Eucalyptus camaldulensis (river red gum) Biogeochemistry: An Innovative Tool for Mineral Exploration in the Curnamona Province and Adjacent Regions

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Weathered Bedrock

The more prominent hills and rises mostly consist of slightly weathered bedrock that is relatively resistant to weathering and subsequent erosion, such as the prominent quartz-magnetite rock that forms the peaks of the Pinnacles, as well as quartz veins and felsic rocks corresponding to many of the rises in the area. Bedrock lithology and structure are the main controls on the spatial variations of weathering and subsequent erosion.

Slightly Weathered Bedrock (SS)

Bedrock in the Pine Creek catchment is slightly weathered. This includes:

- Middle and South Pinnacle Peaks – quartz magnetite; and,
- Staurolite Ridge – staurolite + sericite + quartz (Brown, 1984).

Both bedrock lithologies (Middle & South Pinnacle and Staurolite Ridge) are more resistant to weathering and erosion than their surrounding bedrock lithologies, and therefore form prominent landforms. The Middle and South Pinnacle bedrock exposures occur in the north of the mapping area, while the NW to SE trending Staurolite Ridge is in the south of the mapping area. These rocks are characterised by the preservation of >90 % of their primary minerals, and are generally characterised by minor surficial ferruginous staining, in particular within visible surface fractures.

The units are mainly sub-divided based on their topographic relief. Slightly weathered bedrock within the landscape is mainly expressed as erosional rises (er), with a moderate relief ranging between 9-30 m. There are some occurrences associated with erosional plains (ep), with a low relief ranging between 0-9 m, and two recordings of slightly weathered bedrock on low hills (el), with a moderate to high relief ranging between 30-90 m.

The slightly weathered bedrock regolith-landform units include: red-brown, coarse angular lithic, and quartzose gravels associated with locally derived colluvium, fine red-brown sands with minor clays (interpreted to be originally aeolian derived), and minor regolith carbonate accumulations, mostly forming a thin veneer on bedrock surfaces and infilling fractures particularly associated with the amphibolites.

The vegetation typically associated with the Middle and South Pinnacle is dominated by sparse *Casuarina cristata (ssp. pauper)* woodland, with minor chenopod shrubs such as *Maireana pyramidata,* with scattered *Acacia victoriae* and *Sida petrophila*. The vegetation associated with Staurolite Ridge is dominated by chenopod shrubs such as *Maireana pyramidata, Maireana sedifolia* and *Atriplex vesicaria,* with scattered *Acacia aneura* and minor *Sida petrophila*.

Colluvial Regolith-Landforms (C)

Colluvial sediments are widespread across the mapping area. Most of the slopes and flanking plains support ephemeral shallow overland flow, dominated by sheetflow with minor colluvial rock fall and talus deposits associated with steeper slopes (Dury, 1966; Langford-Smith & Dury, 1964). These typically conform to a topo-sequence extending across erosional rises either flanking bedrock exposures or shallow subcrop across rise and hill crests, passing downslope into sheetflow depositional plains. Many of the sheetflow deposits have characteristic ‘tiger-striping’ (‘contour banding’) surficial lag patterns defined by alternating transverse bands several meters wide consisting of pebbly surface lags separated by more densely vegetated chenopod shrubland colonising fine sand and silt dominated materials (Dunkerley & Brown, 1995; Wakelin-King, 1999).

Sheet-flow sediments (CH)

Several sheetflow regolith-landform units have been identified within the mapping area. These occur in association with the following landforms: low hills (CHel); erosional rises (CHer); erosional plains (CHep); depositional plains (CHpd); drainage depressions (CHed); and, sheetflood fans (CHfs). One low hill landform with sheet-flow sediments was recorded in the area (Table 4.26).

Table 4.26: Description of sheet-flow deposits on a low hill at the Pine Creek catchment.

Regolith-landform units (RLUs)	Distribution	Dominant regolith lithology	Surficial features	Minor attributes	Vegetation	Geohazard
$CHel_1$	north, flanking the Middle Pinnacle and South Pinnacle	angular to sub-angular lithic and quartzose gravels (10-150 mm), sands and silts	angular to sub-rounded red-brown sands with minor silts and clays	Minor powdery, nodular and hardpan regolith carbonate accumulations	dominated by chenopod shrubs such as *Maireana pyramidata* and *Maireana sedifolia*, with minor *Atriplex vesicaria* and scattered *Sida petrophila* and *Bassia ssp*	talus deposits

Sheet-flow erosional rise landforms are expressed as an erosional rise (er), with a moderate topographic relief ranging between 9-30 m, incised by alluvial drainage depressions and alluvial depositional plains. The two main CHer units were mapped in the area are shown in Table 4.27, and are sub-divided largely based on their surficial lag.

Table 4.27: Description of sheet-flow deposits on erosional rises in the Pine Creek catchment.

Regolith-landform units (RLUs)	Distribution	Dominant regolith lithology	Surficial features	Minor attributes	Vegetation	Geohazard
$CHer_1$	south, with minor exposures in the north where it forms a thin (<1m) cover.	angular to sub-rounded red-brown sands with minor silts and clays	angular to sub-rounded lithic and quartzose gravels (5-30 mm)	powdery, nodular and hardpan regolith carbonate accumulations	dominated by chenopod shrubs including *Maireana pyramidata* and *Maireana sedifolia*, with minor *Atriplex vesicaria* and scattered *Sida petrophila* and *Bassia ssp*	
CHer	northwest	angular to sub-rounded milky quartz, red-brown sands with minor silts and clays	angular to sub-rounded lithic and quartzose gravels (10-150 mm)	powdery, nodular and hardpan regolith carbonate accumulations	dominated by chenopod shrubs including *Maireana pyramidata* and *Maireana sedifolia*, with minor *Atriplex vesicaria* and scattered *Sida petrophila* and *Bassia ssp*	

Sheet-flow erosional plain landforms are expressed as an erosional plain (ep), with a low topographic relief ranging between 0-9 m, incised by alluvial drainage depressions. Two main CHep units mapped in the area are shown in Table 4.28 and are sub-divided largely based on their surficial lag.

Table 4.28: Description of sheet-flow deposits on erosional plains in the Pine Creek catchment.

Regolith-landform units (RLUs)	Distribution	Dominant regolith lithology	Surficial features	Minor attributes	Vegetation	Geohazard
$CHep_1$	northwest, with a few exposures in the southwest	angular to sub-rounded red-brown sands with minor silts and clays	angular to sub-rounded lithic and quartzose gravels (5-30 mm)	minor powdery, nodular and hardpan regolith carbonate accumulations	Dominated by chenopod shrubland, dominated by *Maireana sedifolia* and *Maireana pyramidata*, with minor *Atriplex vesicaria* and scattered *Acacia aneura*, *Sida petrophila* and *Bassia ssp*	None recorded.
$CHep_2$	northwest, east and southwest of the mapping area	angular to sub-rounded smoky quartzose lag, red-brown sands with minor silts and clays	angular to sub-rounded lithic and quartzose gravels (5-10 mm)	minor powdery, nodular and hardpan regolith carbonate accumulations	dominated by chenopods including *Maireana pyramidata* and *Maireana sedifolia*, with minor *Atriplex vesicaria*, *Acacia aneura* and *Bassia ssp*	None recorded.

