# Lithogeochemistry of Pegmatites at Broken Hill: An Exploration Vector to Mineralisation

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## SUMMARY

A sampling program was undertaken to assess pegmatite geochemistry with the view to using the data to vector towards economic mineralisation. The work has shown that pegmatites hosted in high grade metamorphic rocks (granulite and upper amphibolite facies) are either leucogranites, quartz-feldspar-mica pegmatites or feldspar-rich pegmatites. In contrast those that occur within lower grade metamorphic rocks (lower amphibolite to greenschist facies) are feldspar poor and quartz-muscovite rich, locally highly sheared, with tourmaline on their margins and as replacements of surrounding host sediments.

Element classification diagrams suggest a geochemical continuum from poorly evolved pegmatites hosted in the highest grade metamorphic rocks to highly evolved pegmatites in the lowest grade metamorphic rocks. Spatially, this trend is broadly from the south and southwest toward the north and northeast and from west to east.

Economic element content is similarly divided into two broad groups;

1. Pegmatites within higher grade metamorphic rocks host elevated lead-zinc-silver-manganese.
2. Pegmatites within lower grade metamorphic rocks contain elevated tin, tungsten, lithium, niobium and tantalum. The presence of abundant tourmaline in association with these indicates highly elevated boron.

Elevated base metals and silver in the granulite and amphibolite facies rock is attributed to the elevated nature of these elements in the metasedimentary protolith being largely the Broken Hill Group. Our interpretation suggests these are probably not allochthonous but are nearly in-situ bodies resulting from partial melting of the Broken Hill Group. Their chemistry reflects that of the surrounding rock. Analysis of the spatial distribution of pegmatites with elevated lead-zinc-silver-manganese indicates many of these are located close to known base metal and/or silver occurrences of the Broken Hill types (BHTs).

In contrast the concentration of tin, tungsten, lithium and other incompatible elements in pegmatites which are allochthonous and intrude rocks of lower metamorphic grade, suggests these elements have accumulated as fractionation has taken place.

This study has highlighted three areas of elevated base metal-silver within pegmatites where no known mineralisation is documented either as an occurrence or in historic exploration data. Systematic pegmatite sampling at Broken Hill has the potential to enable vectoring toward buried silver-lead-zinc ores of the Broken Hill type.

**Key words:** Pegmatite, lithogeochemistry, fractionation, sampling media.

## INTRODUCTION

Silver City Minerals Limited (SCI) has been exploring in the Broken Hill district since incorporation in 2008. During that time, it has reviewed a variety of legacy geochemical data available for the district and has conducted its own geochemical sampling programs. The Company concludes from this work that historic geochemical data is restricted in its usefulness due to a variety of features including paucity of outcrop, limited geographical extent of surveys, limited element range and relatively high levels of detection for certain techniques.

SCI wanted to conduct a regional-scale reconnaissance sampling program that would provide a broad range of elements at low detection limits. It wanted to cover most of its tenements in the district to help define or locate a broad range of mineral deposit styles, different lithological units and any regional alteration patterns.

Modern, cost-effective laboratory techniques using near complete four acid digestion with a combination of inductively coupled plasma-atomic emission spectrometry (ICP-AES) and inductively coupled plasma-mass spectrometry (ICP-MS) provide a way to analyse a large range of elements, to low levels of detection, with accuracy and precision.

Rocks of the Willyama Supergroup ubiquitously host pegmatite. The protolith comprises predominantly quartzo-feldspathic sediments and bimodal felsic and mafic volcanic rocks. Mapping by the NSW Geological Survey suggest the total pegmatite rock mass, including rocks described as leucogranites, might be as much as 20% of the total rock sequence. In his revision of metamorphic isograds at Broken Hill, Fitzherbert (2015) shows that the deformation pattern of the rocks during the peak metamorphism has configured the isograds such that they are largely conformable to stratigraphy. This means the oldest rocks (Thackaringa and Broken Hill Groups) are metamorphosed to higher grade granulite and upper amphibolite facies and younger rocks (Sundown and Paragon Groups) are metamorphosed to lower amphibolite to greenschist facies. He describes pegmatite and leucogranite within the granulite and upper amphibolite facies as a lower sill complex because they form bodies which are largely stratabound. Pegmatite hosted in lower grade rocks (lower amphibolite and greenschist facies) he refers to as the upper sill complex.

