Exploration for Lithium-Caesium-Tantalum (LCT) pegmatites in New Zealand

Mathijs van de Ven[1], Michael Gazley[2], René Sterk[1], Sean Aldrich[1], Erik Werner[1]

[1]*RSC Mining and Mineral Exploration, 109 Princes Street, Wellington, New Zealand. m.vandeven@rscmme.com*
[2]*RSC Mining and Mineral Exploration, 93 The Terrace, Wellington, New Zealand.*

Keywords
catchment analysis, stream sediment samples, prospectivity, Central Zambia, Hohonu Batholith

ABSTRACT

Prospectivity analysis has shown that the northern parts of the West Coast of the South Island are prospective for lithium-caesium-tantalum (LCT) pegmatites. Here we present a case study from Central Zambia to show how one might use stream sediment samples to narrow down the search area to find mineralised pegmatites. Stream-sediment samples were collected to identify anomalous catchments or parts thereof. After in-fill stream sediment samples were collected and analysed, soil sample programmes were planned in target areas. This approach resulted in the delineation of an Ce-La-Th soil anomaly that could reflect a REE-mineralised pegmatite in the subsurface. Using our learnings from exploring for pegmatites in Australia, Mozambique, and Zambia, we propose a strategy to test the LCT prospectivity of the Hohonu Batholith on the West Coast.

INTRODUCTION

Demand for lithium is rapidly growing due to an increasing number of applications in new technologies such as batteries and high-performance metals. To better understand New Zealand's minerals endowment, GNS Science recently completed a prospectivity analysis for lithium and identified several prospective areas on the West Coast of the South Island (Turnbull *et al.*, 2018). This report showed that parts of the northern West Coast, South Island, New Zealand are prospective for lithium-caesium-tantalum (LCT) pegmatites. The report also noted that to date, "There has been almost no research or exploration focused on understanding New Zealand's lithium potential" (Turnbull *et al.*, 2018; p. 49). Leveraging our understanding of exploration and mining projects in Australia, Mozambique and Zambia, we present an effective exploration strategy for LCT pegmatites in New Zealand, with a focus on the northern part of the West Coast. We present a case study from Zambia, where we have effectively employed this strategy to identify prospective pegmatites in an 1,831 km^2 licence area.

EXPLORATION STRATEGY OVERVIEW

In an underexplored area like New Zealand, an important first exploration step is to generate a representative and internally consistent geochemical dataset of LCT-pathfinder elements (e.g. Li, Cs, Ta, Nb, Be, Sn, W, K, and Rb). The easiest way to do this is through stream-sediment sampling. With a consistent sampling methodology, large geochemical datasets can be collected by stream-sediment sampling which can be used to identify smaller areas (catchments) that are of interest for follow-up exploration work.

Anomalies in stream sediment samples can be followed up with mapping, rock-chip sampling, or soil sampling to identify the source of anomalism. The premise of this exploration approach is effectively sampling the right sample media at the right time in the programme to narrow the search area as rapidly as possible—or to sterilise large areas of an area of interest rapidly.

GEOCHEMICAL METHODS

The key LCT pathfinder elements are typically hosted in minerals that are resistant to conventional acid-digest methods such as columbite-tantalite (Nb, Ta), cassiterite (Sn) and scheelite (W). It is therefore critical that rock samples are prepared using a destructive method such as sodium-peroxide fusion prior to acid digest and ICP-

MS/AES analysis. By contrast, stream sediments (and possibly soil samples) have lower concentrations of acid-resistant minerals than fresh rock, and direct treatment by four-acid digest methods is appropriate. Portable X-ray fluorescence (pXRF) can be extremely useful in LCT pegmatite exploration as Cs, Ta, Nb, Sn W, K and Rb can all be robustly quantified by pXRF if the appropriate instrument and analysis mode has been selected; it can also provide Si concentration data which can add significantly to a four-acid digest analysis which does not report Si.

One of the challenges of exploration for LCT pegmatites, is that it is not possible to analyse at ore-grades except by a few select laboratory methods (e.g. Na-peroxide fusion followed by ICP-MS/AES analysis) due to the use of Li borate as a flux in most fusion methods and the resistate nature of the associated mineralogy.