Sheet-flow depositional plain landforms within are expressed as a depositional plain (pd), with a low relief landform in regions of deposition, with incision by colluvial and alluvial drainage depressions. The three main types of CHpd mapped in the area are shown in Table 4.29 and are largely sub-divided based on their surficial lag.

Table 4.29: Description of sheet-flow deposits on depositional plains in the Pine Creek catchment.

Regolith-landform units (RLUs)	Distribution	Dominant regolith lithology	Surficial features	Minor attributes	Vegetation	Geohazard
$CHpd_1$	centrally in the northeast and southeast of the mapping area	sub-angular to sub-rounded coarse lithic and quartzose sands	sub-rounded red-brown sands and silts, with sub-angular to sub-rounded lithic and quartzose gravels (5-15 mm)	minor fragments of regolith carbonate accumulations	Dominated by chenopod shrubland, dominated by *Maireana sedifolia* and *Maireana pyramidata* with scattered *Bassia ssp*	None recorded.
$CHpd_2$	northeast and south margins of the mapping area	sub-angular to sub-rounded coarse lithic and quartzose sands	sub-rounded red-brown sands and silts, with sub-angular to sub-rounded lithic and quartzose gravels (5-10 mm)	minor fragments of regolith carbonate accumulations, and maghemite (γ-Fe_2O_3)	dominated by chenopod shrubs including *Maireana sedifolia* and *Maireana pyramidata* with scattered *Bassia ssp*	None recorded.
$CHpd_3$	north, northwest, west and southwest of the mapping area	sub-angular to sub-rounded coarse lithic and quartzose sands	sub-rounded red-brown sands and silts, with sub-angular to sub-rounded lithic and quartzose gravels (5-20 mm)	minor fragments of regolith carbonate accumulations	Dominated by chenopod shrubland, dominated by *Maireana pyramidata* and *Maireana sedifolia* with scattered *Acacia aneura* and *Bassia ssp*	None recorded.

A $CHed_1$ unit forms an elongated drainage depression ranging from 3–10 m wide within a low relief land surface. It is centrally on the western margin of Pine Creek, and forms a conduit between the adjacent $CHpd_1$, $CHer_1$ and $ISps_1$ landforms, terminating in surrounding alluvial drainage depressions, and the major contemporary ephemeral alluvial channel. It is characterised by sub-angular to sub-rounded red-brown quartzose lithic sands and silts derived from locally weathered exposed bedrock, with sub-angular to sub-rounded lithic fragments and gravel lags (10-40 mm). The vegetation is dominated by *Acacia aneura* with minor chenopods such as *Maireana pyramidata* and *Atriplex vesicaria*.

A $CHfs_1$ unit is in the east and southeast of the mapping area. It is has 'tiger-stripe' ('contour banding') surficial lag patterns identified by alternating transverse bands several meters wide, consisting of angular to sub-rounded lithic and quartzose gravels within red-brown fine sands and silts, separated by dense vegetation dominated by chenopod shrubs such as *Maireana pyramidata*, *Maireana sedifolia* and minor *Atriplex vesicaria*, colonising the fine sand and silts.

Alluvial Regolith-Landforms (A)

Alluvial sediments are mostly associated with the major contemporary drainage systems, such as Pine Creek and its major tributaries. In the south of the Pine Creek catchment, alluvial drainage depressions flow into a series of ephemeral swampy floodouts and depositional plains, where the alluvial system is less entrenched within the flanking plain (i.e. intersection point floodouts). Alluvial landforms consist of alluvial channels (ACar), alluvial depositional plains (Apd), alluvial plains (Aap), alluvial drainage depressions (Aed) and alluvial fans (Afa).

Alluvial sediments (A)

One $ACar_1$ regolith-landform unit was recorded in the mapping area corresponding to the channels of Pine Creek, Stirling Vale Creek, Gum Creek and Kelly Creek. The channels are ephemeral and meandering, attenuated by alluvial plains that grade into drainage depressions in their headwaters, within the Barrier Ranges. Pine Creek is the largest of the drainage channels in the area, flowing in between the Middle and South Pinnacle. These units are characterised by an approximate channel width ranging between 50-80 m, and include minor braided channels with occasional levees. They are composed of imbricated gravels (5-30 mm diameter) derived from the surrounding exposed bedrock, and minor exposures within the channels. The sediment load consists of sub-angular to sub-rounded, red-brown quartzose sands and silts, with sub-angular to sub-rounded lithic fragments, with minor heavy minerals. The vegetation is dominated by open woodlands of *E. camaldulensis* with minor *Acacia victoriae*.

One Apd_1 unit was recorded in the mapping area. Alluvial depositional regolith-landforms flank all margins of the large ephemeral channels and smaller tributary alluvial drainage depressions in the southern part of the mapping area. The Apd_1 has sub-rounded to rounded quartz sands and minor quartzose and lithic fragments (5-15 mm), with fine-grained red-brown sands and silts with minor clays. The vegetation is dominated by chenopod shrubs, such as *Maireana pyramidata*, with minor *Atriplex vesicaria*, and *Bassia ssp*.

The alluvial plains are broad, slightly undulating low-relief landforms, hosting moderately incised channels and slightly incised drainage depressions. The main types of Aap in the mapping area are shown in Table 4.30 and are largely sub-divided based on their vegetation.

Table 4.30: Description of alluvial sediments on alluvial plains in the Pine Creek catchment.

Regolith-landform units (RLUs)	Distribution	Dominant regolith lithology	Surficial features	Minor attributes	Vegetation	Geohazard
Aap_1	northern margins of the main ephemeral meandering Pine Creek channel	sub-rounded to rounded fine-grained red-brown sands and silts	minor clays and gravels, comprised mostly of quartz and lithic fragments (5-15 mm)	sub-angular to sub-rounded coarse quartz sands and minor quartzose lithic gravel	dominated by *Acacia victoriae* with minor chenopod shrubs such as *Maireana pyramidata*, and *Atriplex vesicaria*	None recorded
Aap_2	margins of the four named ephemeral meandering channels in the area	sub-rounded to rounded fine-grained red-brown sands and silts	minor clays and gravels comprised, mostly of quartz and lithic fragments (5-15 mm)	sub-angular to sub-rounded coarse quartz sands and minor quartzose lithic gravel	dominated by chenopod shrubs including *Maireana pyramidata*, and *Atriplex vesicaria* with minor *Acacia victoriae*	None recorded

The three main types of Aed in the mapping area are upstream of the major and minor alluvial channels, and form a dendritic network incised into the surrounding interfluves.

