

The Lemont GeoLithium Project

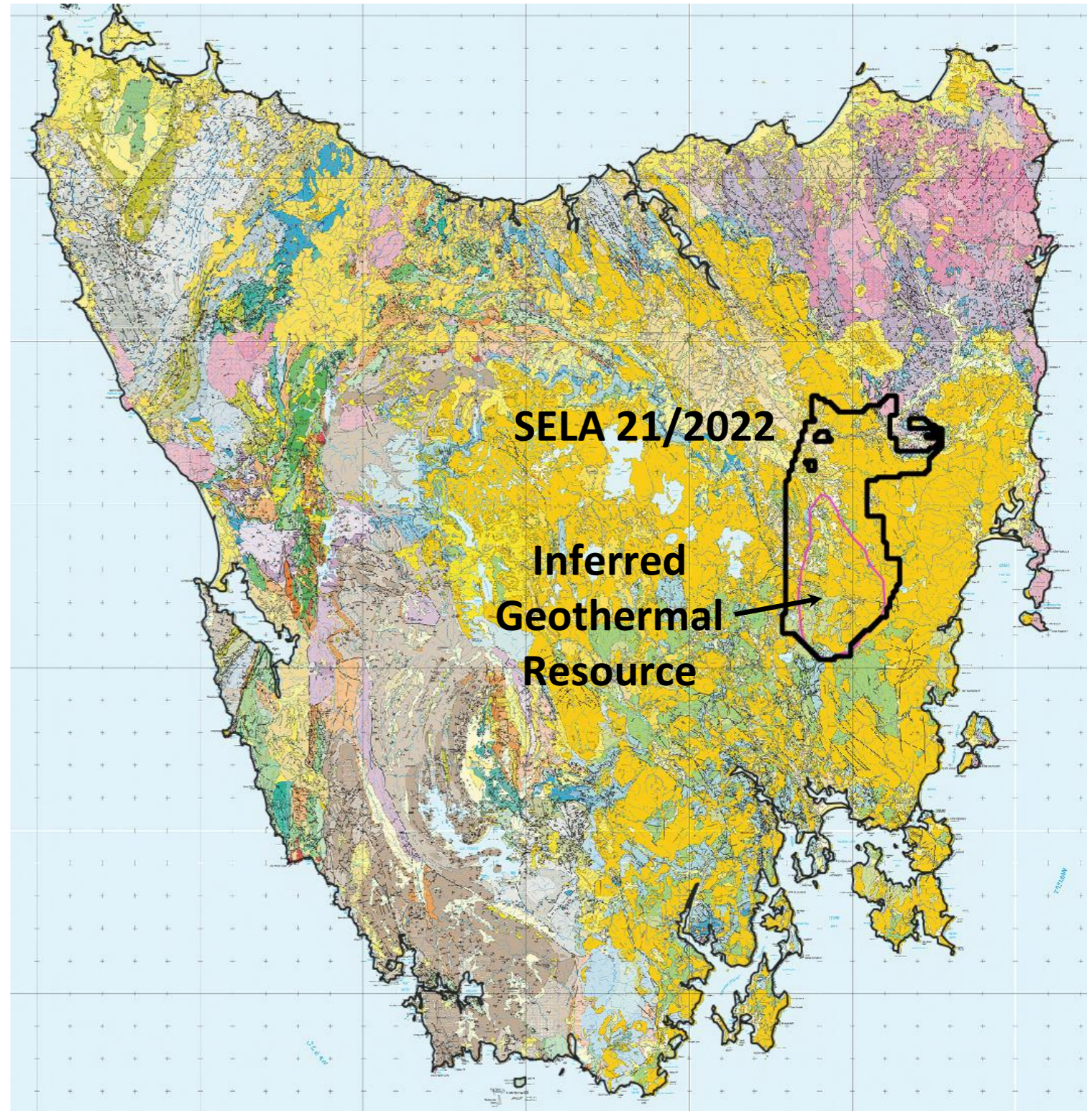
*Direct lithium extraction
and electricity from
geothermal brine*



