LithoSpace - a Geochemical Data Platform for Extra-terrestrial Mineral Exploration

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SUMMARY

The importance of visualising spatial data from extra-terrestrial bodies such as the Moon, Mars and asteroids is increasing with the renewed interest in space exploration and its associated search for usable resources. LithoSpace provides the digital infrastructure to visualise extra-terrestrial spatial data including points of interest and samples collected, along with corresponding geochemistry and other analytic data. Based on LithoSurfer's proven technology for terrestrial data types, we show how the advance of data analytics and exploration tools can benefit the expanding frontiers of extra-terrestrial resource exploration. Having highly detailed relational data models enables the platform to analyse disparate data types and find relations and patterns in data collected from rovers or probes in relation to satellite imagery and topographic features. Having all data in a standardized format then provides researchers and explorers the choice to use advanced algorithms for more detailed and automated exploration of those datasets.
In this study we confirm the original findings that all Apollo-11 samples are of basaltic geochemical composition but more importantly we demonstrate, using standardised and cleaned geochemistry data that already exists for the moon, that slight variations in geochemical composition can be visualized and pointed out by using LithoSpace's unique cloud-based geochemistry tools.

Key words: geochemical, spatial data, extra-terrestrial, minerals, resources, space mining

INTRODUCTION

Since Apollo-11 successfully returned moon surface samples over 50 years ago, geologists have had a tiny window into the geochemistry and mining potential of the Luna surface. However, with less than 400 kg of samples collected from a relatively small area (NASA, 2022) the full view of the moon's potential to yield minerals and elements important for establishing a permanent presence on the moon and eventually for our growing needs has been elusive. Studies on moon samples and earth analogues have hinted at the prospect of more extensive mineralisation (Colson, 1992, Richardson et. al 2012) but the limited number of currently available moon samples is not sufficient to confirm this assumption. More sample missions will be necessary in future to help us obtain a better understanding of the mineral potentials on Moon and Mars to ensure the future colonization of those extra-terrestrial bodies will be possible as a self-sustainable mineral source must be established to ensure survival and growth of those human outposts.

With the recent launch of Artemis, a vastly greater amount of data will be collected from remote and physical sources leading to more discoveries including the potential of mineral discoveries and extra-terrestrial mining. However, like most data sets collected over decades, data gets stored in different formats and is not structured in a consistent way to enable it to be queried, interrogated, and compared.

Unstructured data across multiple repositories is not a problem exclusive to extra-terrestrial data. Fortunately, Lithodat has tackled this problem for Earth data (Geochemistry, SIMS, Fission Track, U/Th/He and others) by creating a platform providing structured data models for spatial geoscience data. The LithoSurfer platform can be used for any spatial data including the data already collected from space and also that to be collected.

Storing and ingesting extra-terrestrial geoscience data

Lithodat's free public platform for storing and analysing terrestrial data (Ausgeochem: https://ausgeochem.auscope.org.au) is becoming established as a fundamental tool for looking at data across a range of geochemical techniques (Boone et al. 2022a, Boone et al. 2022b). With its detailed structured data models created in association with leading scientists in their fields (e.g., Boone et al. 2022b) users can upload their own analytical data (using simple drag and drop) or use existing public data to view relationships previously hidden. Figure 1 shows a selection of currently available tools that allow data to be synthesised.