Our hypothesis is that a significant portion of those hosted in granulite and upper amphibolite facies rocks formed by partial melting of existing sequences. As such these have largely formed at or close to the position of melt (close to the solidus isotherm). Volumetrically insignificant pegmatites are hosted within and intrude lower grade metamorphic rocks. These are characterised predominance of quartz and muscovite, paucity of feldspar and by strong greisen-like alteration halos including abundant tourmaline. These are considered to be allochthonous.

In this regard pegmatites might be considered unique, in that their chemistry might reflect that of the original rock (sedimentary or volcanic rocks), the chemistry of the rock they pass through when moving from high to low metamorphic grade and the chemistry of any incompatible elements that become concentrated in allochthonous melts. Implicit to the concept is they may be geochemically "sampling" the original rock sequences.

The Broken Hill district hosts a variety of mineral deposits including zinc-lead-silver, silver-lead, copper-cobalt, tungsten and tin. A number of these are thought to be stratabound, especially the Broken Hill type (BHT) zinc-lead-silver mineralisation. We hypothesize pegmatites will have trace element abundances which will indicate if a particular pegmatite has passed through, or melted mineral deposits hosted in the original rock. By systematically sampling pegmatites on a regional, district-wide scale this technique might enable mineral explorers to vector towards previously unknown, buried mineral deposits.

Broken Hill is an ideal location to test this concept due to the abundance of pegmatites and an understanding of the location and style of existing mineralization. Pegmatites comprise simple assemblage of relatively coarse feldspar, quartz and mica. Mica is predominantly muscovite and biotite occurs locally. In the upper sill complex quartz and muscovite are abundant with feldspar being minor. Other minor minerals such as garnet, magnetite, tourmaline, amblygonite, cassiterite, wolframite and beryl have been described along with sulphides. This paper outlines the results of this sampling program.

## METHOD AND RESULTS

The sampling program was designed using the known pegmatite occurrences within GIS datasets from the Geological Survey of NSW (GSNSW). Many more pegmatite outcrops were located during the program and more importantly were often the only outcropping material in the residual soils. Samples of between 2.5kg and 3.0 kg were collected from an area up to 50 metres by 50 metres at each site. They were a mixture of the visually representative mineralogy.

All samples were analysed at ALS Laboratories in Orange using the ME-MS61 analytical method. This uses near-complete four acid digestion with a combination of inductively coupled plasma-atomic emission spectrometry (ICP-AES) and inductively coupled plasma-mass spectrometry (ICP-MS). In addition to data derived from this sampling program the GSNSW provided other archived data.

Using the seamless digital geology generated by the GSNSW each sample was assigned the stratigraphic group and metamorphic facies according to GSNSW nomenclature based on its location. The results were as follows:

1. K-Rb and K-Cs ratios show systematic variation from granulite to green schist facies metamorphism and from older to younger rocks. Data shows a fractionation trend towards lower grade metamorphism and younger rocks (Figures 1and 2). A common source rock or melt is likely to be a psammo-pelitic sedimentary sequence (Figure 3). This is consistent with the mapped stratigraphy.

2. Pegmatites hosted in rocks of the Thackaringa and Broken Hill Groups (predominantly granulite to upper amphibolite facies) are enriched in copper-cobalt (in the Thackaringa Group) and lead-silver-zinc-manganese (in the Broken Hill Group). This is consistent with the style of mineralisation hosted within each group. Of particular interest are pegmatites from the Broken Hill Line-of-Lode which are highly elevated in silver and lead results from the Line-of-Lode pegmatites (Figure 4). Blue-green plumboan feldspars are common in rocks close to BHT deposits.