Aed units are elongated drainage depressions ranging in width from 3-15 m within a low relief land surface. They include heterogeneous regolith material, which is a reflection of the subcropping lithological units that have been eroded and incised. They are mostly composed of sub-angular to sub-rounded red-brown quartzose lithic sands and silts, with minor lithic clasts (10-40 mm) (Table 4.31). Further sub-division is largely based on vegetation assemblages.

Table 4.31: Description of alluvial sediments in alluvial drainage depressions in the Pine Creek catchment.

Regolith-landform units (RLUs)	Vegetation	Geohazard
Aed_1	dominated by *Acacia aneura* with minor chenopods including *Maireana pyramidata* and *Atriplex vesicaria*	progressive gullying from surrounding landforms, and minor sink holes.
Aed_2	dominated by *Acacia victoriae* with minor chenopods such as *Maireana pyramidata* and *Atriplex vesicaria*	progressive gullying from surrounding landforms, and minor sink holes.
Aed_3	dominated by chenopods including *Maireana pyramidata* and *Atriplex vesicaria*, with minor *Hypericum perforatum*	progressive gullying from surrounding landforms, and minor sink holes.

One Afa_1 unit was recorded in the mapping area. The alluvial fan regolith-landforms are in the northeast and southwest of the study area. The alluvial fans are on the southern side of Staurolite Ridge and on the eastern side of the aeolian sand longitudinal dunefield, extending from the footslope of regolith-landforms of greater relief. The Afa_1 is characterised by sub-rounded to rounded fine-grained red-brown sands, silts and clays with minor gravels comprised mostly of quartz and lithic fragments (5-15 mm). The vegetation is dominated by chenopod shrubs including *Maireana pyramidata* with minor *Atriplex vesicaria*, and *Bassia ssp*.

Aeolian Regolith-Landforms (I)

Aeolian regolith deposits consist of sediments that have been transported and deposited by the wind. Two aeolian regolith-landforms are recognised in the area. Aeolian sediments range between forming major to minor components of all regolith materials on rises and hillcrests to forming extensive longitudinal dunefields and sandplains in the lower lying landscape settings. Aeolian landforms include longitudinal dunefield (ISul) and sand plains (ISps).

Aeolian sand (IS)
One $ISul_1$ unit was identified in the south, on the eastern side of Pine Creek, and between Pine Creek and Stirling Vale Creek. Deposition of the two units appears to be associated with the westerly winds and the local interference of Staurolite Ridge in the south and the Middle Pinnacle in the northeast. The $ISul_1$ unit is characterised by rounded and spherical fine-grained quartzose sands and silts, with coarser fractions including quartzose sands and minor lithic fragments exposed within the swales. The vegetation is dominated by chenopod shrubs including *Maireana pyramidata* and minor *Atriplex vesicaria,* and grasses dominated by *Stipa ssp* and *Astrebla ssp*.

One $ISps_1$ unit was recorded in the mapping area, mostly in the southwest, south and southeast of the study area. The $ISps_1$ has irregular hummocky dunes with rounded to well-rounded, fine-grained quartzose sands and silts, with coarser fractions of quartzose sands and minor lithic fragments exposed within the swales. The vegetation is grassland dominated by *Stipa sp.* and *Astrebla ssp.* with minor chenopods including *Maireana pyramidata* and *Atriplex vesicaria.*

4.5.1 Statistical Analyses of Biogeochemical Results

Forty-nine elements were analysed by XRF and ICP-MS. The total elemental analytical results for the *E. camaldulensis* are included in Appendix F. The concentrations for the following elements were below the analytical detection limits: Be, Bi, Er, Eu, Ga, Ge, Hf, Ho, Lu, Mo, Nb, Ni, Sn, Ta, Tb, Th, U, Y, Tb and Zr. The chemical composition of twenty-seven elements are dectectable from *E. camaldulensis* leaf tissue samples taken along Pine Creek, of which twenty-seven had 75% of their values above their analytical detection limits. The Student's T-test is a statistical method that assesses whether the means of two groups are statistically similar or different from each other. The results revealed that for the majority of the twenty-seven elements () that the null hypothesis **"There are no significant differences between the means and that both groups are derived from the same population"**, at a significance level of 0.05 was rejected, and that within the data there are multiple populations. These populations are thought to be defined as:

- Pinnacles (Pine Creek): *E. camaldulensis* neighbouring the Barrier Pinnacles mineralisation and those thought to be associated with the surrounding host rocks.

However, Ba, Ca, Mg, Mn, P, Rb and Sr supported the null hypothesis, suggesting that these elements are derived from one population. It is interesting to note that Ca, Mg, Mn and P are considered essential, while Ba could possibly be an analog for Ca given their chemical similarities; likewise Rb is an anolg for K, if either were a limiting factor.

	Mean	Variance	Observations	df	t Stat	P(T<=t) two-tail
Ag (background)	0.03	0.005	200	13	-4.28	0.00090
Ag (ore zone)	0.54	0.2	14			
Al (background)	281	21483	200	13	-2.99	0.01
Al (ore zone)	518	86627	14			
As (background)	-0.38	0.2	200	13	-4.84	0.0003
As (ore zone)	2	3	14			
Ba (background)	8	239	200	15	-1.08	0.30
Ba (ore zone)	13	253	14			
Ca (background)	9760	6526398	200	14	0.02	0.98
Ca (ore zone)	9744	9519625	14			
Cd (background)	0.3	0.05	200	13	-2.77	0.016
Cd (ore zone)	1	1.0	14			
Ce (background)	0.1	0.02	200	14	-3.98	0.0014
Ce (ore zone)	0.4	0.05	14			
Cl (background)	4976	1512289	200	17	-3.37	0.0037
Cl (ore zone)	5789	709348	14			
Cs (background)	0.009	0.0001	200	15	-3.01	0.0088
Cs (ore zone)	0.02	0.0001	14			
Cu (background)	5	2	200	14	-6.22	2.2E-05
Cu (ore zone)	9	6	14			
Dy (background)	0.008	0.0001	200	14	-3.12	0.008
Dy (ore zone)	0.02	0.0001	14			
Fe (background)	98	1459	200	13	-2.83	0.014
Fe (ore zone)	186	13135	14			
Gd (background)	0.01	0.0001	200	14	-2.90	0.012
Gd (ore zone)	0.024	0.0003	14			
K (background)	11508	5768386	200	15	3.37	0.004
K (ore zone)	9406	5026425	14			
La (background)	0.07	0.002	200	13	-3.28	0.006
La (ore zone)	0.17	0.01	14			
Mg (background)	1428	99930	200	14	-0.37	0.7
Mg (ore zone)	1473	204268	14			
Mn (background)	159	11651	200	16	1.06	0.3
Mn (ore zone)	135	6441	14			
Na (background)	1199	579216	200	16	-2.98	0.009
Na (ore zone)	1724	392609	14			
Nd (background)	0.07	0.001	200	13	-3.19	0.007
Nd (ore zone)	0.15	0.009	14			
P (background)	1140	33737	200	18	1.67	0.1
P (ore zone)	1085	12565	14			
Pb (background)	8	439	200	13	-4.48	0.001
Pb (ore zone)	168	17858	14			
Pr (background)	0.02	0.0001	200	13	-3.69	0.003
Pr (ore zone)	0.04	0.0007	14			
Rb (background)	2	2	200	14	0.32	0.8
Rb (ore zone)	2	2	14			
S (background)	1033	18100	200	14	-3.24	0.006
S (ore zone)	1217	43976	14			
Si (background)	1622	454324	200	14	-2.80	0.014
Si (ore zone)	2571	1573936	14			
Sr (background)	45	324	200	14	-1.63	0.1
Sr (ore zone)	54	426	14			
Zn (background)	46	290	200	13	-3.59	0.003
Zn (ore zone)	130	7629	14			

Table 4.32: The two tailed t-statistical test for *E. camaldulensis* (Pine Creek) reveals that the majority of the elements have p-values less than 0.05, rejecting the null hypothesis of equal means.