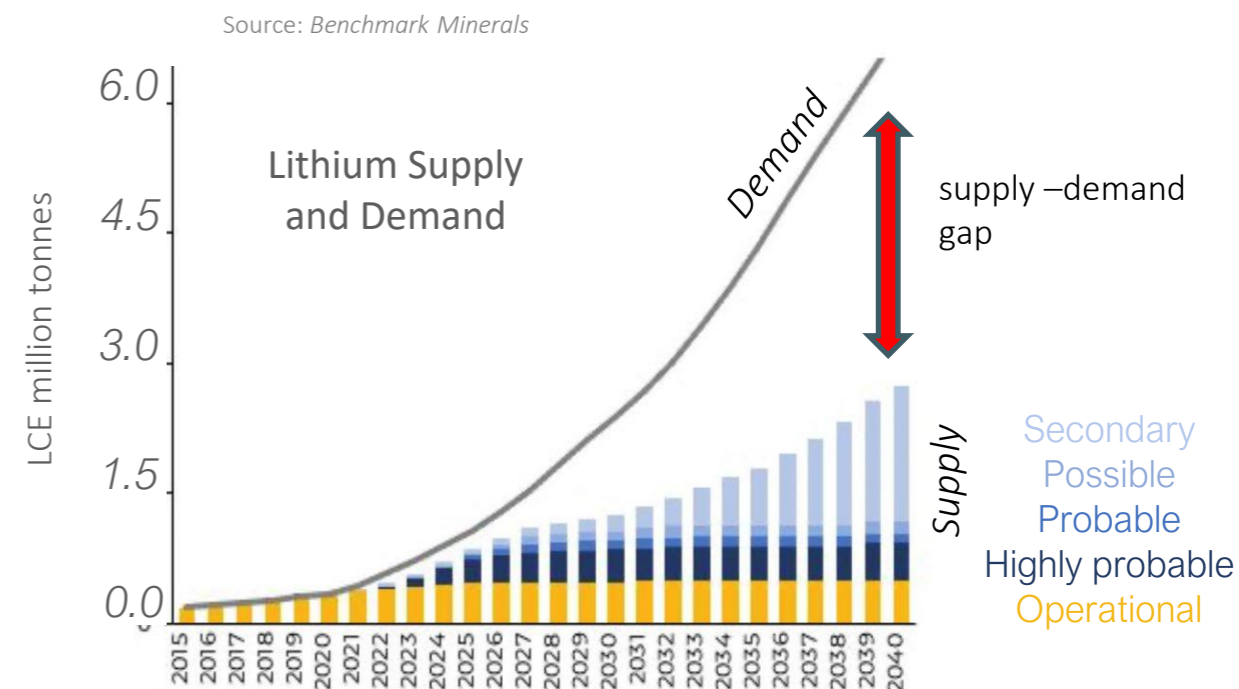
Image: AusLAMP low resistivity zone at 7km depth

*Geoscience Forum, Tullah
1 December 2022*

- SELA 21/2022 is a combined Cat_6 (geothermal) and Cat_1 (metals) application.
- The aim is to extract lithium from geothermal brine, using electricity generated from geothermal energy with excess power to the grid.
- The required elements for a successful operation are:
 - Heat
 - Lithium
 - Flow rate



- Lithium has the highest electro-chemical potential of all metals. It will continue to play a major role in the electrification of ‘everything’.
- Lithium currently mostly comes from Australian hard-rock mining and South American evaporative playas.
- **Increasing demand for lithium has led to the identification of large resources in geothermal and oil-field brines.**
- Lithium is used in two main forms: Lithium carbonate (Li_2CO_3) and lithium hydroxide monohydrate ($\text{LiOH}\cdot\text{H}_2\text{O}$).
- Lithium in brine is described in mg/l or in mg/kg (\equiv ppm) Li. For our purposes here, these are equivalent. As a commodity, it is described as either Li or LCE (x5.323).