3. Pegmatites within the lower amphibolite to greenschist facies rocks, located predominantly within the younger Sundown and Paragon Groups are elevated in incompatible elements caesium, gallium, lithium, niobium, rubidium, tantalum, thallium which are characteristic of LCT (Lithium-Caesium-Tantalum) pegmatites and are associated with localised tin and tungsten mineralisation. These rocks are considered to be allochthonous; intruding into the host sequence and are strongly fractionated above the sillimanite-K-feldspar isograd (Figure 2). Zinc silver, manganese, copper and uranium show some enrichment in the more fractionated pegmatites (Figure 6). Lead shows depletion a REEs indicate no enrichment.

### Exploration Targets

Two areas of anomalous lead, silver and zinc results have been identified for further follow-up; the Riddock prospect south of the Allendale Mining Field (Figure 5) and the Limestone prospect north-west of Broken Hill (Figure 6). Both areas have had limited exploration previously and at Limestone contamination from an old smelter has made soil and XRF results unusable. Both areas also have the anomalism near the Hores Gneiss a formation known to be associated with BHT style mineralisation. Both areas have significant residual cover with the pegmatites often the only outcrop. At Limestone this is important as sampling pegmatite negates the issues around contaminated soil cover.

**Figures and Tables**

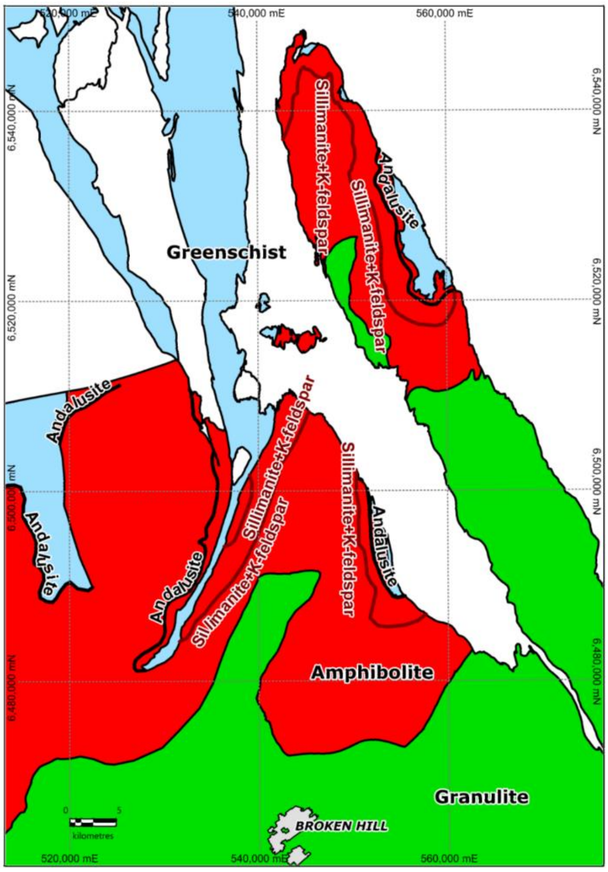


**Figure 1: Distribution of metamorphic facies in the Broken Hill Block**

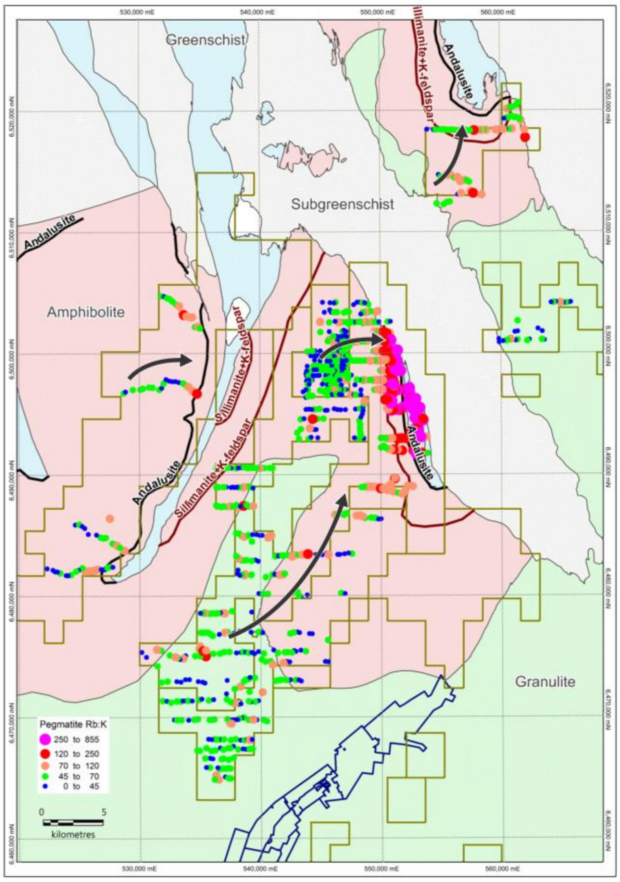


**Figure 2: Thematic map of Rb/K in pegmatites indicating increased fractionation towards lower metamorphic facies rocks.**

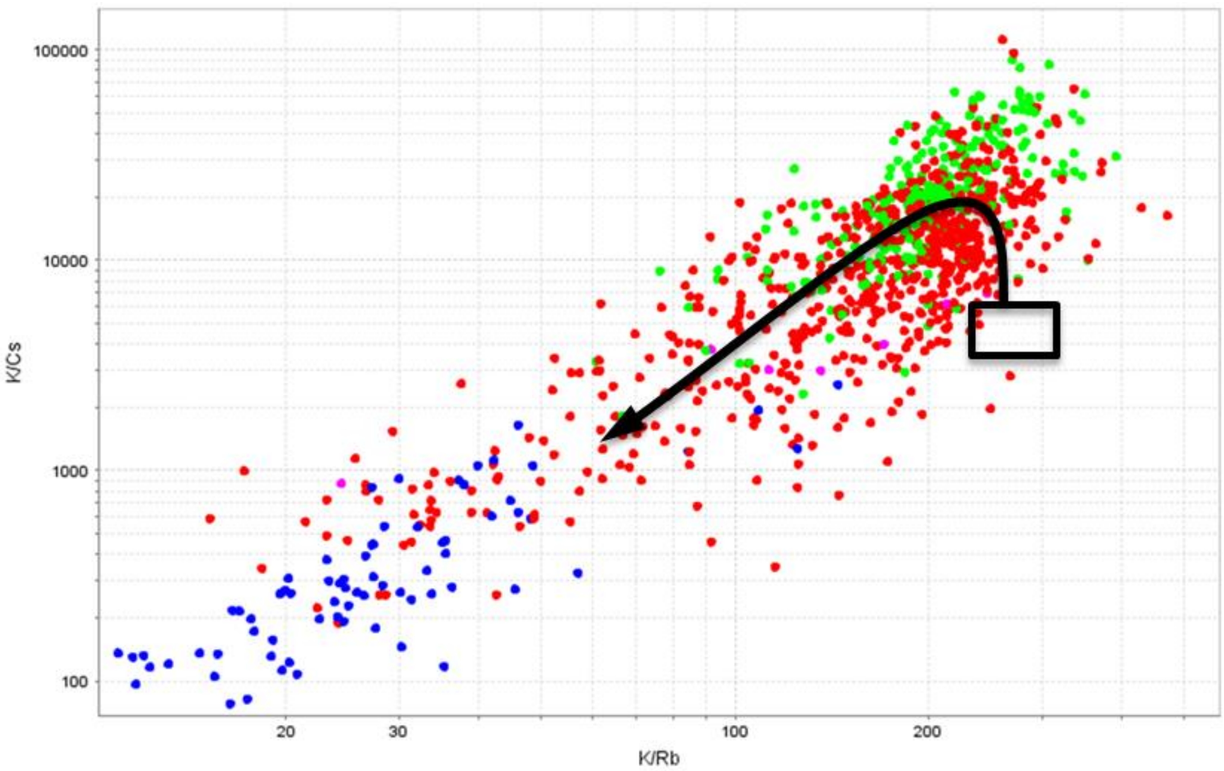


**Figure 3. Fractionation trends indicate pegmatites come from a common source (Green dots are pegmatites in granulite facies metasediments, red in amphibolite facies and blue in greenschist facies, square denotes average upper crust and North American Shale Composite material).**