In order to better define the popoulations within the data, the data were subjected to futher statistical analysis through the application of factor analysis (Principal components analysis). Charactersitics of principal components are as follows:

- the first component extracted accounts for a maximal amount of the total variance in the observed variables;
- the second component extracted will account for a maximal of variance in the data set that was not accounted for by the first component, and that it will be uncorrelated with the first component;
- the third component extracted will account for a maximal of variance in the data set that was not accounted for by the second component, and that it will be uncorrelated with the second component; and,

- the fourth component extracted accounts for a maximal of variance in the data set that was not accounted for by the third component, and that it will be uncorrelated with the thrird component.

Rotated Component Matrix

	Component			
	1	2	3	4
Ag	0.913	0.298	0.064	0.171
Al	0.38	0.376	0.164	0.712
As	0.919	0.285	0.034	0.14
Ba	0.129	-0.028	0.773	0.242
Ca	0.012	0.147	0.885	-0.041
Cd	0.666	0.242	-0.057	0.21
Ce	0.497	0.771	0.105	0.29
Cl	0.237	-0.015	-0.075	-0.33
Cs	0.271	0.433	0.107	0.647
Cu	0.799	-0.012	0.146	-0.07
Dy	0.224	0.848	-0.025	0.188
Fe	0.489	0.4	0.122	0.669
Gd	0.284	0.869	0.033	0.191
K	-0.135	-0.24	-0.093	-0.183
La	0.471	0.796	0.095	0.262
Mg	-0.104	0.073	0.636	0.116
Mn	-0.242	0.606	-0.045	-0.189
Na	0.122	0.155	-0.521	-0.04
Nd	0.435	0.828	0.069	0.267
Ni	0.399	0.096	-0.077	-0.468
P	-0.096	-0.041	0.118	0.049
Pb	0.917	0.289	0.057	0.148
Pr	0.513	0.756	0.119	0.236
Rb	-0.007	-0.123	-0.126	0.068
S	0.28	0.201	0.025	0.052
Sb	0.916	0.289	0.01	0.173
Si	0.329	0.378	0.181	0.721
Sm	0.409	0.813	0.053	0.177
Sr	0.161	0.04	0.904	0.078
Zn	0.829	0.307	-0.052	0.13

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 7 iterations.

Total Variance Explained

	Initial Eigenvalues		
Componen	Total	% of Variance	Cumulative %
1	12.9	43	43
2	3.281	10.937	53.937
3	2.689	8.962	62.899
4	1.957	6.524	69.423

Figure 4.27: Principal component analysis, the table lists the components in order of their eigenvalues, with the first component being the most relevant.

First components elements Ag, As, Cd, Cu, Pb, Sb and Zn are chemically similar to the base metals that characterise the Broken Hill Group and associated Pb-Zn sulphide mineralisation at the Barrier-Pinnacles Mine. Similar elemental suites occur in a number of drill holes (Rugless and Govett, 1984) and through sulphur isotope work undertaken by Parr (1994).

The second component elements Ce, Dy, Gd, La, Nd, Pr and Sm are thought to be associated with the Mn-oxides and/or garnet sandstones, as they have a tendency to adsorb elements that they come into contact with. Of the REEs (rare-earth elements) highlighted all of them with the exception of Dy are classified as LREE (light rare-earth elements). Charactersitics of the Barrier Pinnacles ore body are the proximal envelopes of Mn-Fe rich ‘garnet quartzites’ to the deposit, these Mn-Fe rich ‘garnet quartzites have a LREE (light rare-earth element) enrichment associated with the footwall and hanging wall Zn lodes (Parr, 1992).

The third component elements, Ba, Ca, Mg and Sr, are associated with the Pb-Zn mineralisation at the Barrier Pinnacles Mine. Work indertaken by Rugless and Govett (1984)

have shown that whilst the Barrier Pinnacles Mine ore is enriched in Ag, As, Cd, Cu, Pb, Sb and Zn, it is also characterised by the depletion of Ba, Ca, Mg and Sr.

The fourth component elements, Al, Cs, Fe and Si, are associated with the abundant alluvial sediments across the area, which predominantly consist of mixed lithic and quartzose sands and gravels with minor quartzose, micaceous and kaolinitic silts and clays (aluminosilicates and Fe-oxides) The Fe-oxides (goethite and hematite) are the major end products of near surface weathering and are characteristic of having a large reactive surface area capable adsorbing cations and anions.

4.5.2 Biogeochemical Results

The chemical composition of twenty-nine elements was detectable from *E. camaldulensis* leaf tissue samples from along Pine Creek. The biogeochemical patterns for all elements highlighted by the principal component analysis, in particular the first component, are described with the aid of elemental scatter plots, box and whisker plot comparisons and biogeochemical maps. Subsequent components are illustrated with the aid of one biogeochemical map that is indicative of the other elements within that component (e.g component two Nd). For all other elements (biogeochemical maps) see appendix H.

4.5.3 Eucalyptus camaldulensis

There were few linear elemental relationships from the *E. camaldulensis* leaf results. The REEs, such as La, Nd and Pr, have a strong linear relationship with Ag, Al, As, Pb and Fe, with correlation co-efficients ranging between Ag; r = 0.70 – 0.72, Al; r = 0.70 – 0.71, As; r = 0.70, Pb; r = 0.70 – 0.72 and Fe; r = 0.73 – 0.74. All REEs also have strong linear relationships with one another. Other elements that also showed strong positive, linear relationships are outlined in Table 4.33.

