Future Energy: Imaging hidden lithium-rich brines with satellite imagery.

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Summary

The salars of the Lithium Triangle in South America contain approximately 55% of the world's lithium resources (Cabello, 2021; Schulz et al., 2017). The source, transportation and concentration of the lithium-brines involves a complex mineral system that is dependent upon climate, weathering, basin closure, surface drainage, hydrothermal and groundwater systems, lithium-bearing rock distribution and geological structural control. A suite of satellite platforms, geological datasets, advanced data analytics and automated workflows has enabled the delineation and targeting of potential lithium-rich salars and paleosalars buried beneath recent sediments and volcanics.

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Introduction

The Lithium Triangle in South America is a region of tectonically driven subsidence, orogenic deserts and plateau uplift. Most of the lithium-brine is concentrated in continental basins filled within the evaporitic salts of the salars and the lithium-rich groundwaters beneath them. The genesis of the lithium-rich brines is related to the leaching and transportation by rainfall, snowmelt, groundwaters and hydrothermal fluids from a source rock (Godfrey et al., 2013; Steinmetz & Salvi, 2021). This is predominately a volcanic pyroclastic (ignimbrite) deposit, but may also be other lithium-rich rocks, such as rhyolites, andesites, dacites, pegmatites and gneissic basement (Meixner et al., 2020). The transported lithium must be concentrated in an internal, closed (endorheic) basin. Integrating detailed satellite derived morphometrics maps with the underlying geology identifies the flow-path inlet points of the drainage in relation to the ignimbrite distribution and the outlet points within a salar or potential paleosalar.

Method

Several satellite platforms have been utilised in the geological and drainage analysis of the region (Figure 1). Over 200 multispectral ASTER satellite images were processed to outline areas of hydrothermal alteration that are related to subsurface hydrothermal fluid flow and that may be associated with the mobilisation of lithium into the groundwater system (Yuan et al., 2021). A detailed structural map highlights areas of fluid localization and possible transportation along faults.

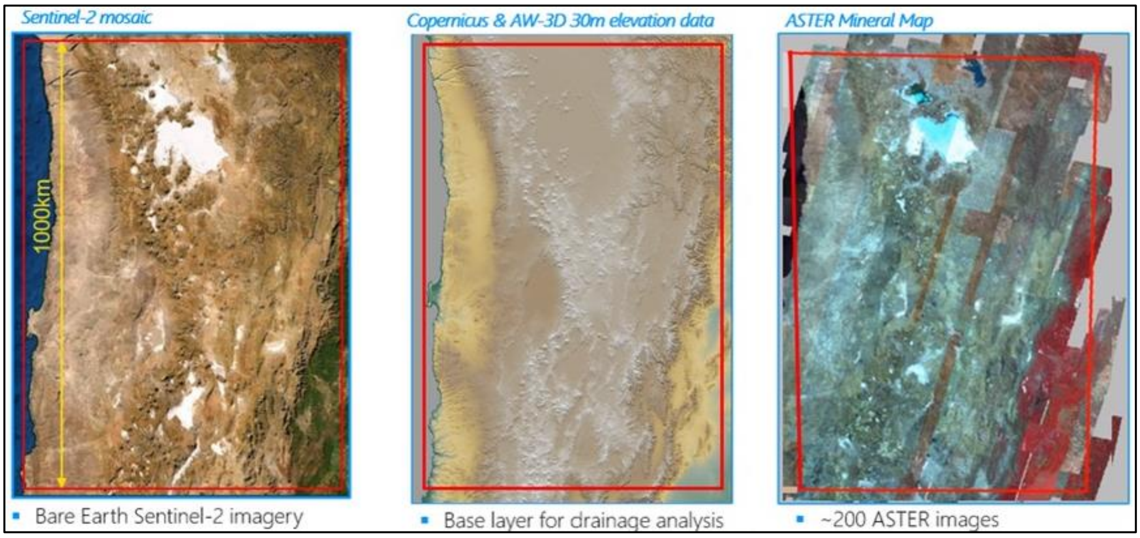

Figure 1. *The use of optical Sentinel-2 imagery for the geological mapping, Copernicus and AW3D elevation data for the drainage analysis and ASTER for multi-spectral clay alteration mapping have enabled large-footprint paleosalars to be outlined.*

The lithium-rich source rocks where ranked based upon their relative lithium content, distribution and leaching/mobilisation potential ranging from; ignimbrites, rhyolites, dacites, andesites, granites, pegmatites to basement gneiss. Figure 2 shows the Source-to-Sink model for the mobilisation and deposition of the lithium-rich brines.