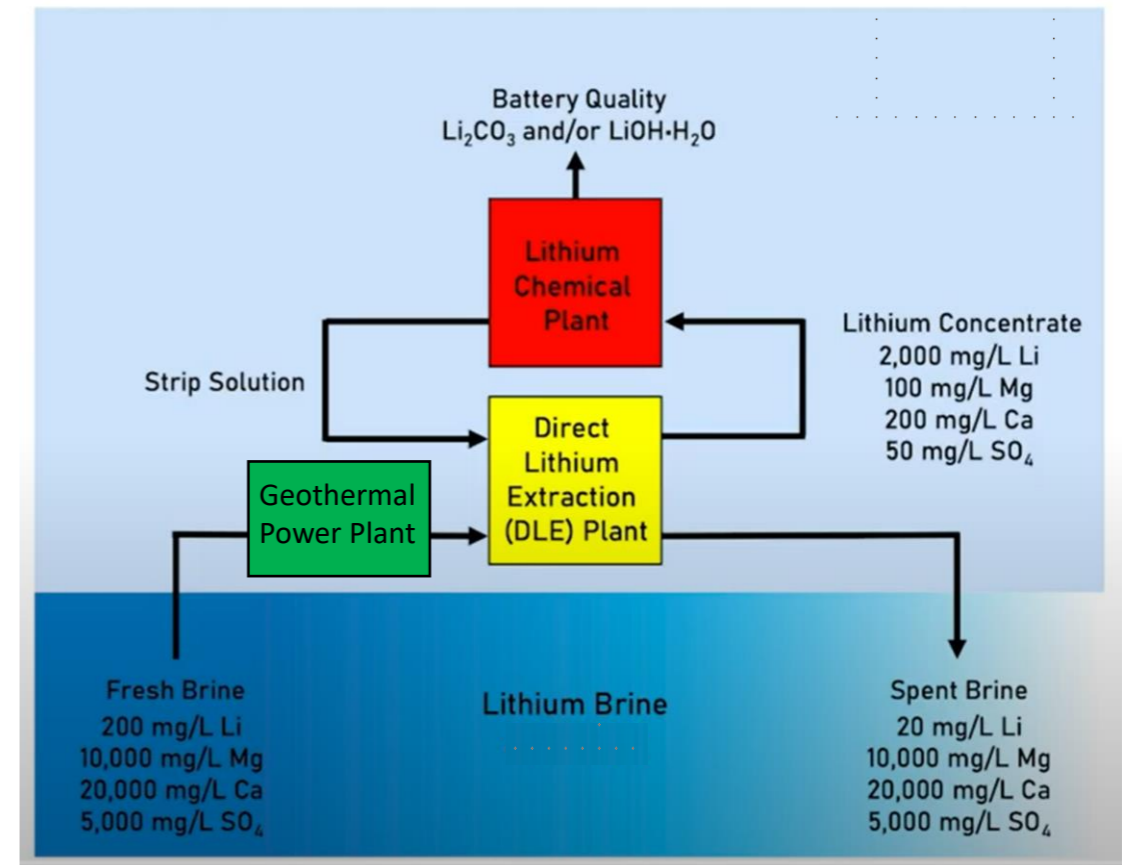


	Deposit Type	Typical Grade	Examples
Hardrock	Pegmatites	1.5-4% Li_2O	Greenbushes, Aust
	Hectorite	0.4% Li_2O	Sonora, Mexico
	Jadarite	1.5% Li_2O	Jadar, Serbia
Brines	Playas / Salars	400-1500 ppm Li	Salar de Atacama, Chile; Salar de Hombre Muerto, Argentina
	Geothermal	100-350 ppm Li	Salton Sea, USA; Upper Rhine Graben, Fr & Ge; Cornwall, UK.
	Oilfield	100-500 ppm Li	Smackover oilfield, Arkansas, USA

Sources: BGS, Jade Cove

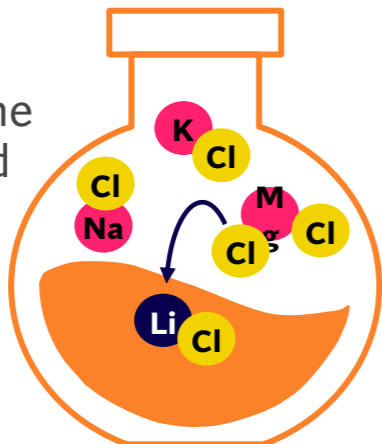
Direct Lithium Extraction (DLE)

- Direct Lithium Extraction or **DLE** describes a group of technologies used to extract lithium from brine.
- DLE is the ‘game-changer’ for geothermal and oilfield brines.
- Globally, there are now well over seventy DLE operations and projects, including several lithium-in-geothermal brine.



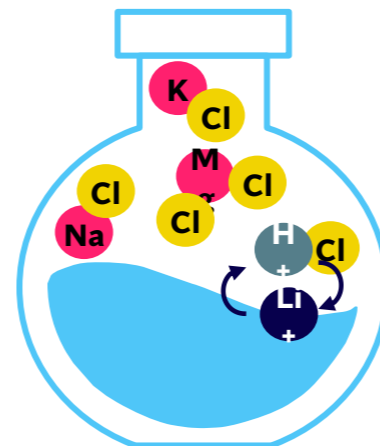
Sorption

LiCl molecule in brine physically adsorbed onto sorbent and removed using strip solution



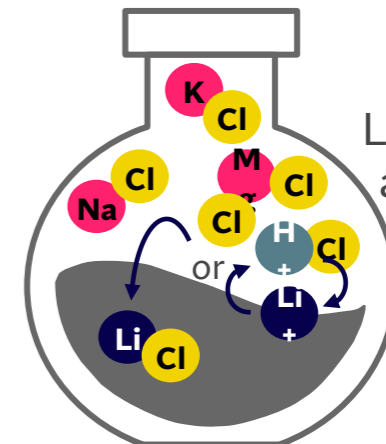
Ion Exchange

Li⁺ ion in brine chemically adsorbed into solid ion exchange material and swapped for other positive ion



Solvent Extraction

Liquid phase with adsorptive or ion exchange-type properties removes LiCl or Li⁺ from brine



- As well as adding more supply, DLE has an excellent environmental / sustainability rating.
- DLE delivers a high-grade, high-purity product suitable for battery manufacture.
- Extracting only heat and lithium (and possibly other metals) before re-injecting back into the ground, a geothermal + DLE operation has low, possibly even zero CO₂ emissions.

Electricity Generation

Acre for Acre GeoEnergy project footprints barely affect other competing interests like hiking, farming, hunting, or someone's backyard view.