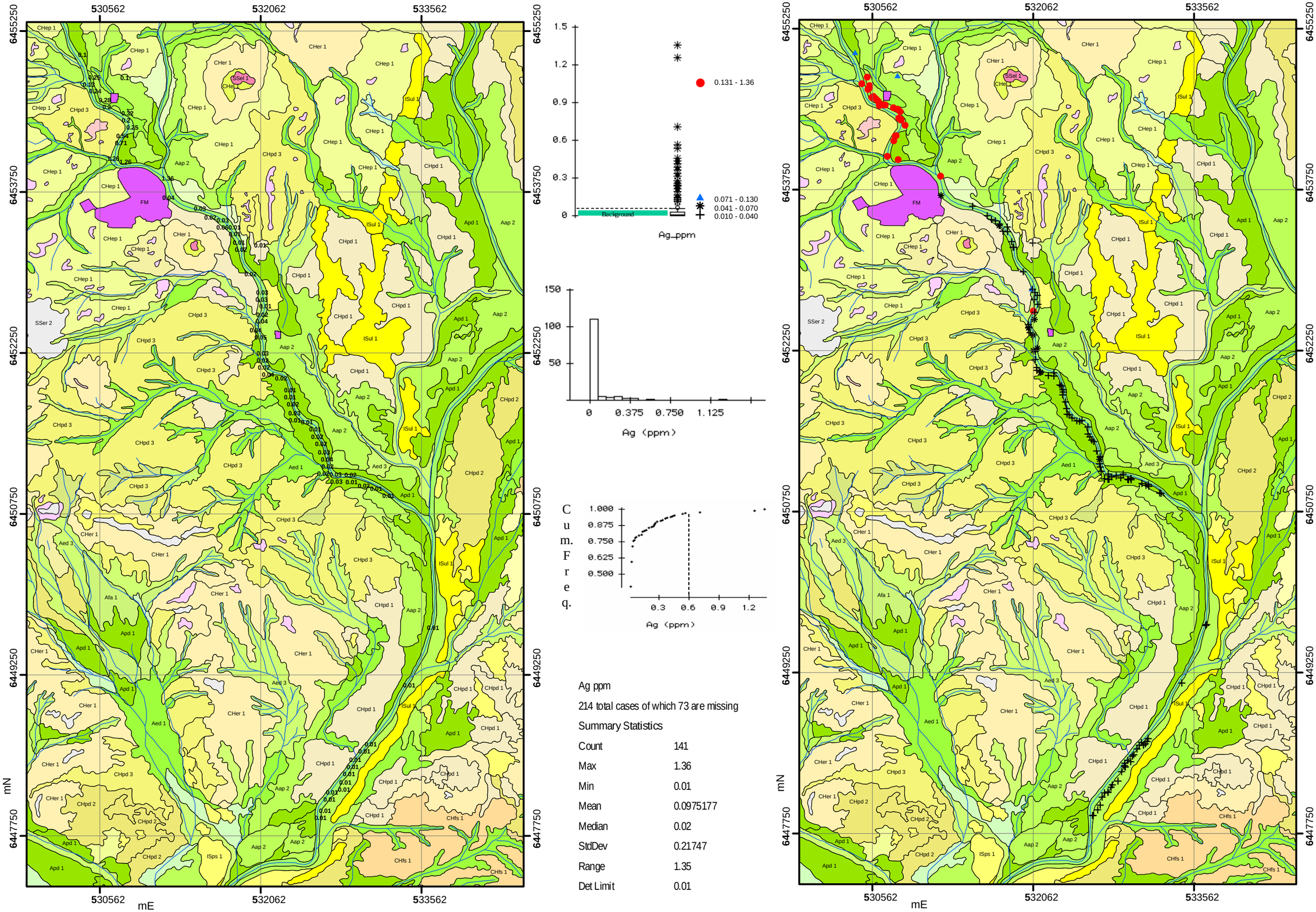
Table 4.33: Elements that show strong positive, linear relationships.

Element correlations	Element correlations
Ag – As (r = 0.98)	As – Pb (r = 0.99)
Ag – Pb (r = 0.98)	As – Sb (r = 0.99)
Ag – Sb (r = 0.99)	As – Zn (r = 0.84)
Ag – Zn (r = 0.85)	As – Cu (r = 0.73)
Ag – Cd (r = 0.70)	As – Cd (r = 0.70)
Ag – Cu (r = 0.70)	As – Cu (r = 0.70)
Ag – Fe (r = 0.70)	As – Fe (r = 0.70)
Pb – Sb (r = 0.98)	Cd – Zn (r = 0.82)
Pb – Zn (r = 0.84)	Cd – Sb (r = 0.72)
Cu – Pb (r = 0.70)	Cd – Pb (r = 0.70)
Cu – Sb (r = 0.70)	Ca – Sr (r = 0.86)
Al – Si (r = 0.99)	Ba – Sr (r = 0.70)
Al – Fe (r = 0.92)	Cs – Fe (r = 0.71)
Al – Ce (r = 0.72)	Cs – Si (r = 0.70)
Fe – Si (r = 0.91)	

Results of *E. camaldulensis* leaves showed a significant biogeochemical relationship with the Broken Hill Group and (associated Pb-Zn sulphide mineralisation), there is also a significant regolith-landform associations expressed in the results. Table 4.34 - Table 4.43 and

accompanying biogeochemical maps (all even numbered figures between Figure 4.28 –Figure 4.46) and results relative to their landscape setting (all odd numbered figures between Figure 4.29 –Figure 4.47) summarises the *E. camaldulensis* element results for Pine Creek.

E. camaldulensis (leaves) Biogeochemistry
Pine Creek Broken Hill W/NSW - (Ag)



HORIZONTAL DATUM: WGS84, UTM ZONE 54S

Figure 4.28: Raw data and spatial distribution of detectable Ag in *E. camaldulensis* (leaves) down Pine Creek with accompanying boxplots, histogram, cumulative frequency plot and summary statistics.