The drainage derived from the elevation data was analysed to highlight the closed (endorheic) basin required for lithium-rich brine concentration, with ‘flat-areas’ and slope models being derived to outline potential paleosalar regions that may exist under recent sediments away from the known salars.

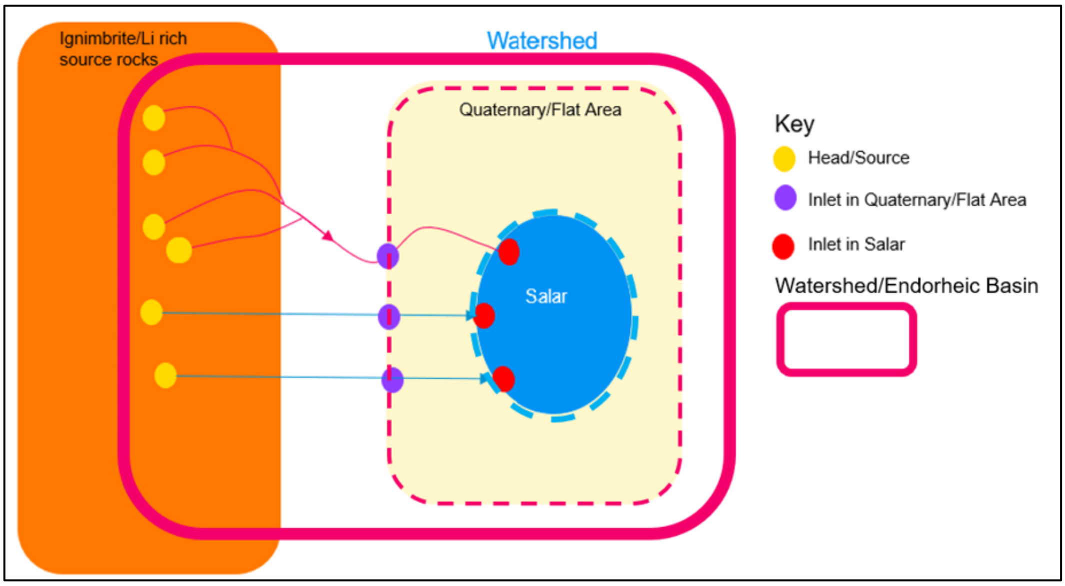

***Figure 2**. A model detailing the key attributes in the lithium-brine mineral system and how it equates to a Source-to-Sink model.*

Analysis of the drainage inlet and outlet points with reference to the underlying ranked lithium-source rocks enables flow-path inlets to be ranked by their lithium potential. Where a mapped stream network enters a salar or other potential lithium sink (at an inlet) the upstream drainage area (or watershed) and the proportion of the lithium-rich source rocks in the watershed was determined. Larger drainage areas with a higher proportion of lithium-rich source rocks upstream of an inlet are favourable as there is more opportunity for lithium to be leached into the stream network. Inlets were used as seeds points to backpropagate upstream to find these watersheds and using various GIS tools determined the proportion of lithium-rich source rocks within each watershed. Inlets to a salar or other lithium sinks link the lithium source (proportion of lithium-rich rock in the watershed), transport (stream network) and sink (the unit which the river drains into). Figure 3 shows an example area from Salar de Atacama. Figure 4 shows an example of the lithium source rock ranking from Salar de Coipasa.