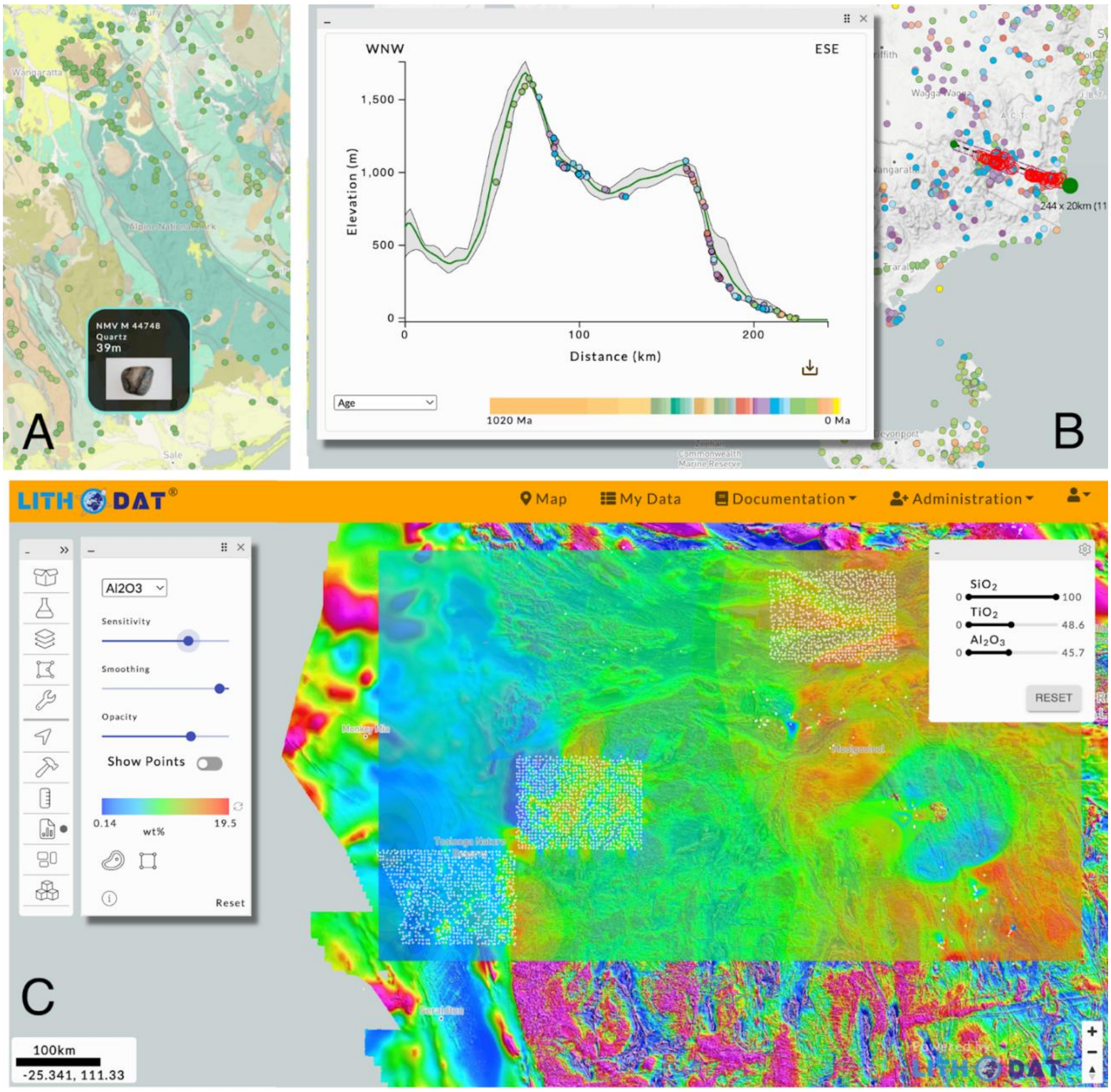

Figure 1. Data from Lithodat's structured relational database can be selected, filtered, and then analysed using the tools provided. A) Filtering samples that include images with a queryable geological map in the background. B) Analysing the Apatite Fission Track data from Southeast Australia using a swath profile to show the relationship between elevation and Fission Track age. C) Contouring Geochemistry data using an Inverse Distance Weighting method (Data WA 2022) showing the relationship between underlying magnetic anomalies (Geoscience Australia, 2022) and Al2O3.