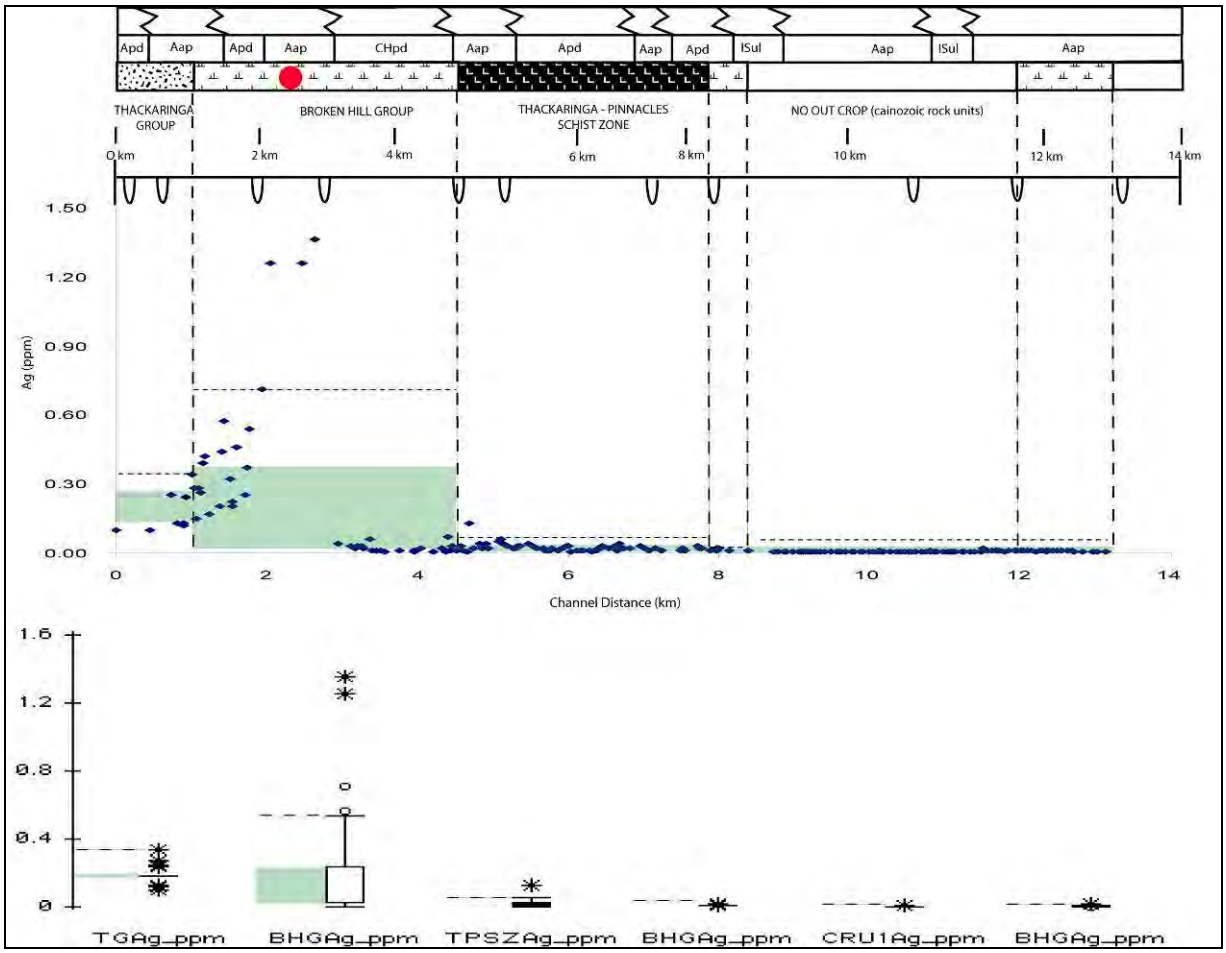
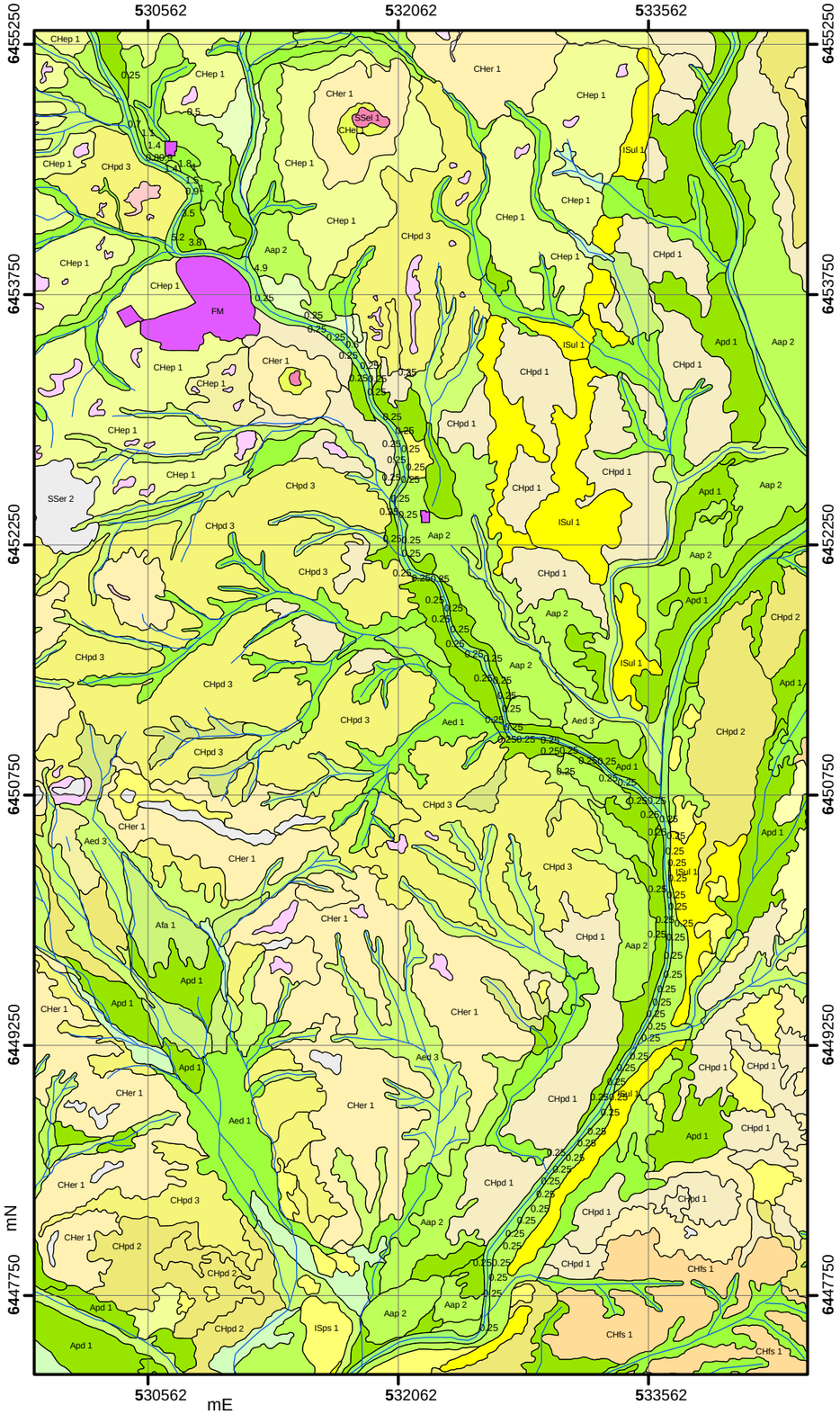