LAND USE
BASED ON ACRES/IGW



Lithium Mining and Extraction

LAND USE

BASED ON ACRES PER TONNE LCE

Evaporative playas-----
Hard-rock mining-----
Geothermal brines-----



CO₂ EMISSIONS AND WATER USAGE

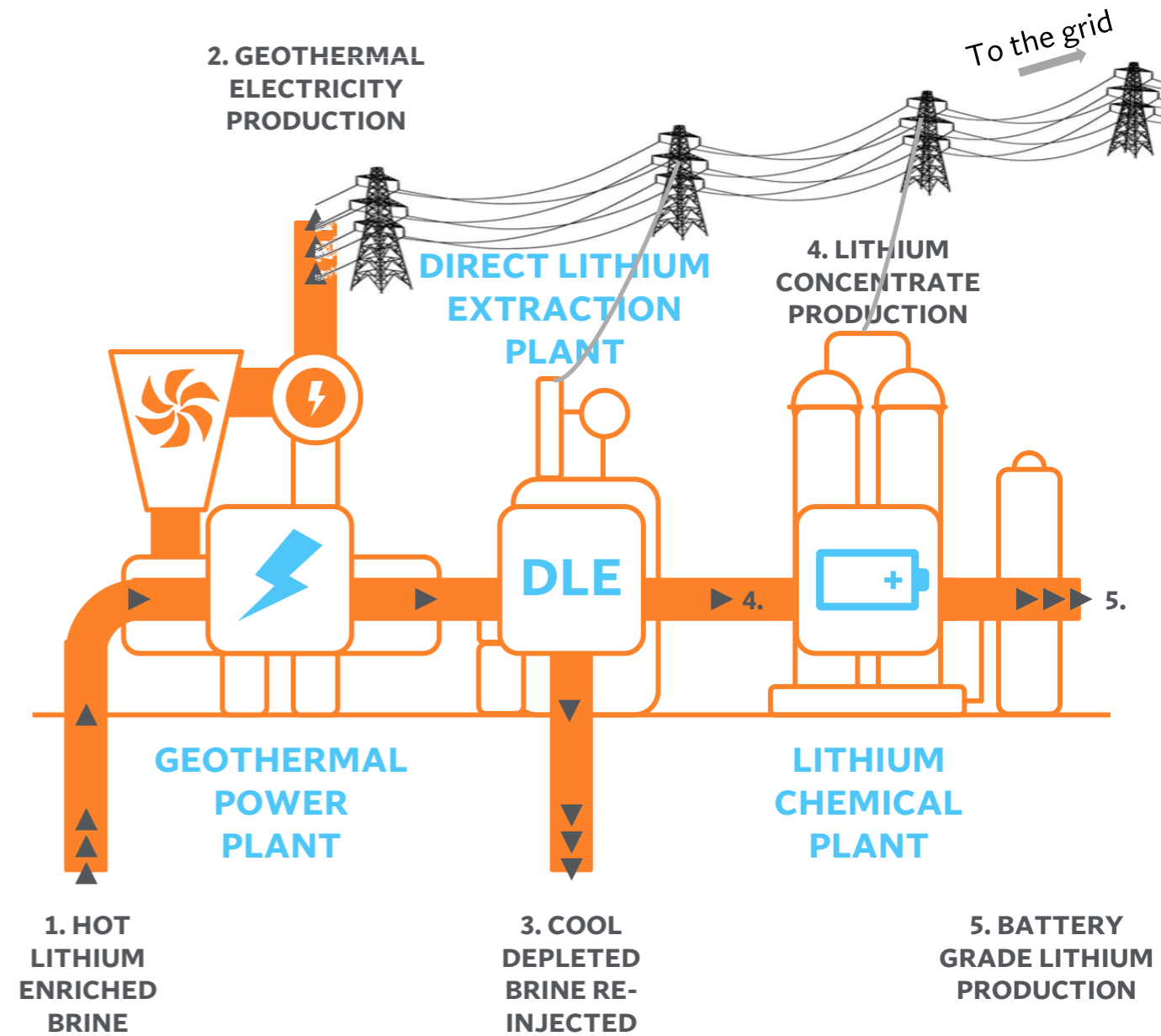
	Hard rock mining	Playa evaporate	Geothermal brines
Emission of CO₂ (per tonne of lithium)	15,000 kg	5,000 kg	0 kg
Use of water (per tonne of lithium)	170 m ³	469 m ³	3 m ³

Lithium sourced from geothermal brines has no emissions, little water consumption and by far the smallest surface footprint.