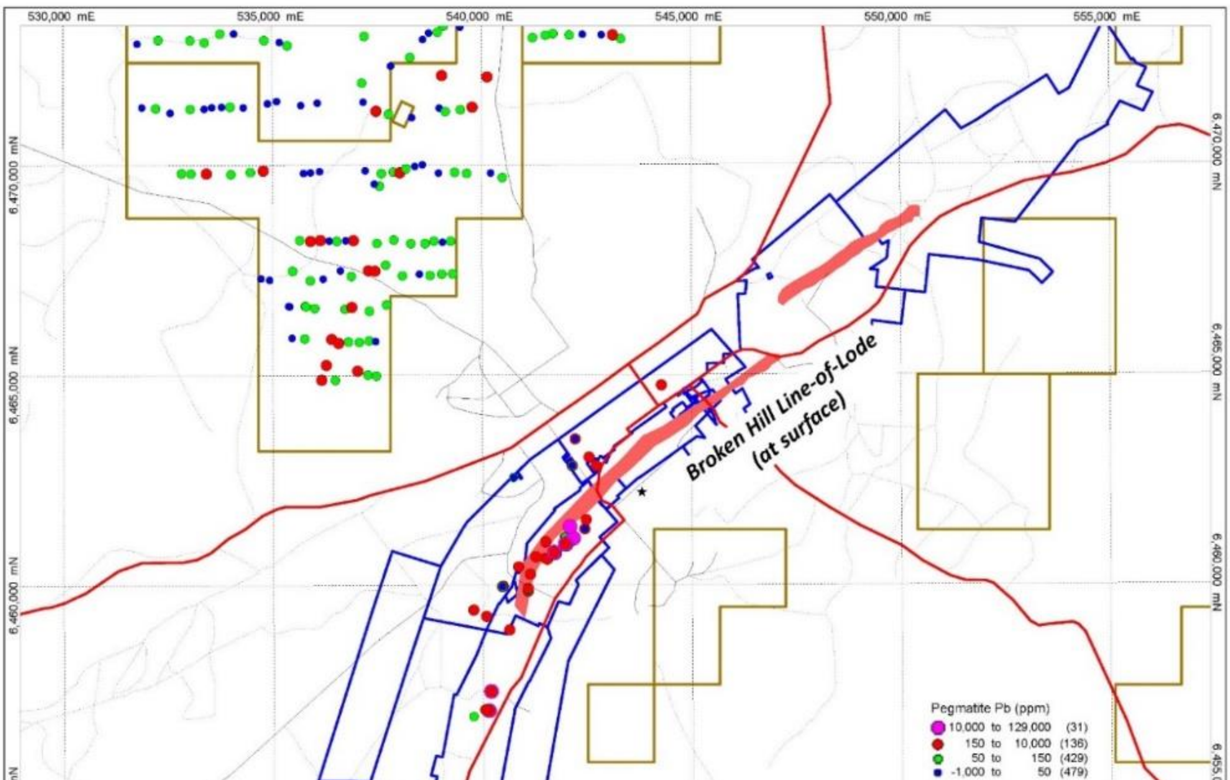


**Figure 4: Anomalous lead values in Broken Hill Line-of-Lode pegmatites.**

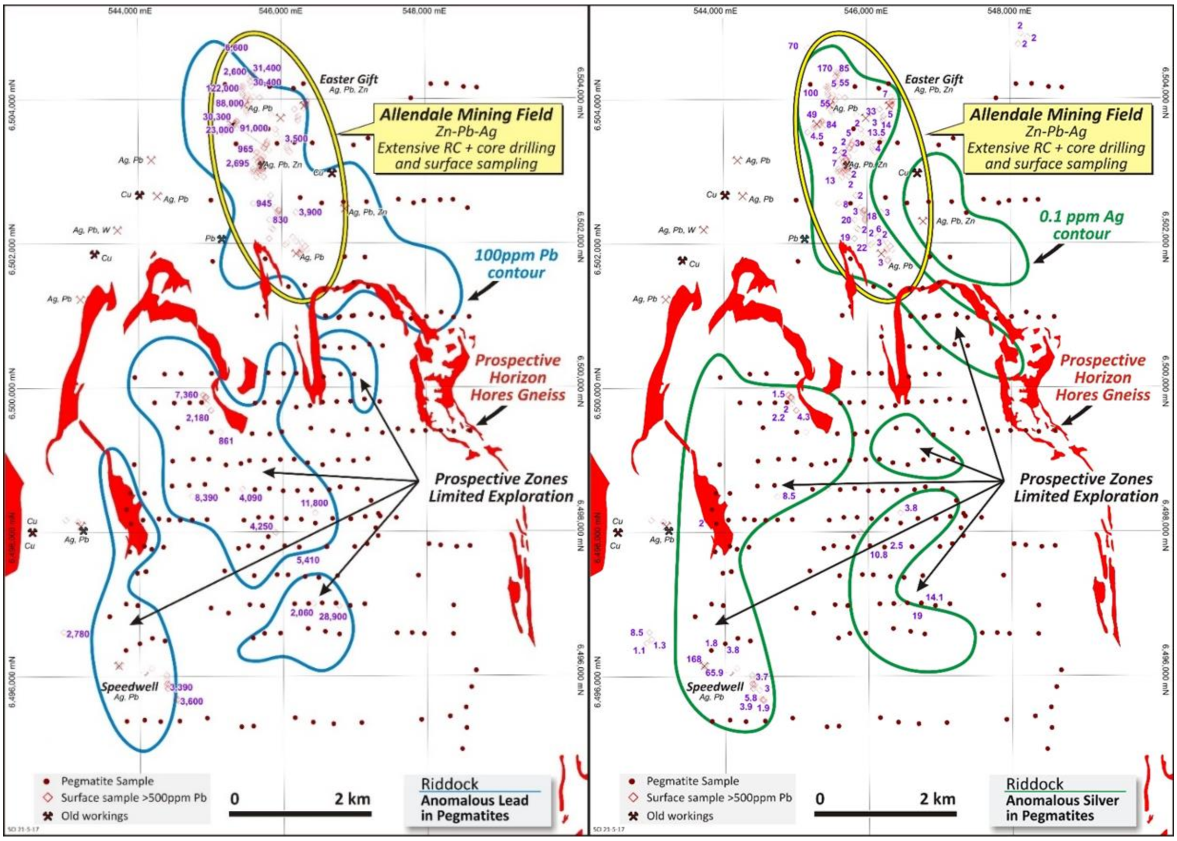


**Figure 5: Riddock prospect, lead (left) and silver (right) anomalies in pegmatites. Purple numbers are rockchips with values of >500ppm lead and >1 g/t Ag, respectively.**