CATCHMENT ANALYSIS

Catchment analysis, when combined with stream or soil geochemical data, can be a useful tool to constrain geochemical anomalies and identify exploration targets in greenfields mineral exploration. The catchment analysis can be performed in QGIS (open source) software using a digital elevation model (DEM, e.g. publicly available, 30-m resolution, Shuttle Radar Topography Mission DEM) of the area of interest. Importantly, the DEM must be modified to fill surface depressions and preserve a downward slope along the flow path. In QGIS this can be achieved using the System for Automated Geoscientific Analyses (SAGA) 'Fill Sinks' module based on the algorithm by Wang and Liu (2006). Subsequently, the channel network can be generated and catchment basins calculated (e.g. using the open source Geographic Resources Analysis Support System (GRASS) 'r.watershed' module).

STREAM-SEDIMENT SAMPLING

Stream-sediment samples, when collected in a consistent fashion, can prove an effective means to identify fractionated granites (e.g. using Rb/K and Rb/Sr proxies) and lithologies enriched in LCT-pathfinder elements. Over the course of multiple projects, we have found sampling the <2 mm fraction from the middle of the main channel to provide an effective sample media. Critically, it is an easy sample to train people to take and is reproducible as it does not require expertise to identify the correct sample location within the channel. However, the sample matrix (e.g. quartz and feldspar) of a stream-sediment sample can dilute the pathfinder elements and spurious relationships may be identified if data are not appropriately treated through the use of normalisation techniques (e.g. z-score) and log-ratio transforms.

SOIL SAMPLING

Once occurrences of fractionated granite hosts or anomalous LCT-pathfinder elements have been identified, soil sampling may be employed to further constrain the location of mineralised pegmatites. However, care needs to be exercised in designing and implementing a soil sampling programme as many LCT-pathfinder elements are immobile in the near-surface environment. Hence, due to limited dispersion of the pathfinder elements in the soil profile, a relatively close sample spacing is required to identify anomalies. Portable XRF technology can assist with analysis of the samples, as elements such as Zr, Nb, Y, Sr, Rb, Cs, Ta, Sn and W can be robustly quantified using these instruments at concentration levels that are useful to target pegmatites.

ROCK-CHIP SAMPLING

One of the key insights that rock-chip samples can provide is to characterise the elemental associations in the system that is being examined. They can confirm what elements are positively correlated with Li which allows more robust interpretation of the stream-sediment and rock-chip samples.

However, care must be taken with the Li content of rock-chip samples; due to its high mobility in the near-surface environment, Li may be significantly depleted in soil-, stream- and even rock samples (sometimes merely 25% of the concentration in an equivalent fresh-rock sample). Therefore, quantitative XRD analysis is required to calculate the actual Li content of a sample based on its modal mineralogy.

CASE STUDY: CENTRAL ZAMBIA

Prior to our commencement of work in this area, there were minimal geochemical data (a handful of rock chip samples). We instigated the workflow outlined here, with a catchment analysis run across the licence area and the location of stream sediment samples laid out. Approximately 1 kg samples were sieved to <2 mm in the field and placed in calico sample bags; they were analysed by method ME-MS61 at ALS Geochemistry, Johannesburg. Once the results of this first phase of stream sediment samples were returned (Figure 1a), they were reviewed and two additional phases of stream sediments were laid out to narrow the search area (Figure 1b), and the potential size of the catchment that would need follow-up exploration. Soil samples were collected from pits 20–40 cm deep; they were sieved to <2 mm in the field. The soil samples were analysed on an Olympus Delta, 10–50 kV, 4W, Ta X-ray tube, pXRF instrument. Methods for data correction and handling are consistent with industry best-practice (e.g. Gazley and Fisher, 2014). The following standards were analysed in the sample stream and subsequently used to calculate a correction factor for each element: OREAS25, OREAS60d, OREAS501b, OREAS600 and OREAS623.

