TRACKING LITHIUM DEPOSITS WITH A REMOTE SENSING-BASED FRAMEWORK

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ENERGY TRANSITION

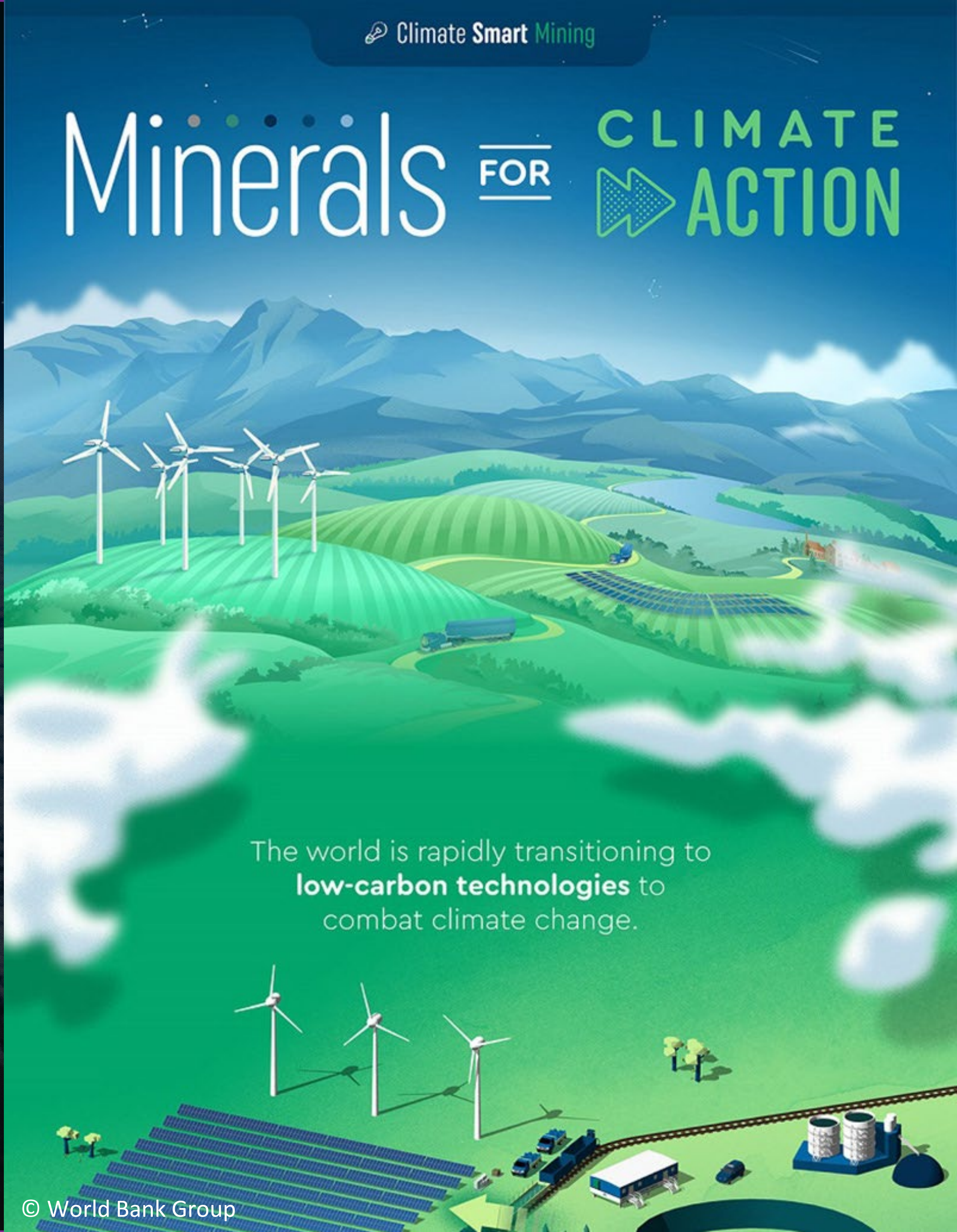
- Global energy sector's shift from fossil fuel-based systems to renewable energy sources like **wind** and **solar**

- Aim to reduce energy-related **greenhouse gas (GHG) emissions** through various forms of decarbonization → **Net-Zero**

- Increase in importance as investors prioritize **environmental, social and governance (ESG)** factors

MINERAL AND METAL NEED

- COP21 Paris agreement – **below 2°** by 2050
- **3bn tonnes** minerals/metals required
- Demand for battery metals
  e.g. lithium: **500% rise** by 2050



LITHIUM

- Lithium is sourced from:
  1. Hard-rock pegmatites
  2. Continental brines
  3. Hydrothermally altered clays