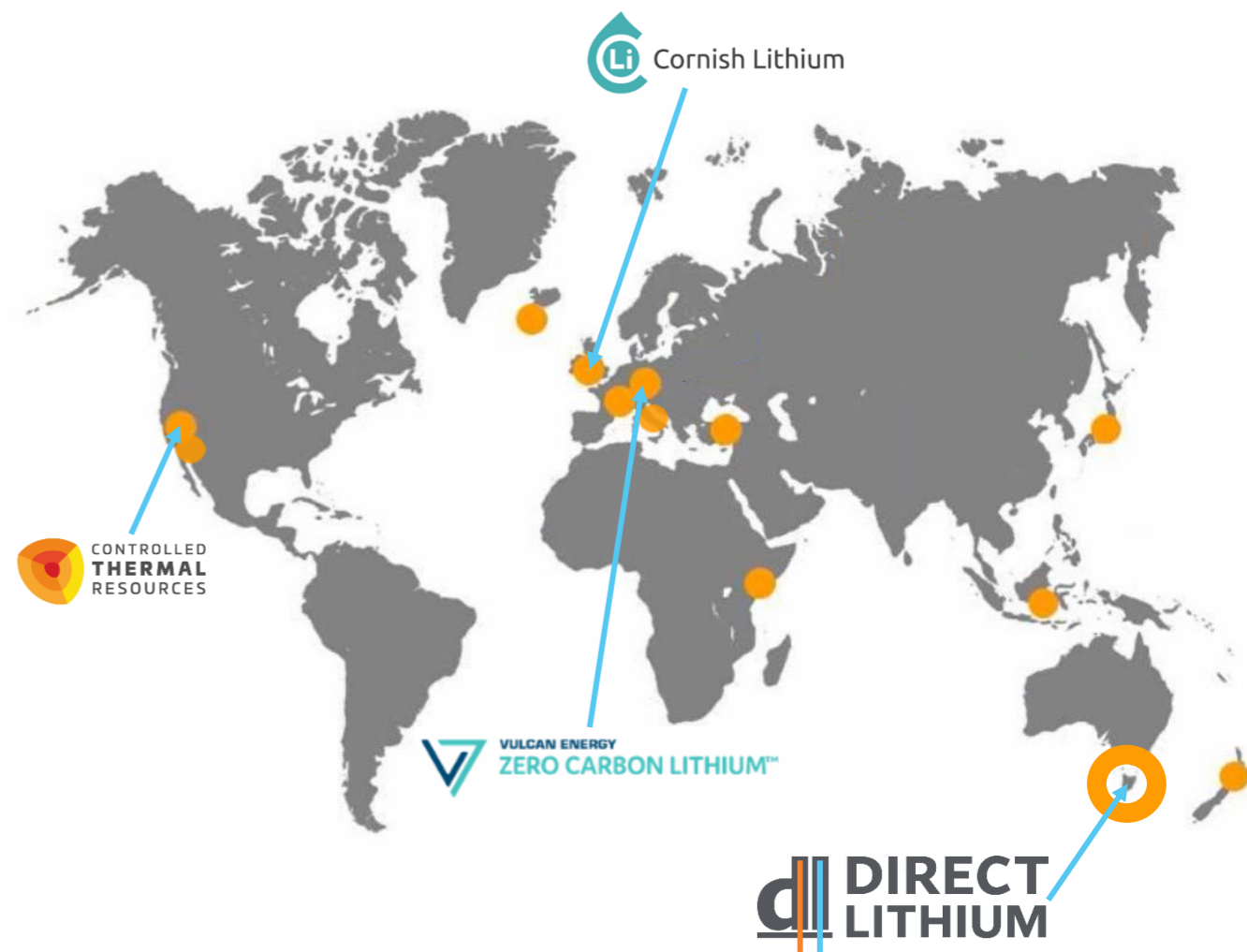
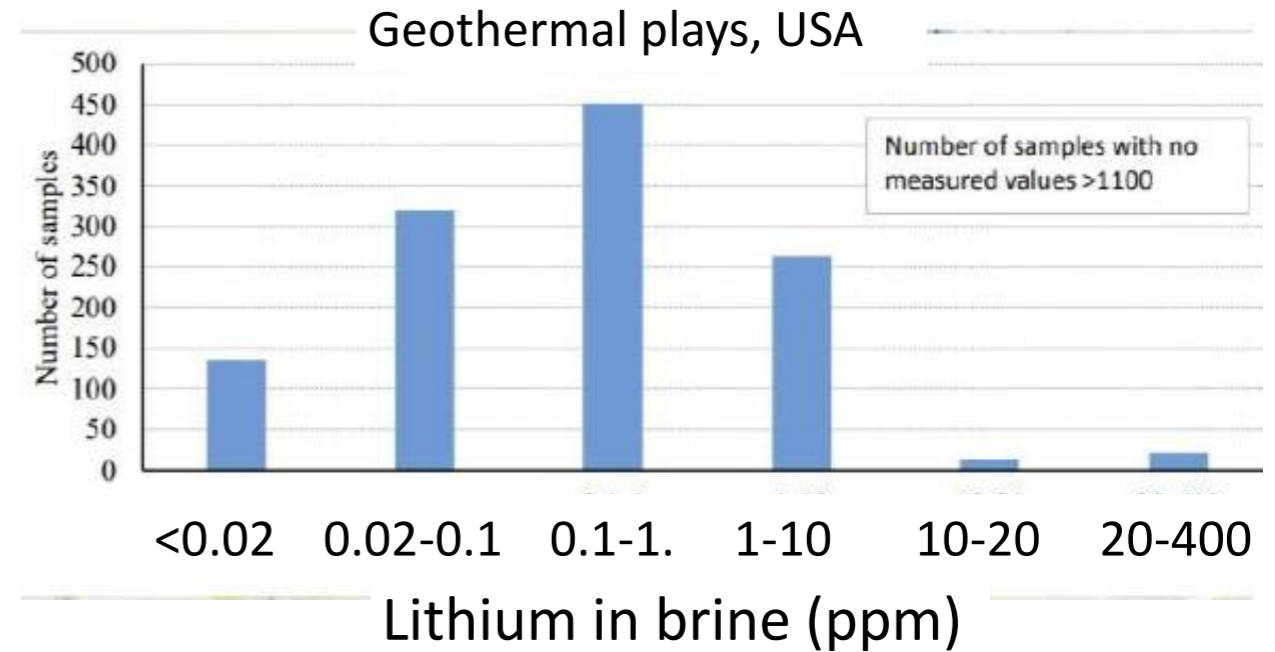
Sources: BBC, Islandbanki & EnergySource

Direct Geothermal Lithium Extraction

- The aim is to produce electricity from geothermal energy.
- And then extract the lithium (and possibly other metals) prior to re-injection.
- With excess electricity exported to the grid.