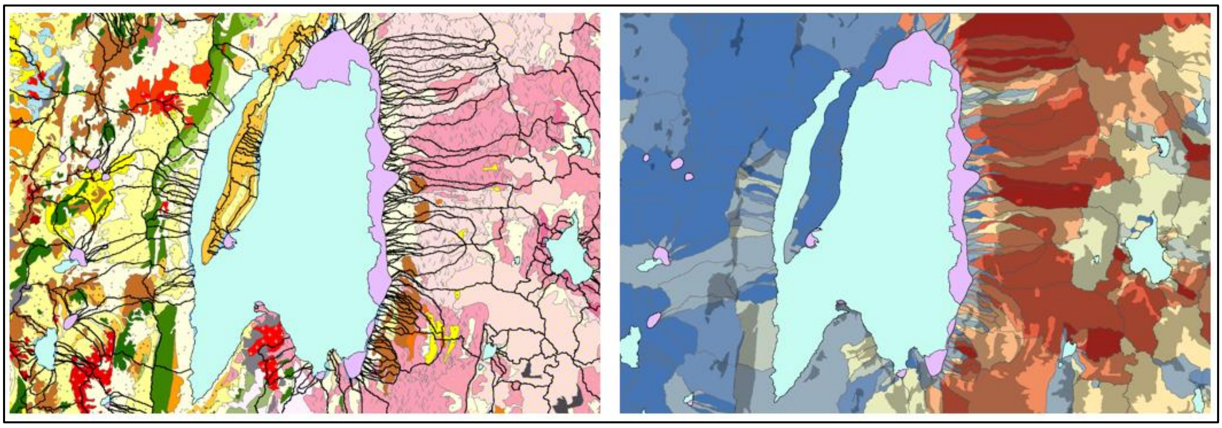

***Figure 3.** Salar de Atacama is shown in the sky-blue in the centre (~50 km wide). The left-hand image has the geological interpretation and the watershed areas of the rivers within the endorheic basin (black polygons). The lilac area to the east of the salar is a Quaternary flat area as outlined by the elevation data. To the right the ranked lithium-rich source rocks (shades of red) have numerous inlets into this flat area and therefore make it of interest for exploration.*

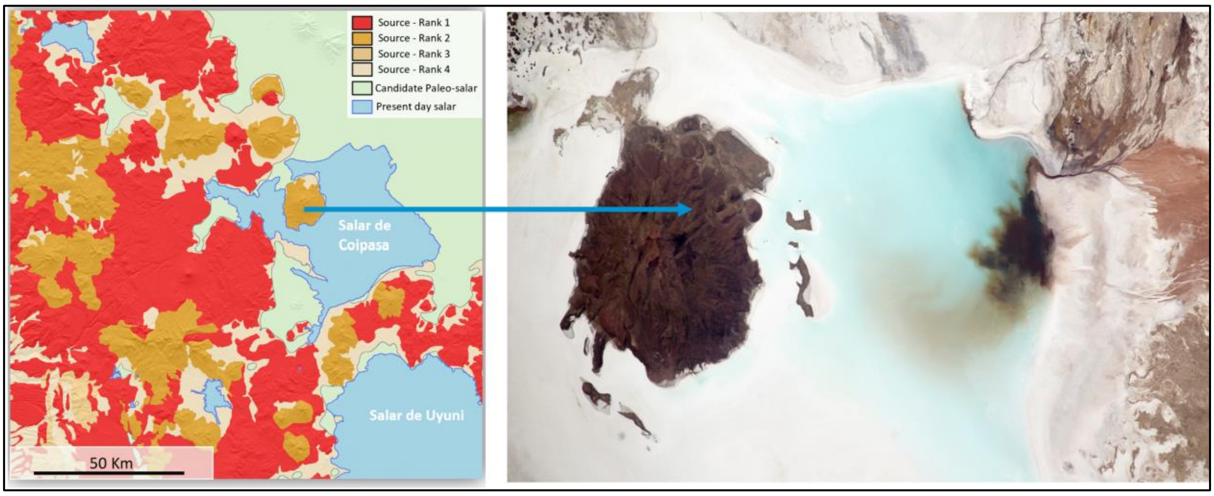

Figure 4. *Lithium source rocks in the Salar de Coipasa and Salar de Uyuni region are ranked by their lithium content and ease of liberation/mobility. Lithium-rich ignimbrites have the highest rank.*

Conclusions

Combining the data sets in a CGG developed advanced data algorithm has enabled a heat map to be derived which delineates areas of lithium-rich brine potential. This has been produced for the entire Lithium Triangle and shows lithium-brine potential for new areas of exploration interest both within known salars and within recent sediment covered paleosalars.

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