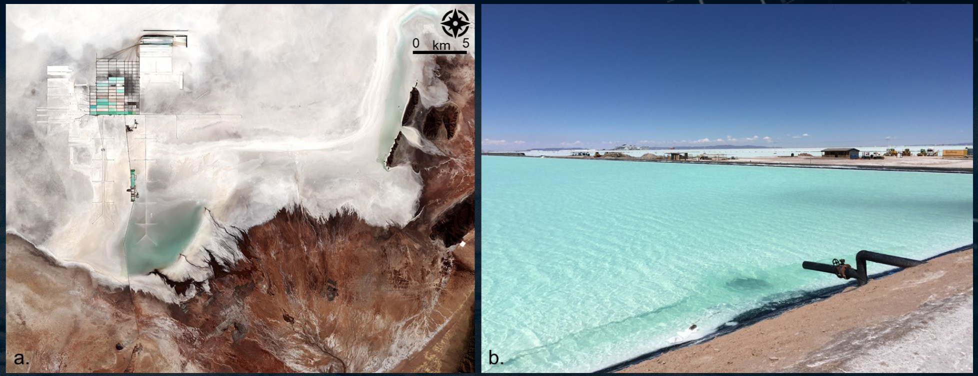
- The first three producers lie within the South American Lithium Triangle
  1. Bolivia – 21 million tonnes resources
  2. Argentina – 19.3 Mt
  3. Chile – 9.6 Mt

LITHIUM BRINES – CORNWALL AND THE LITHIUM TRIANGLE

- Recognised in 1864 within warm brines (51°C; 680 l/min) entering mines
- Derived from biotite alteration and leaching of granite
- Fluid flow influenced by NW-SE fault zones

➢ Can remote sensing map geothermal brines associated with lithium?

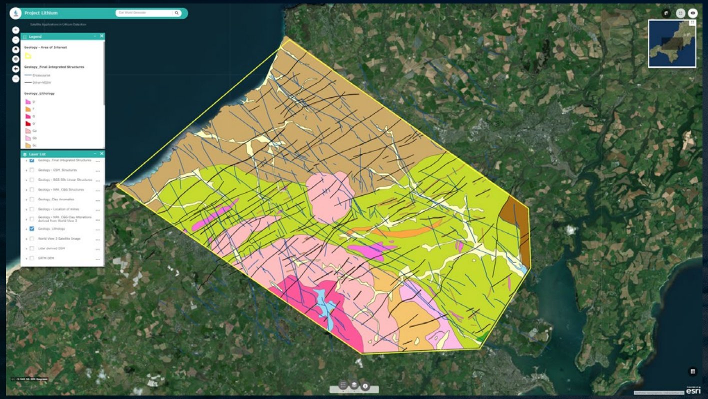
➢ What are the environmental constraints?



- Found in basins of salt lakes
- Water (rich in lithium) flow to the salars and then evaporated, concentrating the minerals
- Over long time periods (~Ma), high-density Li brines collect in a nucleus

➢ Can remote sensing be used to create a consistent and seamless methodology for tracking lithium mass?

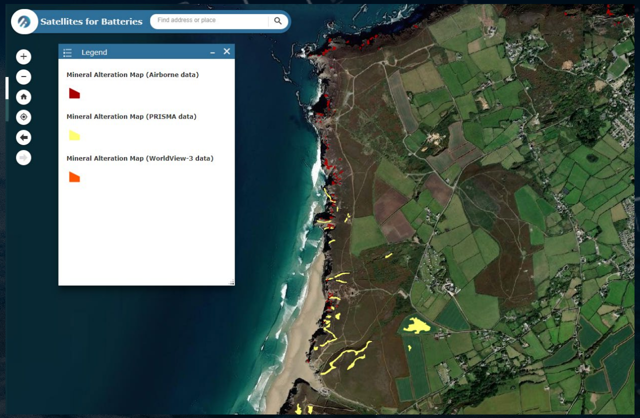
CORNWALL – ALL ABOUT REMOTE SENSING PROXIES

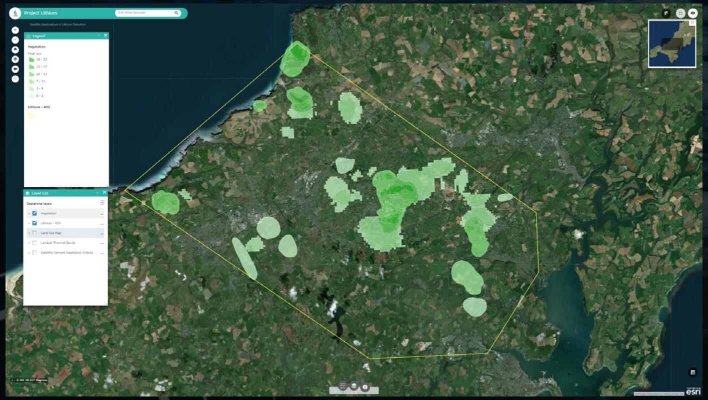


Faults
- Digitalisation existing maps
- Lineament mapping (SRTM, S2)
- OBIA (magnetic, radiometric)
- Experimental DL (SRTM, S2)