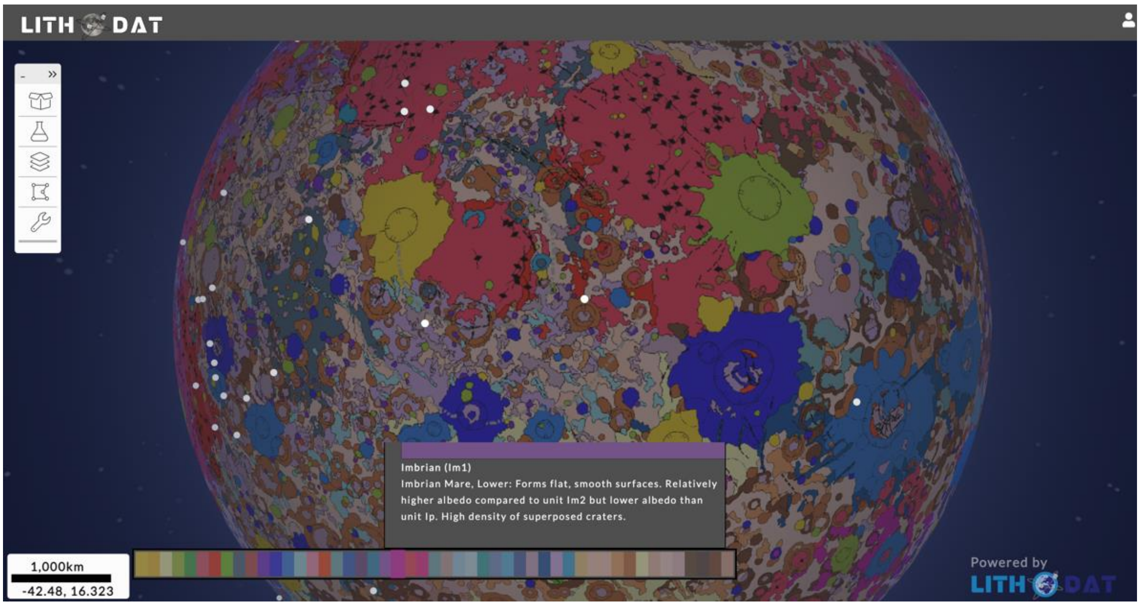

Figure 2. LithoSpace displaying the geology of the moon (USGS, 2022) and landing and crash sites (NASA, 2022) for Earth derived crafts over the last 50 years. Over the coming decades the amount of data available to view will dramatically increase and hence the need to be able to view and store the data in ways that make it easily available.

Lithodat's LithoSpace is now being used to look at all geochemical data that has been acquired by all six Apollo lunar missions and published by NASA (NASA 2022, Figure 2 and Figure 3). Our team of subject matter experts cleaned and normalised this data and imported it in our customised relational geochemistry data model so that it can be viewed and analysed within LithoSpace. As additional geochemistry data is found or created it can be easily uploaded through our Extract Transform Load (ETL) pipeline and once the data is in a relational context it enables the user to find, visualise, analyse, and extract the data with ease. LithoSpace's Open REST API also enables the direct data flow from machines acquiring data in the field or in the laboratory adding it directly to the relational database. This means data from future rover and handheld analytical instruments is available in real-time and can be analysed at mission control or in any research part of the scientific team.

Analysis of lunar geochemistry data

Special lunar overlays such as a global lunar geology map (Figure 2) or elemental concentration maps (such as Fe or Ti using the existing tools shown in Figure 1C) can be created and help with future planning and interpretation of analysed geochemical signatures. Any raster of interest can be added to LithoSpace's UI after it has been appropriately georeferenced and prepared. We store these additional background maps in our own cloud-based geoserver instance where it will be served as a fully queryable WMS layer. The combination of custom made background maps together with geochemical data from our database can be used together to calibrate automated algorithms identifying new potential deposit locations on Moon and Mars.

In this study we report on 47 geochemical analyses of rock samples that were collected during the Apollo-11 mission (Figure 3). All Apollo-11 geochemical results from NASA's published sample catalogue (Kramer et al., 1977) were extracted, cleaned, standardised and imported into our LithoSpace data platform. The built-in geochemical analytical tools for Rare Earth Elements (REE) and Trace Elements or Ternary plots (Figure 4) confirmed previous findings that those compositions are of basaltic composition. Although this is not a new observation, the exercise was to show how improved and easy to use analytics and on-the-fly interpretations and rock classifications can be carried out in the LithoSpace platform. We believe that using these tools future studies will have increased understanding of rock compositions and mineralisation processes on our distant neighbours.