The exploration method employed to identify fractionated granites, and to outline a REE soil sample anomaly from an 1,831 km^2 licence in Zambia, was relatively low effort and low cost. During the first stream-sediment sample phase, 109 samples were collected; the results of which outlined three areas with potentially fractionated granites. Ninety-one phase 2 and 3 stream-sediment samples were collected to identify anomalous catchments or parts thereof. Using the phase 2 and 3 data, soil sample programmes were planned in two of the target areas. In total, 1,248 soil samples collected were collected and analysed using a pXRF instrument. This resulted in the delineation of an Ce-La-Th soil anomaly that could reflect a REE-mineralised pegmatite in the subsurface. While the pegmatite that was identified is probably not LCT-type, based on the elemental associations it is more likely an Nb-Y-F-type pegmatite, its discovery demonstrates the efficacy of this method to find pegmatites in a large search area.

HOHONU BATHOLITH, NEW ZEALAND

As previously noted, Turnbull *et al.* (2018) showed that parts of the northern West Coast, South Island, New Zealand are prospective for LCT pegmatite mineralisation (Figure 2a). Our Zambian case study uses catchment analysis to identify the number, and location, of stream-sediment samples that would be required to complete a first pass assessment of the LCT potential of the Hohonu Range. The Hohonu Range is comprised almost entirely of the Deutgam Granodiorite (part of the Hohonu Batholith), which is predominantly an alkali-feldspar megacrystic, coarse grained biotite-granodiorite with a U-Pb zircon age of 110.4 ± 2.2 Ma (e.g. Waight *et al.*, 1997).

A total of 31 stream-sediment samples are required to sample the Hohonu Range to cover most catchments <5 km^2 (Figure 2b). Sample collection is likely straightforward and efficient as many of these samples can be collected from the river flats and farmland around the margin of the Hohonu Range. Once analysed, geochemical results can be explored using element ratios (e.g. K/Rb) and transformed to account for quartz and feldspar dilution (e.g. centred-log ratio, Si normalisation). These ratios, along with normalised and transformed data could, at relatively low cost and low effort, provide insights into the prospectivity of this part of the Hohonu Batholith. Accordingly, decisions can be made on whether follow-up work is required, or whether the prospectivity of this part of the batholith is low.

CONCLUSION

Several aspects of pegmatite exploration can make it seem challenging but with the right exploration strategy, potentially mineralised areas can be rapidly and cost-effectively identified. Stream-sediment samples can play a key role in identifying fractionated granites and areas that are enriched in LCT-pegmatite-associated elements. Here, we have presented two case studies: one from central Zambia where we show how stream-sediment samples narrowed the search ellipse from an area of 1,831 km^2 to several catchments of <10 km^2. This resulted in a soil sample grid being laid out that identified a possible pegmatitic unit that was enriched in La, Ce and Th. Second, following on from the prospectivity work of Turnbull *et al*. (2018), we show how efficiently a first pass assessment of the LCT potential of the Hohonu Range might be completed with the collection of 31 judiciously located stream-sediment samples.