Mineral alterations

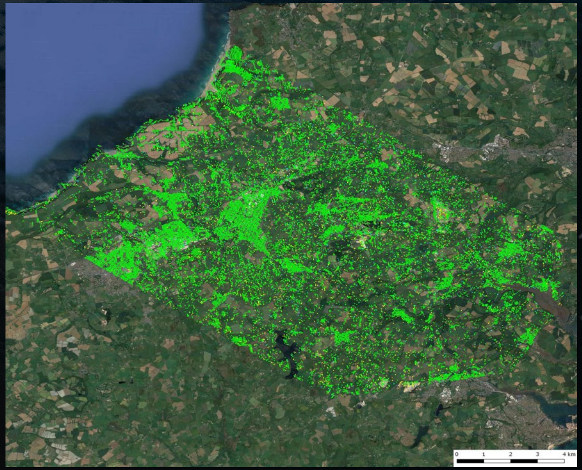
Clay-minerals & reference
- Hi-res WV3-SWIR
- ASTER
- PRISMA
- Airborne hyperspectral





Vegetation anomalies
- Hi-res land cover classification (WV3)
- Land surface temperatures (L8)
- Vegetation indices (S2)

Surface displacements
- C-band (S1)
- L-band (Palsar)



Rossi et al., "An earth observation framework for the lithium exploration", IEEE, 2018

CORNWALL – EXPERT KNOWLEDGE (PHASE I)