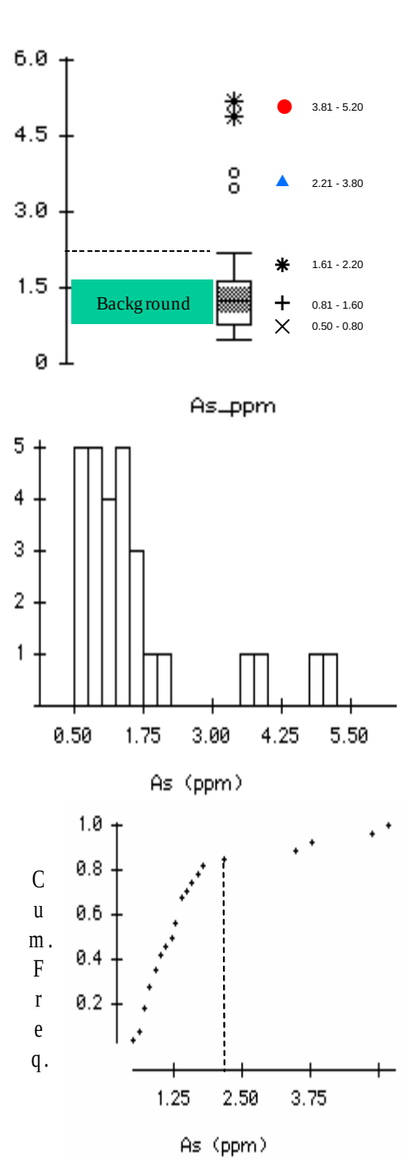
Figure 4.29: Ag concentrations within *E. camaldulensis*, flanking different land-form settings along Pine Creek. Thackaringa Group (TG), Broken Hill Group North (BHGN), Thackaringa-Pinnacles Schist Zone (TP/SZ), Broken Hill Group Central (BHGC), Cainozoic rock units (CRU) and Broken Hill Group South (BHGS). Green region denotes 'values below the mean", red dot the approximate location of the Barrier Pinnacles Mine and the dashed line indicates the 90th percentile.

Element (ppm) [detection limit] Analytical Method	**Parameters**	**Total data set (C) n=214**	**Setting**					
			Thackaringa Group TG (Apd, Aap) n=9	**Broken Hill Group BHG(N) (Aap, Apd & CHpd) n=42**	**Thackaringa-Pinnacles Schist Zone TP/SZ (Aap, Apd) n=60**	**Broken Hill Group BHG (C) (Apd & ISul) n=7**	**No outcrop (CRU) (ISul, Aap) n=61**	**Broken Hill Group BHG(S) (Aap) n=35**
Ag [0.01] ICP-MS	Concentration range (Mean)	0.01-1.36 (0.01)	0.1-0.34 (0.2)	*-1.36 (0.3)	*-0.13 (0.02)	0.01-0.02 (0.01)	*-0.01 (0.01)	*-0.02 (0.01)
	25th - 75th percentile	0.01-0.04	0.12-0.26	0.01-0.37	0.01-0.03	0.011-0.018	Small data range	Small data range
	95% confidence level	0.02	0.07	0.12	0.005	0.005		
	>90th percentile (outliers), # of samples	0.07-1.36 (29)	No outliers'	0.57-1.36 (5)	0.13 (1)	No outliers'		
	E. camaldulensis position with the greatest concentration.	north region of Pine Creek catchment, and adjacent to the Barrier Pinnacles Mine and depositional regolith-landform units Aap_2.	southern margin at the interface between TG and BHG (N). Down stream of an NW intersecting Aed unit. Flanked by regolith-landform units Aap_2 and $CHpd_3$.	northern margin at the interface between TG and BHG(N) and adjacent to the Barrier Pinnacles Mine. Flanked by regolith-landform units Apd_1, and $CHpd_3$.	northern margin at the interface between BHG (N) and TP/SZ, and central down stream of depositional flood out region. Flanked by regolith-landform units $CHpd_1$, $ISps_1$ and Aap_2.	northern margin at the interface between BHG (CL) and TP/SZ. Flanked by regolith-landform unit Apd_1.		

Table 4.34: Variations of Ag concentrations within *E. camaldulensis* (river red gums), flanking different land-form settings along Pine Creek. Initial values concentration range (mean), 25th - 75th percentile concentration range, 95 % confidence; level, >90th percentile (outliers), C= composite sample, * signifies values below detection limit.

E. camaldulensis (leaves) Biogeochemistry
Pine Creek Broken Hill W/NSW - (As)



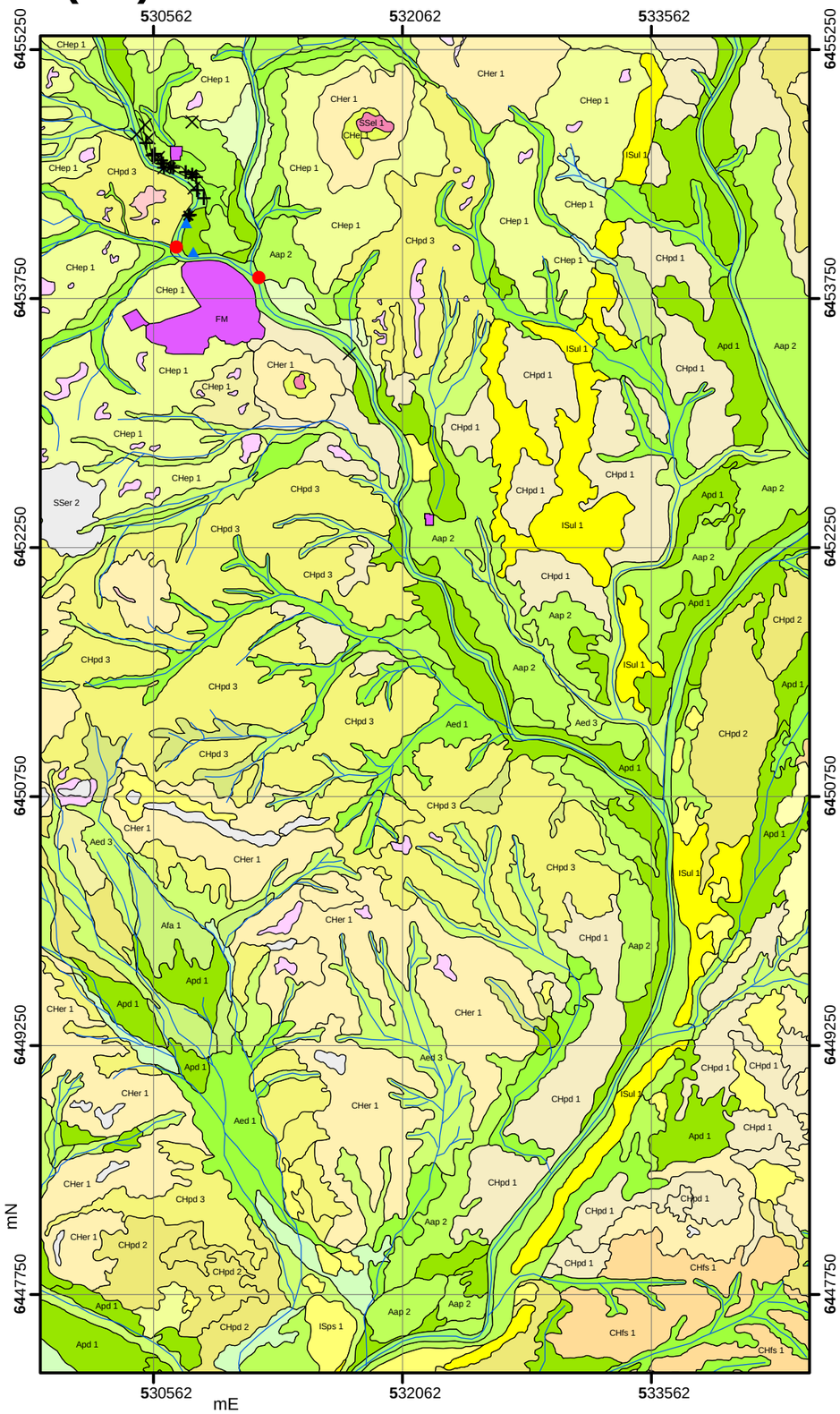


As ppm

214 total cases of which 186 are missing

Summary Statistics

Count	28
Max	5.2
Min	0.5
Mean	1.59643
Median	1.25
StdDev	1.2426
Range	4.7
Det Limit	0.5



HORIZONTAL DATUM: WGS84, UTM ZONE 54S

Figure 4.30: Raw data and spatial distribution of detectable As in *E. camaldulensis* (leaves) down Pine Creek with accompanying boxplots, histogram, cumulative frequency plot and summary statistics.