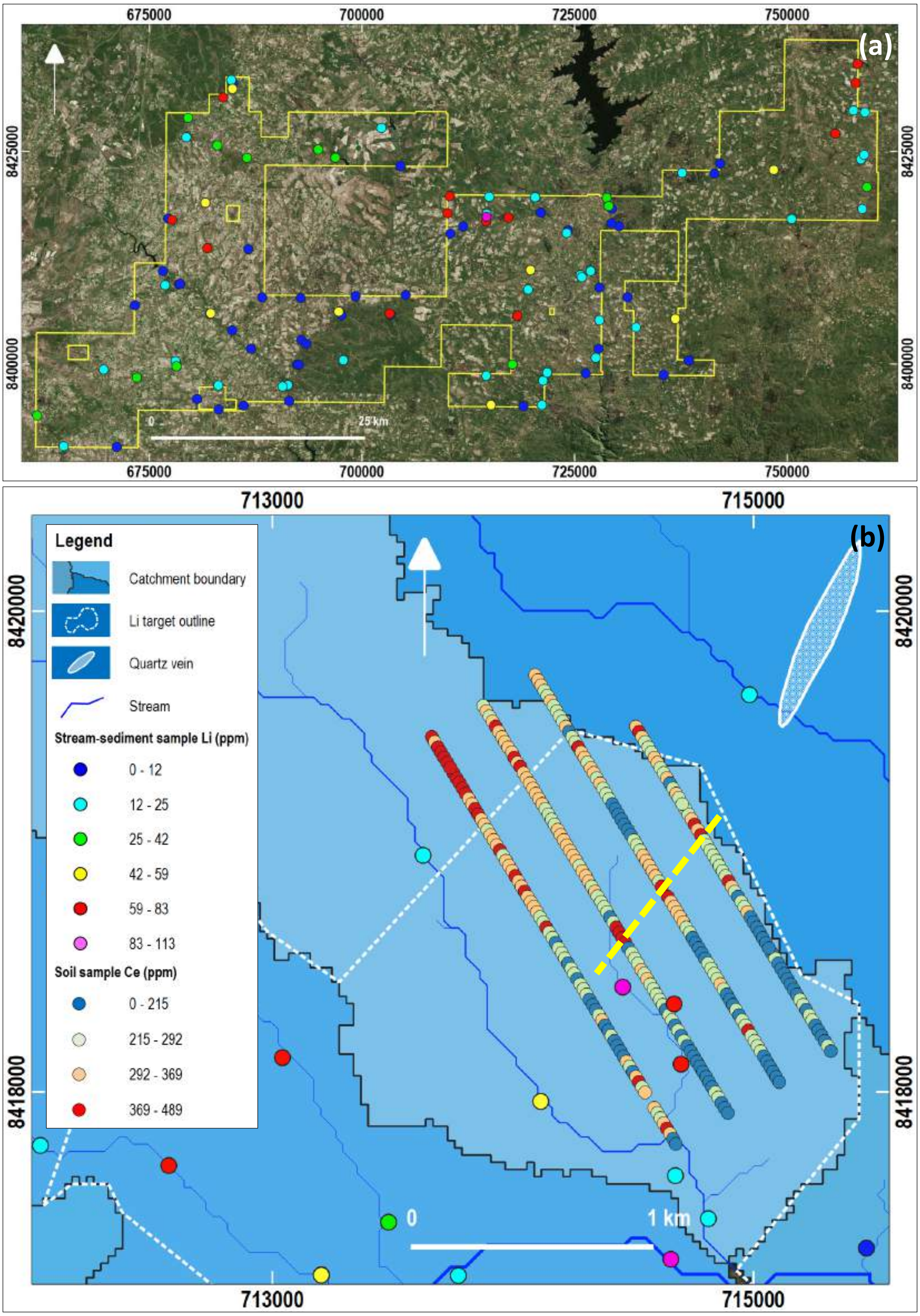

Figure 1 (a) Phase one stream-sediment samples over the entire project area coloured by Li (ppm); three areas for follow-up sampling are indicated; (b) stream sediments at target 2, after all three phases of stream sediment sampling—white dashed lines indicate extent of stream sediments with anomalous Li content as defined by the catchment analysis and samples. Soil sample grid with lines orientated perpendicular to the regional fabric coloured by Ce (ppm). The yellow dashed line indicates a NE-SW trend in Ce, La and Th.