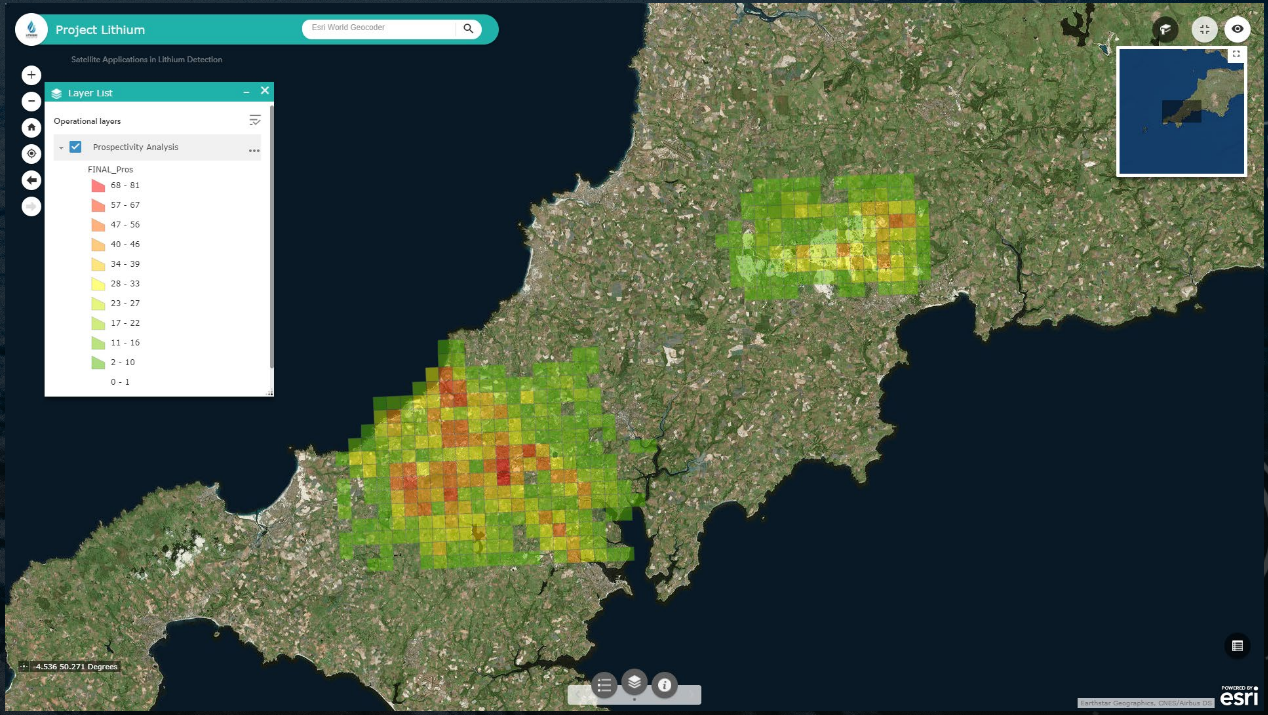
ground campaign

↓

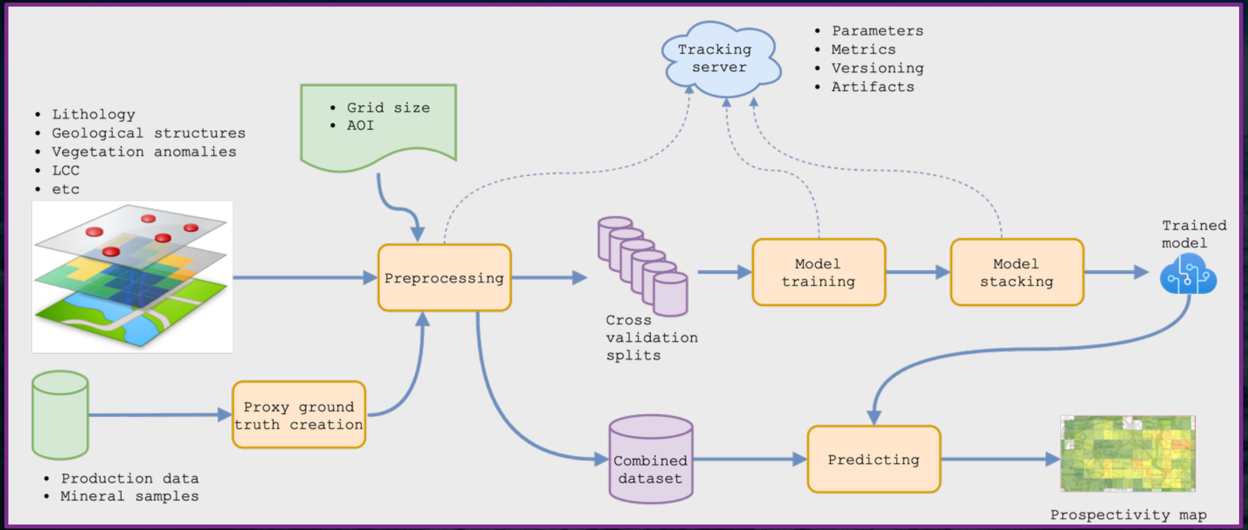
proxies weighting

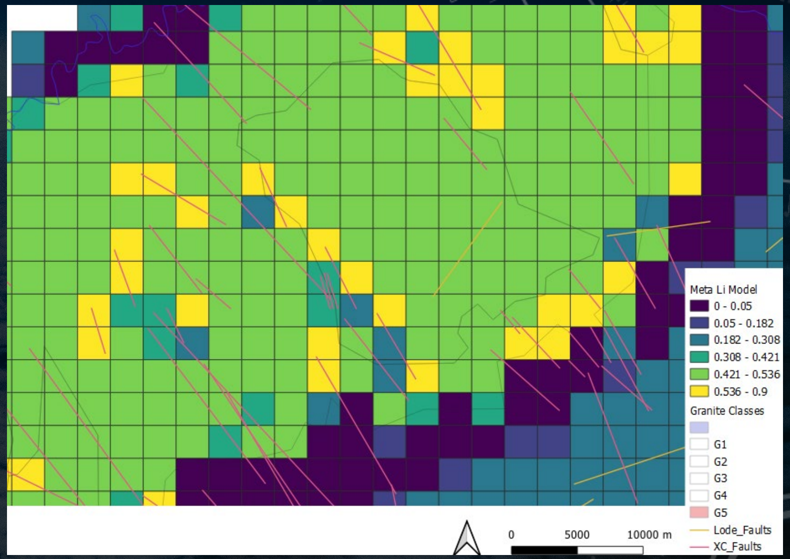
↓

prospectivity map



CORNWALL – MACHINE LEARNING (PHASE II)