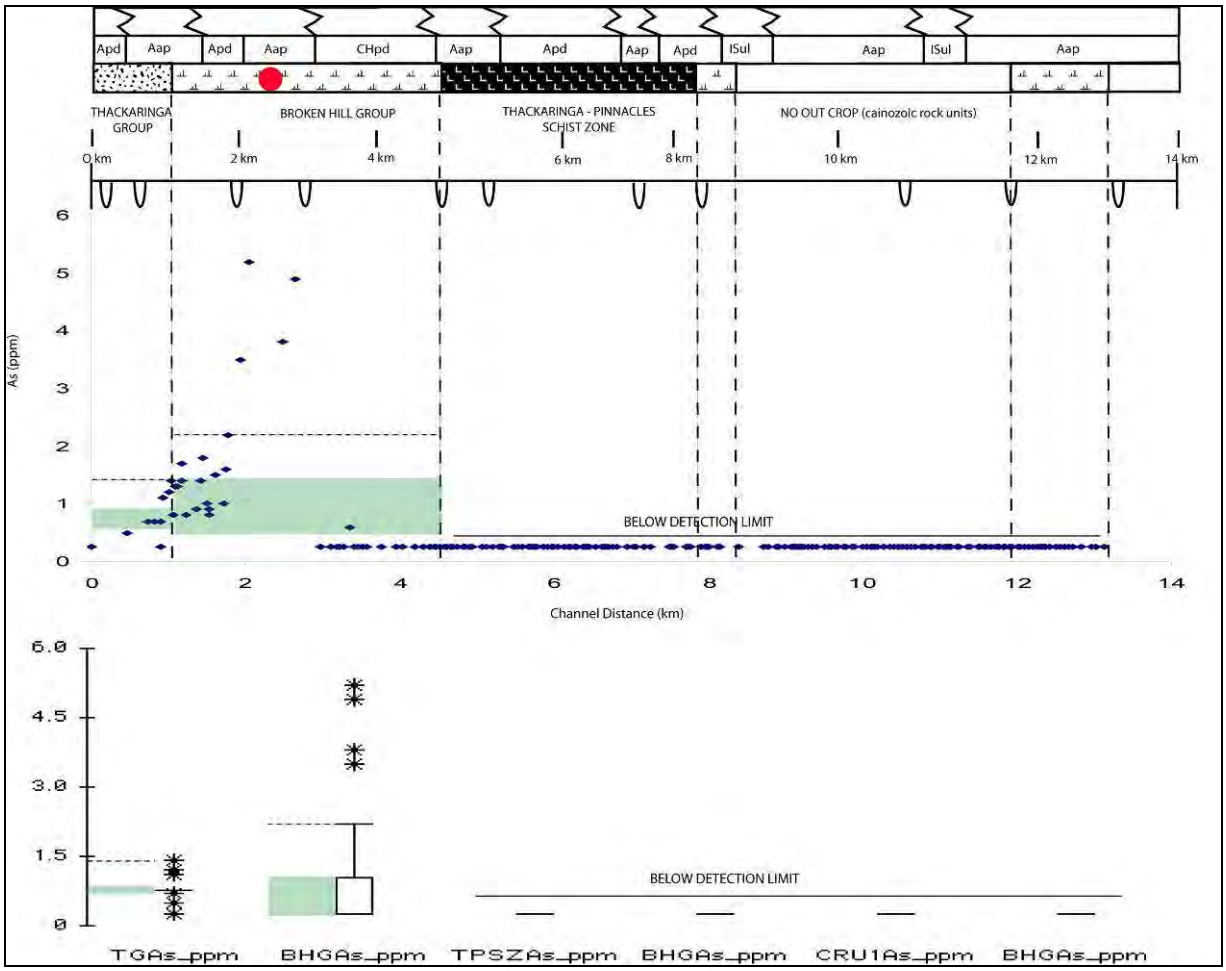


Figure 4.31: As concentrations within *E. camaldulensis*, flanking different land-form settings along Pine Creek. Thackaringa Group (TG), Broken Hill Group North (BHGN), Thackaringa-Pinnacles Schist Zone (TP/SZ), Broken Hill Group Central (BHGC), Cainozoic rock units (CRU) and Broken Hill Group South (BHGS). Green region denotes 'values below the mean, red dot the approximate location of the Barrier Pinnacles Mine and the dashed line indicates the 90th percentile.

Element (ppm) [detection limit] Analytical Method	**Parameters**	**Total data set (C) n=214**	**Setting**					
			Thackaringa Group TG (Apd, Aap) n=9	**Broken Hill Group BHG(N) (Aap, Apd & CHpd) n=42**	**Thackaringa-Pinnacles Schist Zone TP/SZ (Aap, Apd) n=60**	**Broken Hill Group BHG (C) (Apd & ISul) n=7**	**No outcrop (CRU) (ISul, Aap) n=61**	**Broken Hill Group BHG(S) (Aap) n=35**
As [0.5] ICP-MS	Concentration range (Mean)	0.5-5.2 (2)	*-1.4 (1)	*-4.95 (2)				
	25th - 75th percentile	0.80-1.60	0.6-0.9	0.5-1.4				
	95% confidence level	0.09	0.31	0.61				
	>90th percentile (outliers), # of samples	2.21-5.20 (4)	No outliers'	3.5-5.2 (4)				
	E. camaldulensis position with the greatest concentration.	north part of the Pine Creek catchment, adjacent to the Barrier Pinnacles Mine and depositional regolith-landform units Aap_2.	southern margin at the interface between TG and BHG (N). Down stream of an NW intersecting Aed unit. Flanked by regolith-landform units Aap_2 and $CHpd_3$.	upstream and adjacent to the Barrier Pinnacles Mine. Flanked by regolith-landform units Apd_1, and $CHpd_3$.	BDL	BDL	BDL	BDL

Table 4.35: Variations of As concentrations within *E. camaldulensis* (river red gums), flanking different land-form settings along Pine Creek. Initial values concentration range (mean), 25th - 75th percentile concentration range, 95 % confidence; level, >90th percentile (outliers), C= composite sample, * signifies values below detection limit.