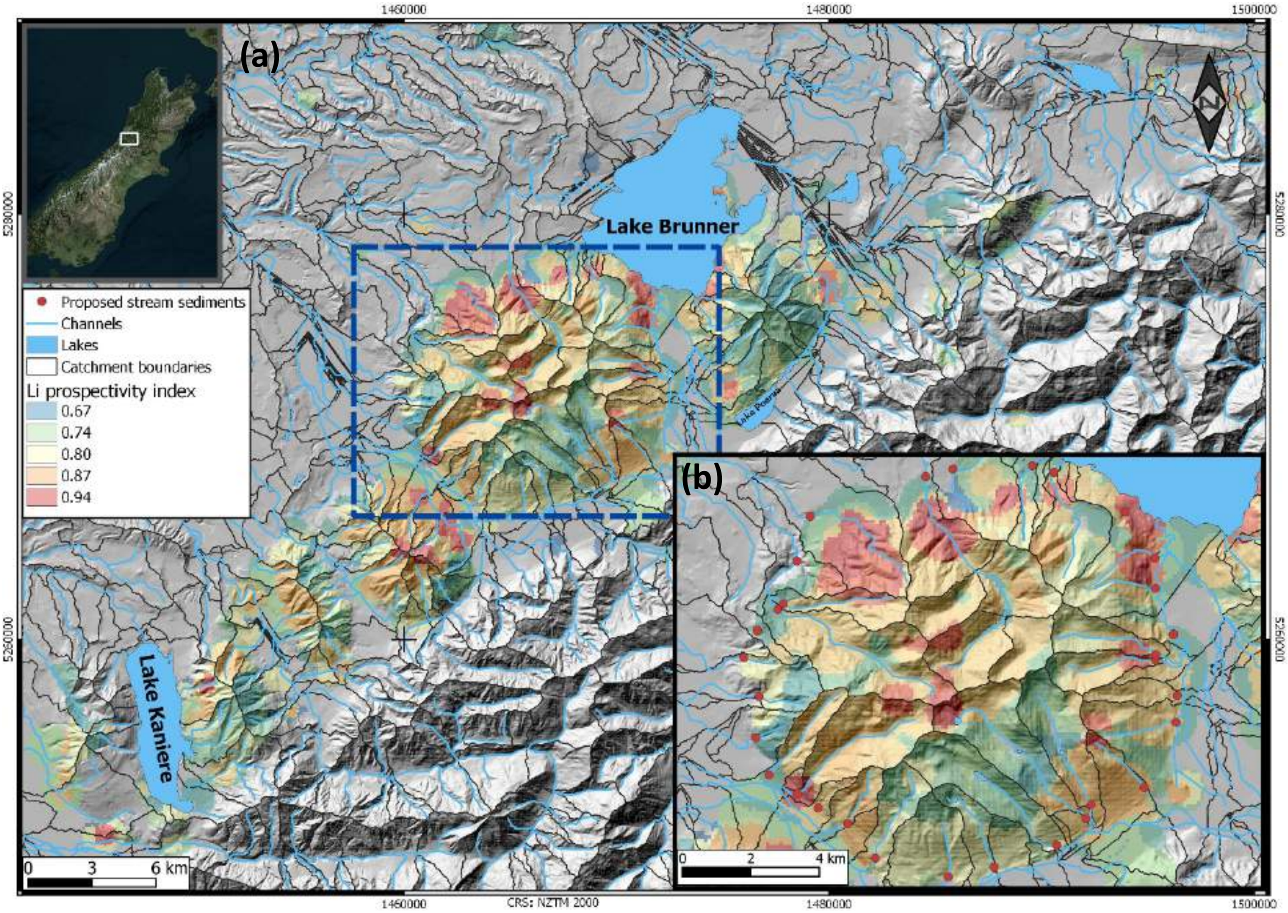

Figure 2 (a) The Li mineral potential map of Turnbull *et al*. (2018) for the northern West Coast, New Zealand, draped over a DEM (SRTM) channels and lakes from LINZ, with catchments outlined in black; (b) a catchment analysis for the Hohonu Range with an example of the stream-sediment samples (pink dots; n = 31) that could be required to quantify the anomalism in elements associated with LCT pegmatites in that batholith.

ACKNOWLEDGEMENTS

Dave Sun's efforts in drafting Figure 2 are greatly appreciated. Matt Hill (GNS) kindly provided a non-ESRI version of the GNS prospectivity work. Hamish Blakemore is thanked for his comments on this paper.

REFERENCES

Gazley, M. F., & Fisher, L. A., 2014. A review of the reliability and validity of portable X-ray fluorescence spectrometry (pXRF) data. In: Mineral Resource and Ore Reserve Estimation—The AusIMM Guide to Good Practice Monograph 30. AusIMM, Melbourne, Australia, p. 82–95.

Turnbull, R.E., Morgenstern, R., Hill, M.P., Durance, P.M.J., & Rattenbury, M., 2018. Lithium Mineral Potential in New Zealand. GNS Science Consultancy Report 2018/63, p. 209.

Waight, T.E., Weaver, S.D., Ireland, T.R., Maas, R., Muir, R.J. & Shelley, D., 1997. Field characteristics, petrography, and geochronology of the Hohonu Batholith and the adjacent Granite Hill complex, North Westland, New Zealand. *New Zealand Journal of Geology and Geophysics*, **40**, 1–17.

Wang, L. & Liu, H., 2006. An efficient method for identifying and filling surface depressions in digital elevation models for hydrologic analysis and modelling. *International Journal of Geographical Information Science*, **20**, 193–213.