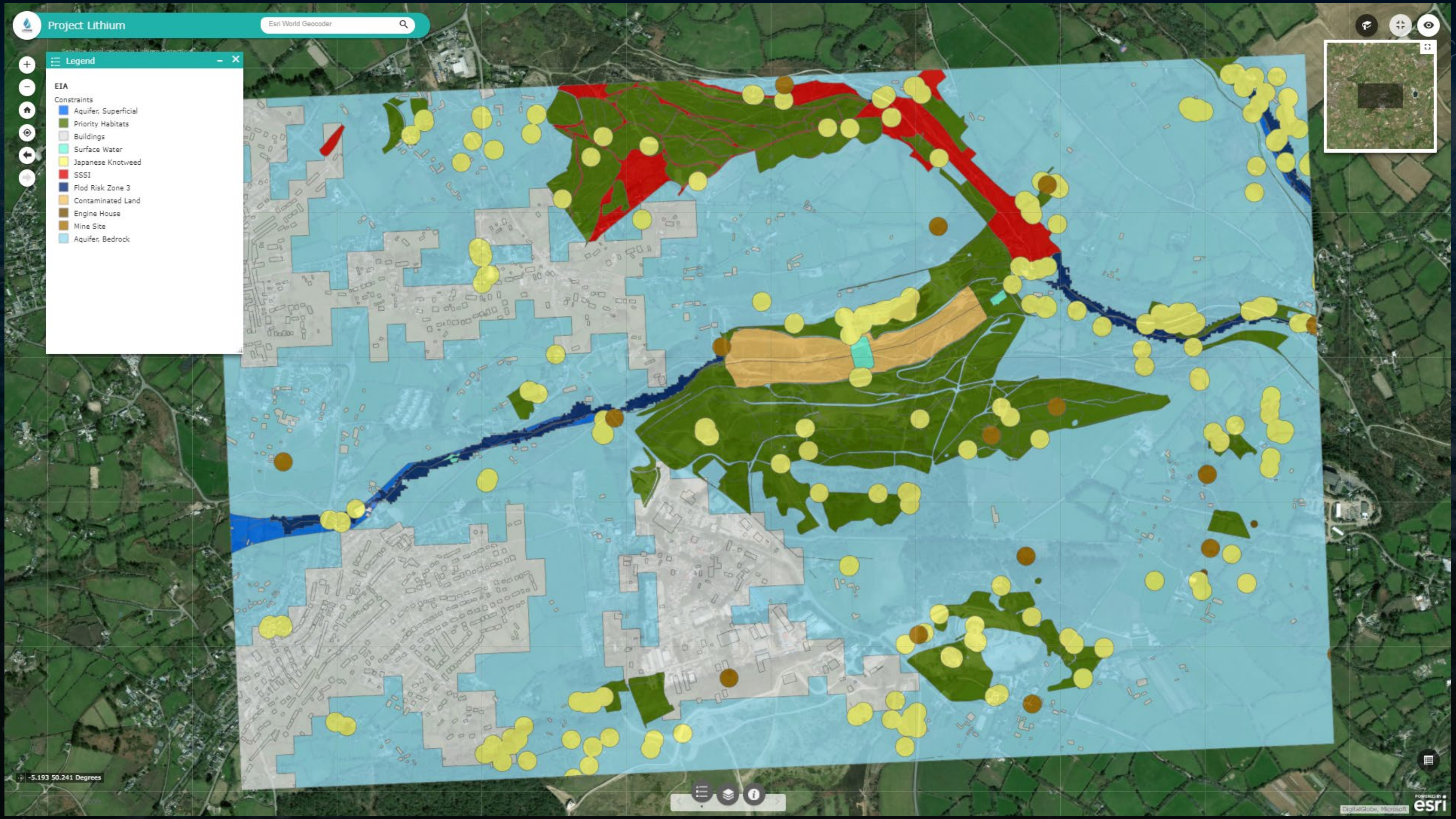
- **Machine learning framework** to derive prospectivity – value of **AI4EO**

- Sparse ground truth – Li samples and historical mining data
- Shallow ML (*model ensembles*: aggregate predictions) to avoid overfitting

- Li resides in minerals known as **micas** - the more enriched micas are associated with granites of type G5