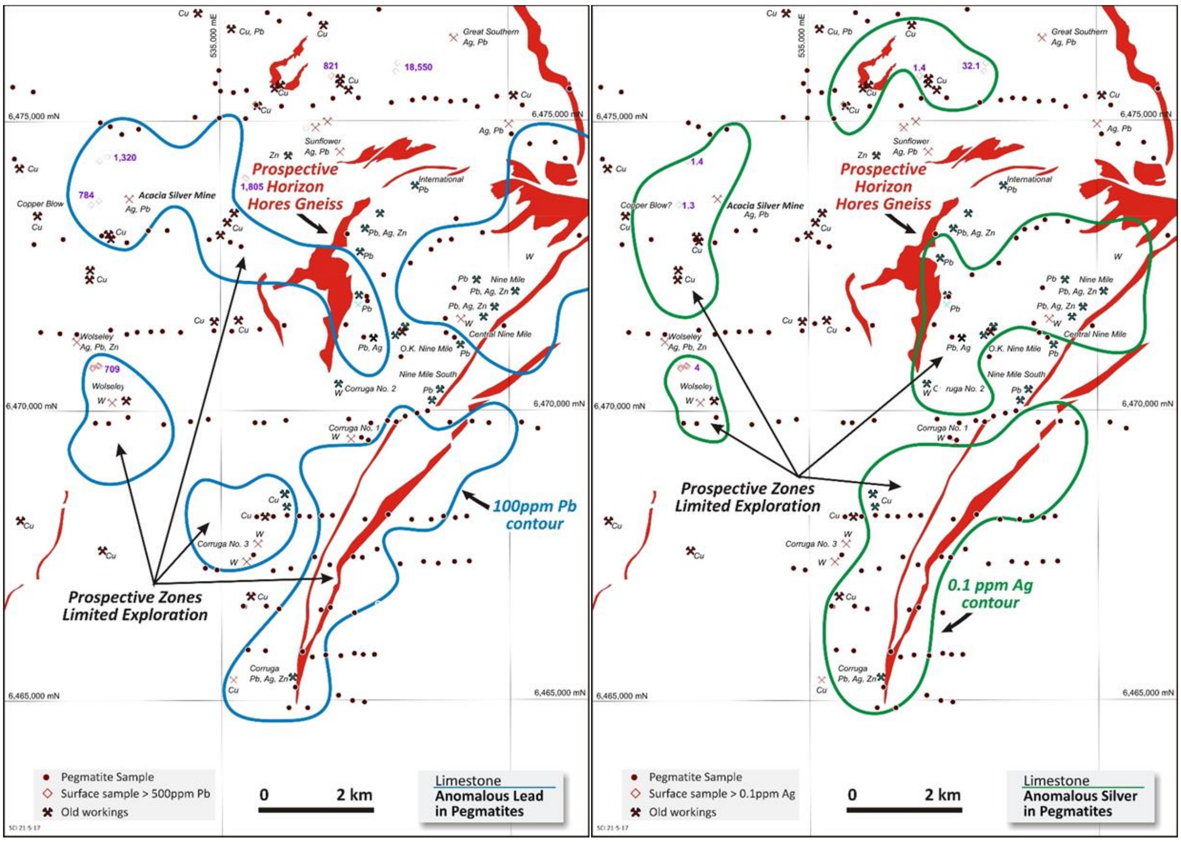


**Figure 6: Limestone prospect, lead (left) and silver (right) anomalies in pegmatites. Purple numbers are rockchips with values of >500ppm lead and >1 g/t Ag, respectively.**

## CONCLUSIONS

The sampling program found pegmatites at Broken Hill are a ubiquitous sampling medium and occur more abundantly than identified by the various mapping datasets. They are often the only outcrop within the residual cover, providing the only reliable sampling media in those areas. Pegmatites are a consistent sampling medium with a simple quartz-feldspar-mica composition. The exception being those located in the Waukeroo tin-tungsten field which are uniquely quartz-muscovite in composition.

The chemistry of the pegmatites reflects their location with respect to stratigraphy and metamorphic grade. In the economic mineral assemblage lead values are highest in the granulite to lower amphibolite facies rock which equates to the Broken Hill Group where most of the lead occurrences are located. Zinc on the other hand appears to have a reverse relationship although the highest values are still found in granulite to amphibolite facies rocks. Tin and tungsten are highest in greenschist facies rocks equating to the younger Sundown and Paragon Groups.

Trace element chemistry suggests fractionation through anatexis within the Broken Hill block from predominantly sedimentary source. Pegmatites hosted in older and higher metamorphic grade rocks are less fractionated compared to the younger and lower metamorphic grade rocks. The more fractionated pegmatites provide vectors to Li, Sn, Ta, W and Nb mineralisation which are interpreted to be more evolved and allochthonous variants.

The data has highlighted at least two areas that warrant further work based on anomalous lead and silver results. Both of these areas have had limited historical exploration in part due to having significant residual soil cover. The pegmatites have provided reliable sampling medium as they have a consistent composition and they outcrop through the residual soils.

## ACKNOWLEDGMENTS

Thanks to Silver City Minerals for allowing this data to be presented at the AEGC. Thanks also to Peter White, Eric Conaghan and Alison Dines for their hard work during the sampling program.

### REFERENCES

Fitzherbert J. A. 2015. Refined peak and retrograde metamorphic isograds for the Broken Hill and Euriowie blocks, NSW. Quarterly Notes Geological Survey of NSW No.143 (1).