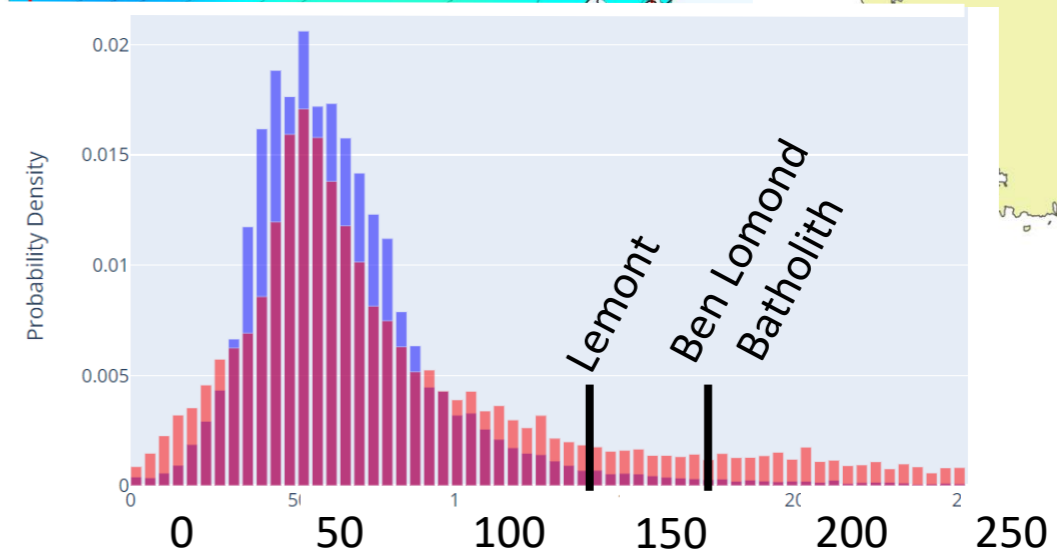
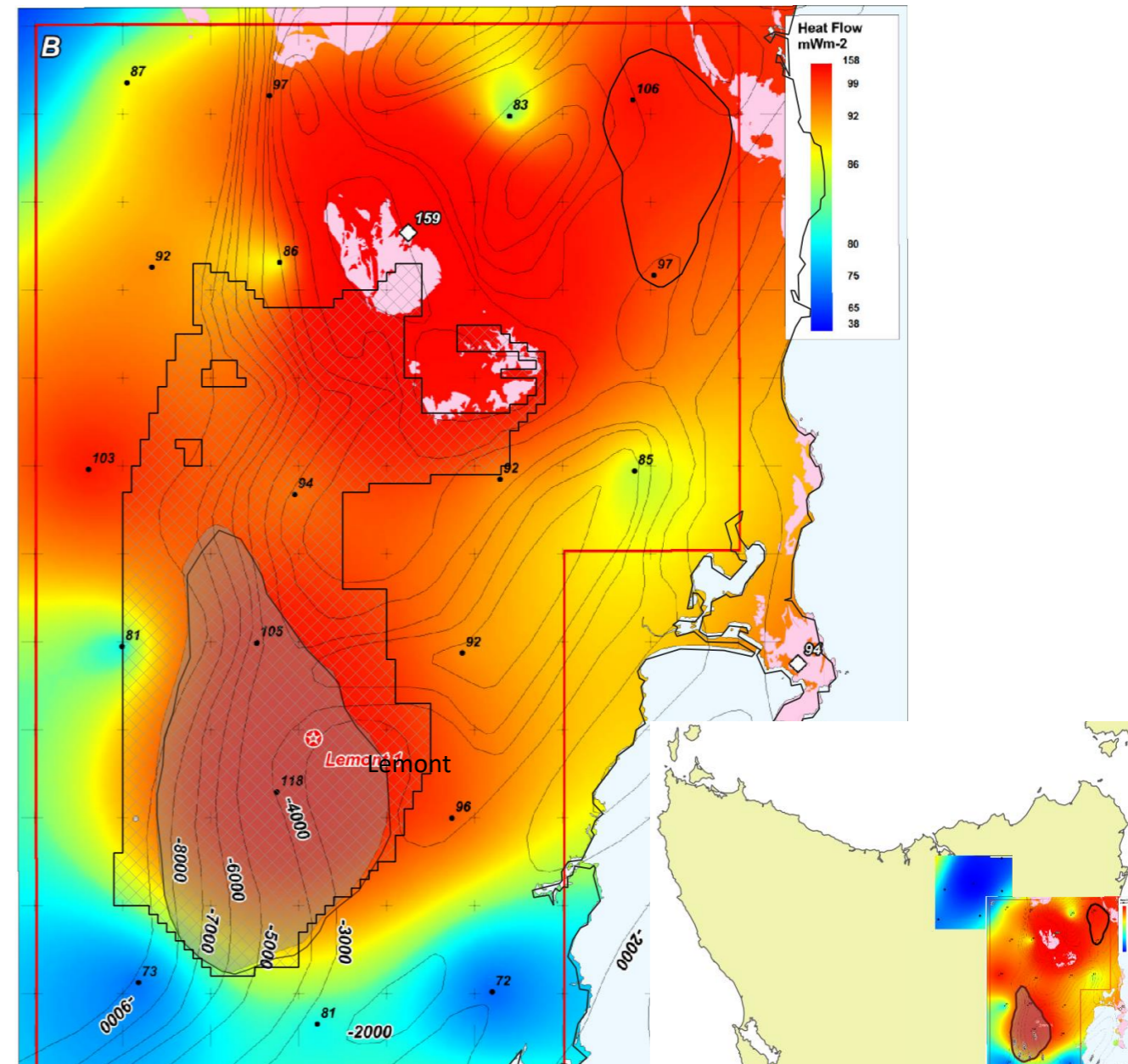