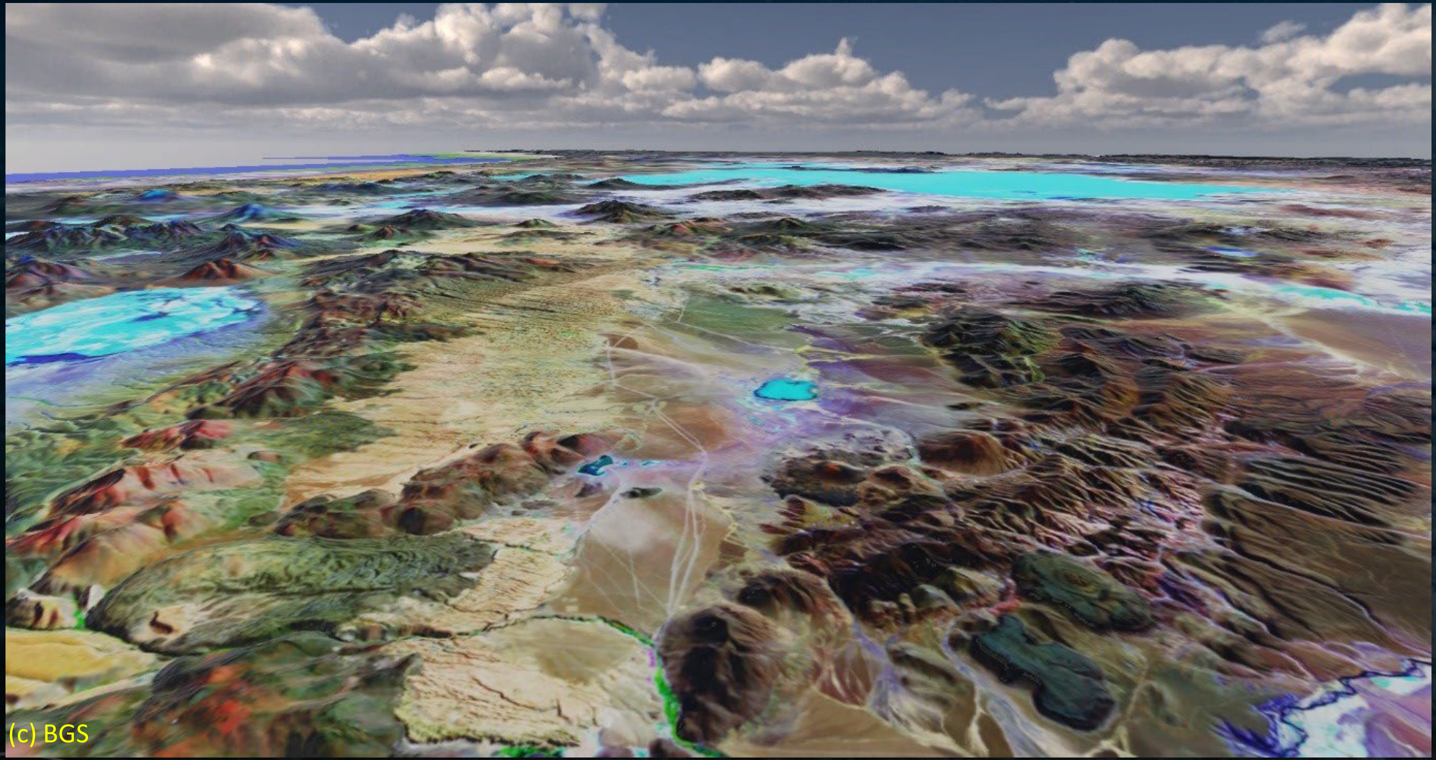
- Li identified in locations where G5 is known to outcrop and the model has recognised inter-granite boundaries
- Li mineralisation looks to coincide with cross-course faulting

CORNWALL – ENVIRONMENTAL CONSTRAINTS



- Land Cover
- Land Use
- Risk Maps
- Local Surveys

BOLIVIA – OVERALL FRAMEWORK



Virtual fieldwork with Geovisionary Software

- Evidence-based model and more general **hydrogeological framework** that employs **openly available satellite remotely sensed data** to describe the source of lithium and its movement in the environment
- Provide "fit for purpose" systems of **reporting** for Li brine resources

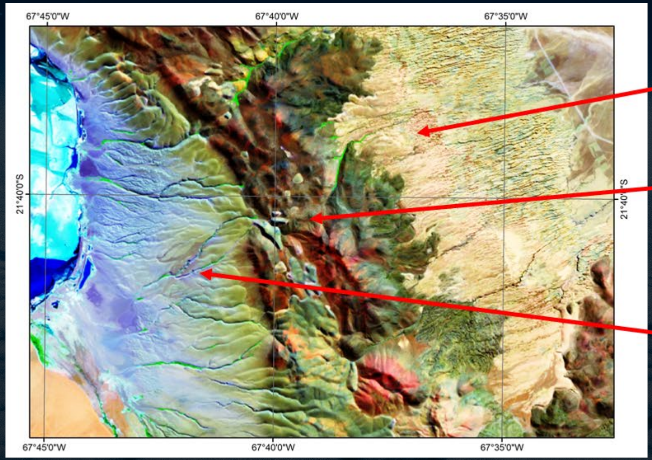
Rossi et al., "Framework for Remote Sensing and Modelling of Lithium-Brine Deposit Formation", Remote Sensing , 2022

BOLIVIA – GEOLOGY

- Sources of lithium are the **recent volcanic rocks** and **derived unconsolidated sediments**