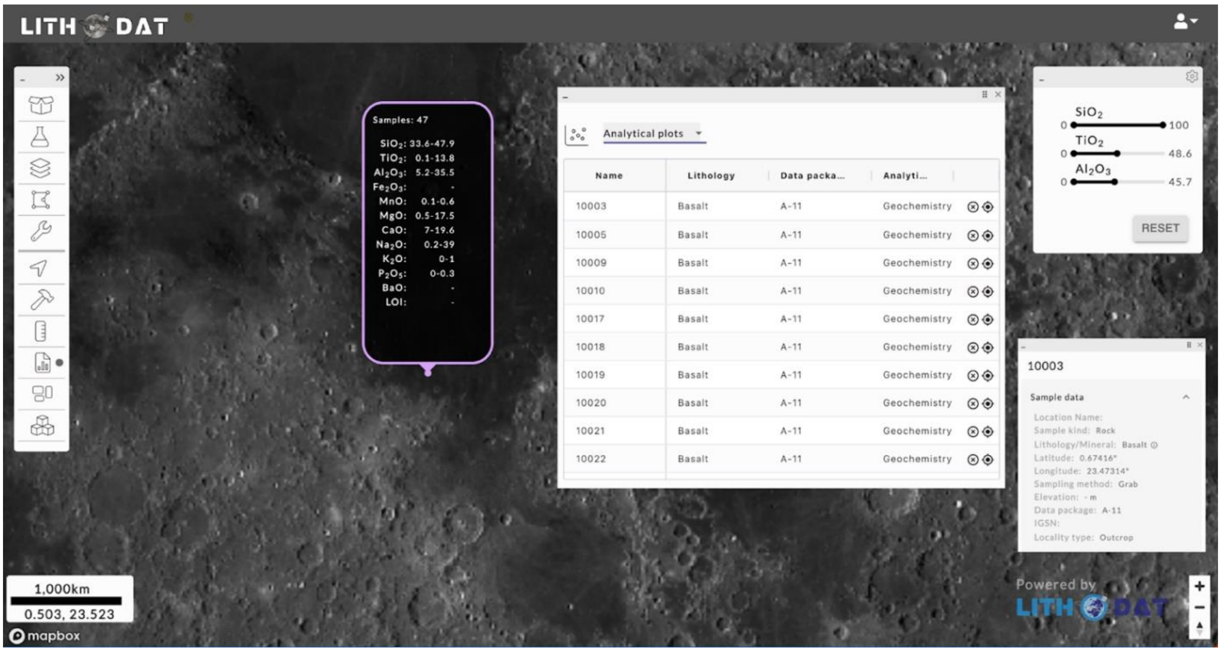

Figure 3. Map showing the location and summary oxide data for samples collected by Apollo-11 (Kramer et al., 1977, NASA 2022).

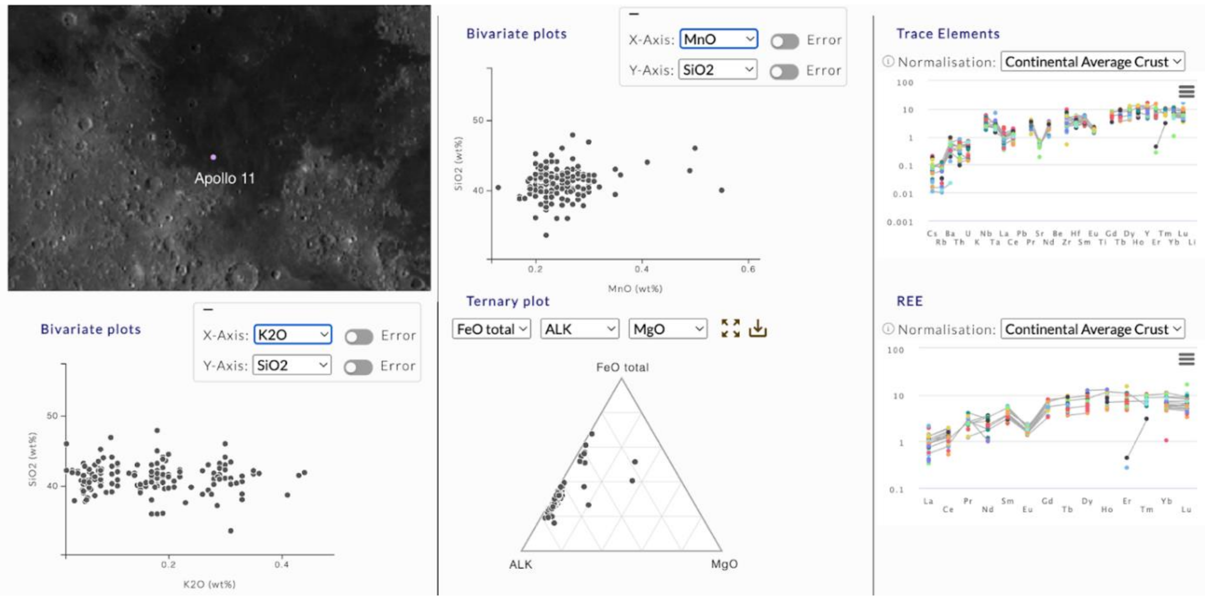

Figure 4. Geochemistry plots for the 47 analyses from rock samples collected from the Apollo-11 mission (Kramer et al., 1977, NASA 2022). LithoSpace's geochemistry tools enabled us to summarise and compare the results from multiple labs and confirm the basaltic composition of all Apollo-11 rock samples from the Moon's surface.

CONCLUSIONS

Even though lunar exploration for minerals is still in its infancy, LithoSpace can help users access the latest technology and data science to assist them with the tentative next steps. We demonstrated that LithoSpace's tools can be utilised to classify geochemical compositions by confirming the basaltic composition of all Apollo-11 lunar samples. Using the set of robust tools developed for terrestrial samples the influx of data from the next series of planned missions can easily be visualised and analysed leading to new discoveries and even unlocking the hidden resources of our extra-terrestrial neighbours. Advanced machine learning and artificial intelligence can be easily applied to our standardised and cleaned datasets, advancing the interpretation and creation of models for future space exploration.

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