- Most geothermal plays are low in Lithium: e.g., USA data.
- But several countries have geothermal DLE projects
- Three areas have projects developing high-grade, ~200ppm Lithium in geothermal brine.
 - Salton Sea, Ca, USA
 - Cornwall, UK
 - Upper Rhine, Ge / Fr
- *Lemont* has the characteristics to be another.



A. Heat B. Lithium C. Flow rate

- Some of Australia's highest heat flows have been recorded in eastern Tasmania. This image includes a historical reading of 159mW/m^2 with KUTh Energy's 2009 heat flow measurements which recorded up to 118mW/m^2 over buried granites.
- The heat generation of outcropping granites in SELA 21/2022 are also among Australia's highest.
- Similar buried 'hot' granites are the interpreted sources of heat for the Inferred Geothermal Resources of Lemont and Fingal.

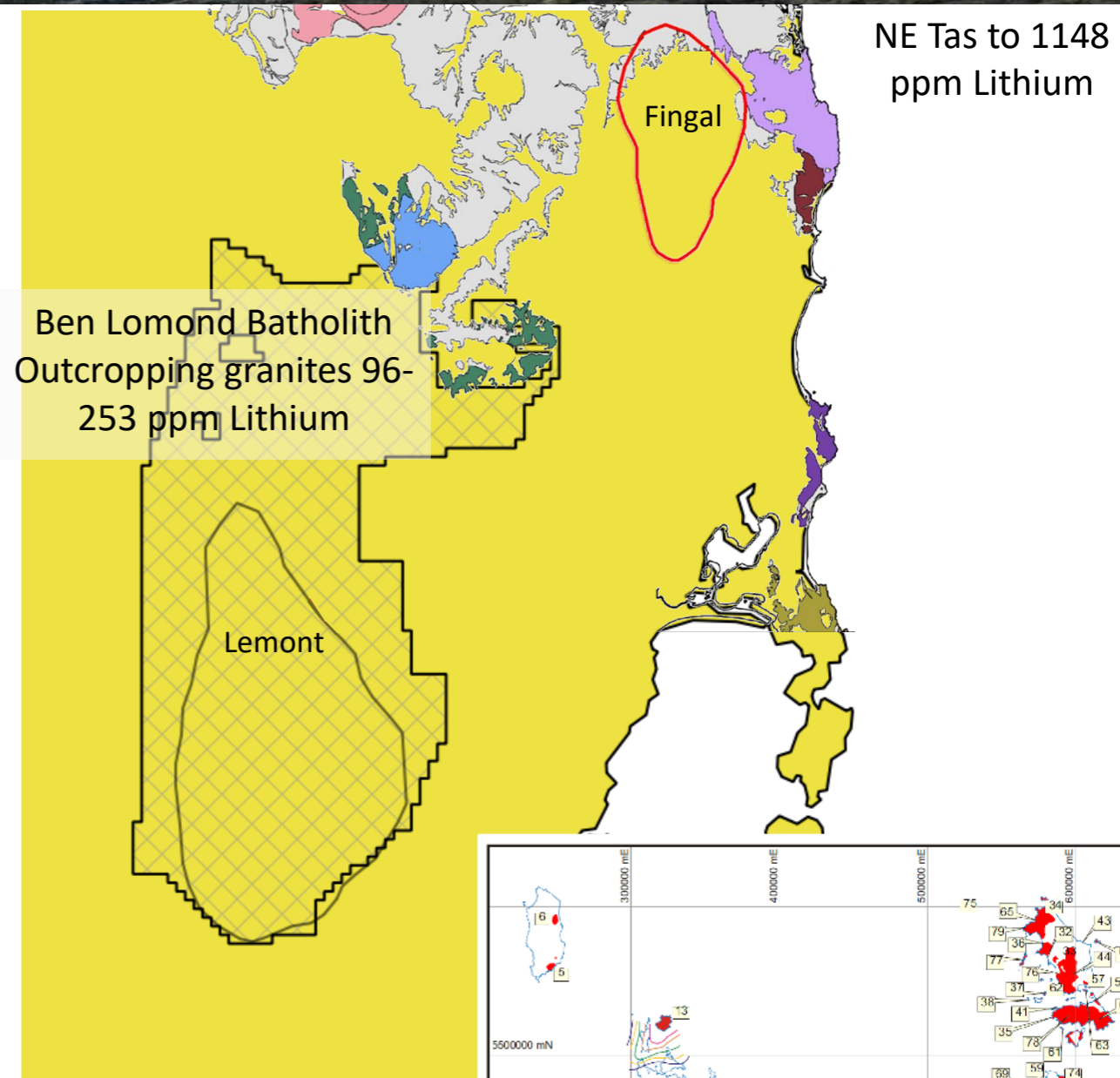


Global heat flow mW/m^2
<https://heatflow.org/>

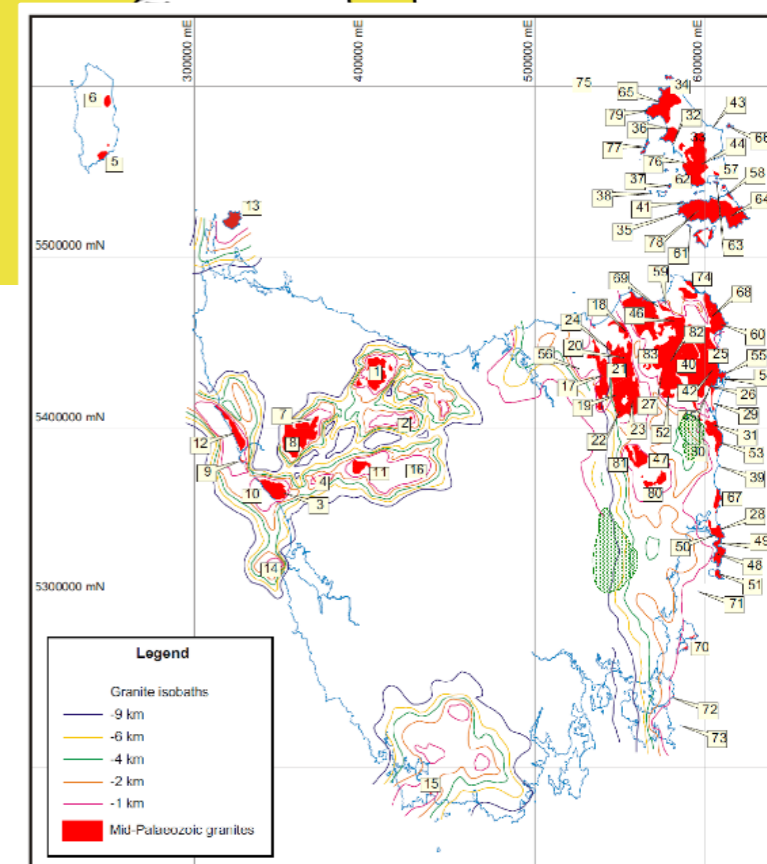
Lithium from Geothermal Brines: *Lemont*

A. Heat **B. Lithium** C. Flow rate