- **First stage**: derivation of the **3D geological model**

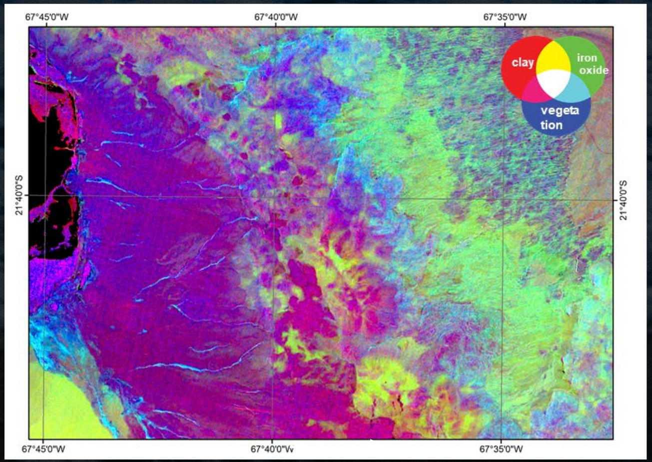
- Integration and interpretation of **optical remote sensing data** and **products** (e.g. ratios) with complementary input datasets

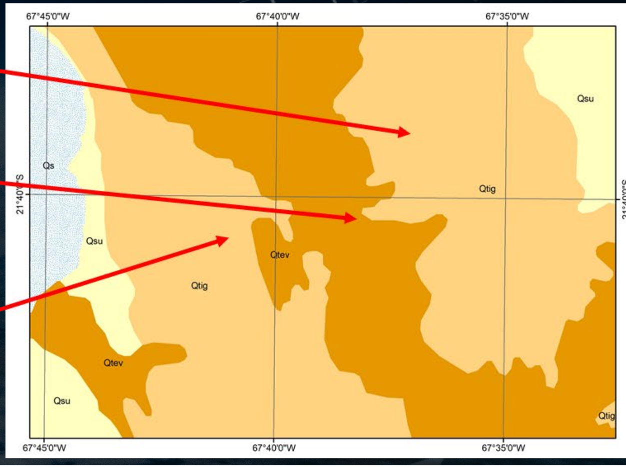


ignimbrites under the lavas

lavas

ignimbrites on top of the lavas: therefore not the same geological unit





Geology 1:250 000

	Qs	*Salt deposits (Holocene and Pleistocene)*
	Ql	*Lacustrine deposits (Holocene and Pleistocene)*
	Qtev	*Stratovolcano deposits (Holocene to Miocene)*
	Qtig	*Ignimbrite (Pleistocene to Miocene)*

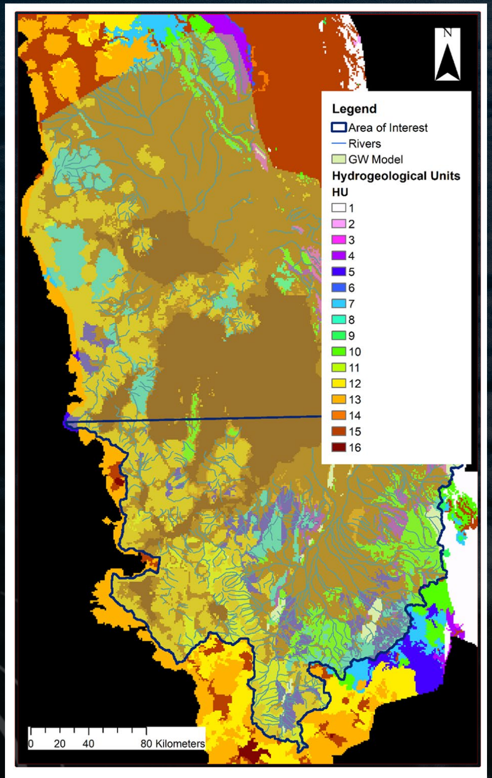
- Output: **enhanced geological map** → **Second stage**: translation into an **hydrogeological attribution map**

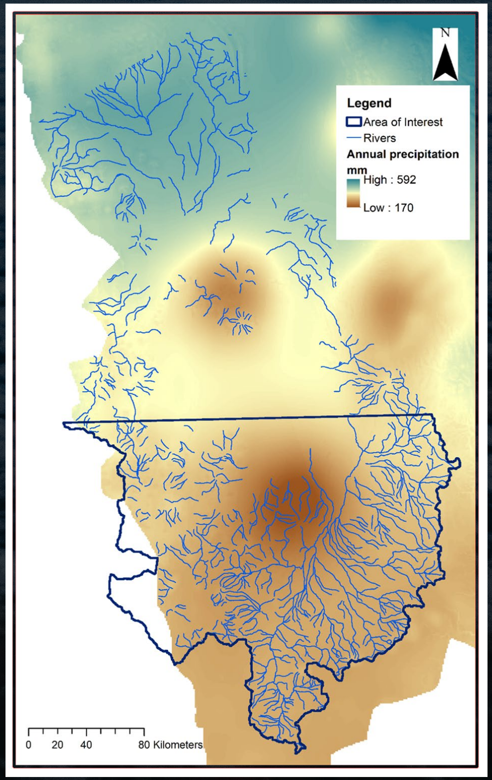
BOLIVIA – HYDROLOGY

- Quantification of the **amount of lithium reaching the salar** and **how long it takes to accumulate**

