemistry, however, is also suggestive of links with acid to intermediate intrusives with a continental crust affinity (Gao & others, 1998; Sun & McDonough, 1989).