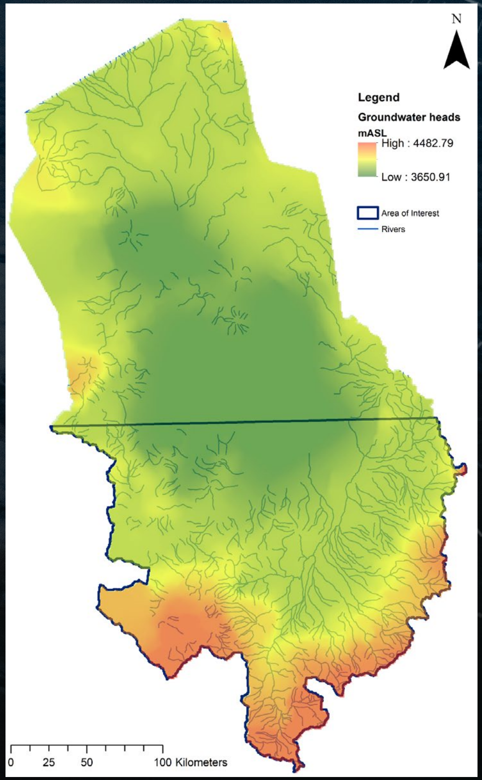
  → Third stage: **groundwater flow** and **particle tracking model** of the Uyuni watershed

- DEM
- River Network
- Land Cover Classification
- Soil Map
- Evaporation
- Rainfall





- Salars in the system act as **low points** attracting groundwater outflow



MODFLOW output

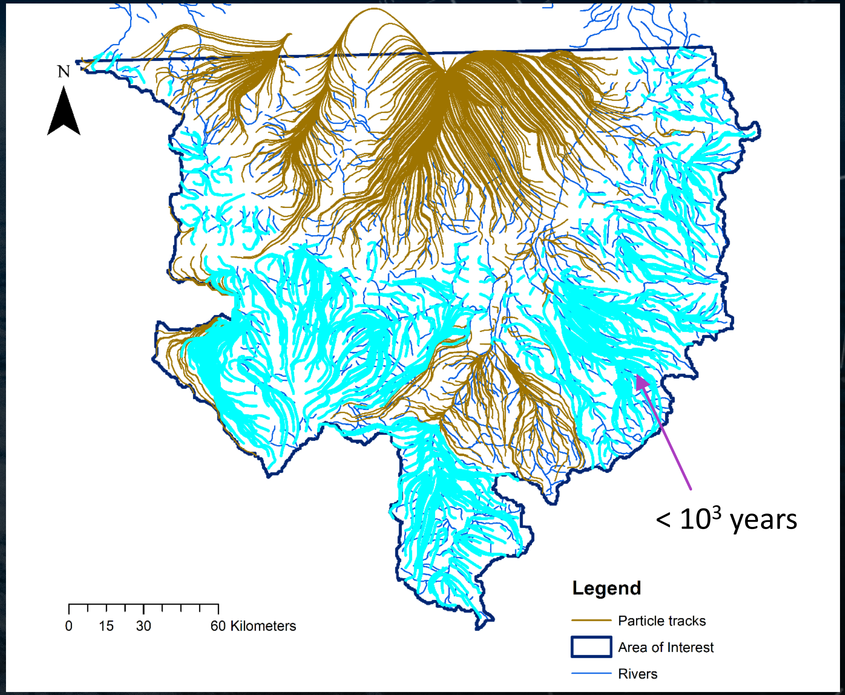
BOLIVIA – MASS BALANCE

particle tracking → **groundwater flow paths**

conceptual modelling → **distribution of Li-bearing rocks**

conceptual modelling literature review → **exchange coefficients to determine water/rock interaction**

→ **lithium mass arriving at the salar**



➔ In the time of travel (~**10^4 years**) sufficient lithium can be leached from the rock mass to provide the likely lithium concentrations in groundwaters of the order of **10 mg/L**

CONCLUSIONS

- Remote sensing is a powerful technology to support and complement existing frameworks linked to
  - Lithium-brine exploration
    - Intersection with data science and/or geology
  - Lithium-brine genesis
    - Intersection with hydrology and geology

- Pilot-plant testing currently ongoing in Cornwall to extract lithium from micas – Cornish Lithium
- Pilot-plant testing currently ongoing in Bolivia to extract lithium sustainably (Direct Lithium Extraction) – YLB

thank you for your attention!

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