- Much of Tasmania is underpinned by granite (inset). Much of it is mineralised, especially in the northeast where granite-associated metals including tin, tungsten and gold have been widely mined.
- Hard rock lithium levels of the Ben Lomond Batholith, to 250ppm Li, are comparable to the ~300ppm of Cornish granites and well above the 24-40ppm Li for granites globally.



Devonian granites: *various colours*.
Ordovician intruded meta-sediments: *grey*.
Younger cover including Jurassic dolerite: *buff*.

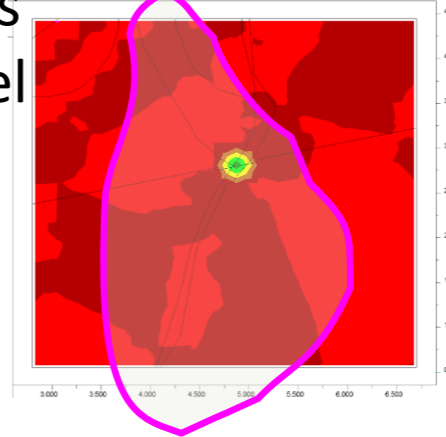


A. Heat B. Lithium C. Flow rate

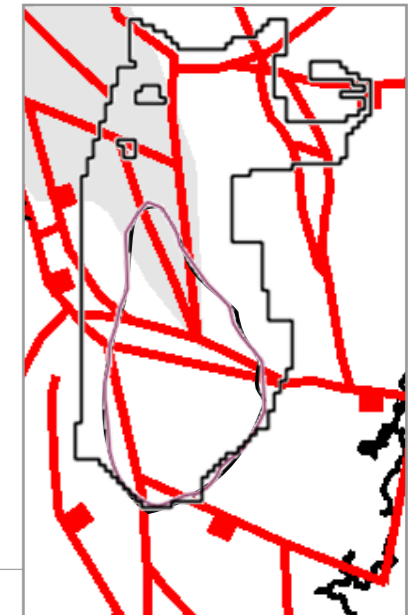
- High flow rates, required to extract commercial tonnages of lithium, requires high permeability: often associated with major faults and fractures.
- Low electrical resistivities can be a good proxy for permeability: the higher the permeability, (non-uniquely) the lower the resistivity.
- The main low resistivity zone coincides with a major structure trending $\sim 105^\circ$ i.e., sub-parallel to Tasmania's maximum horizontal compressive stress direction, and therefore a likely site for enhanced permeability.

MT resistivity
at 3km

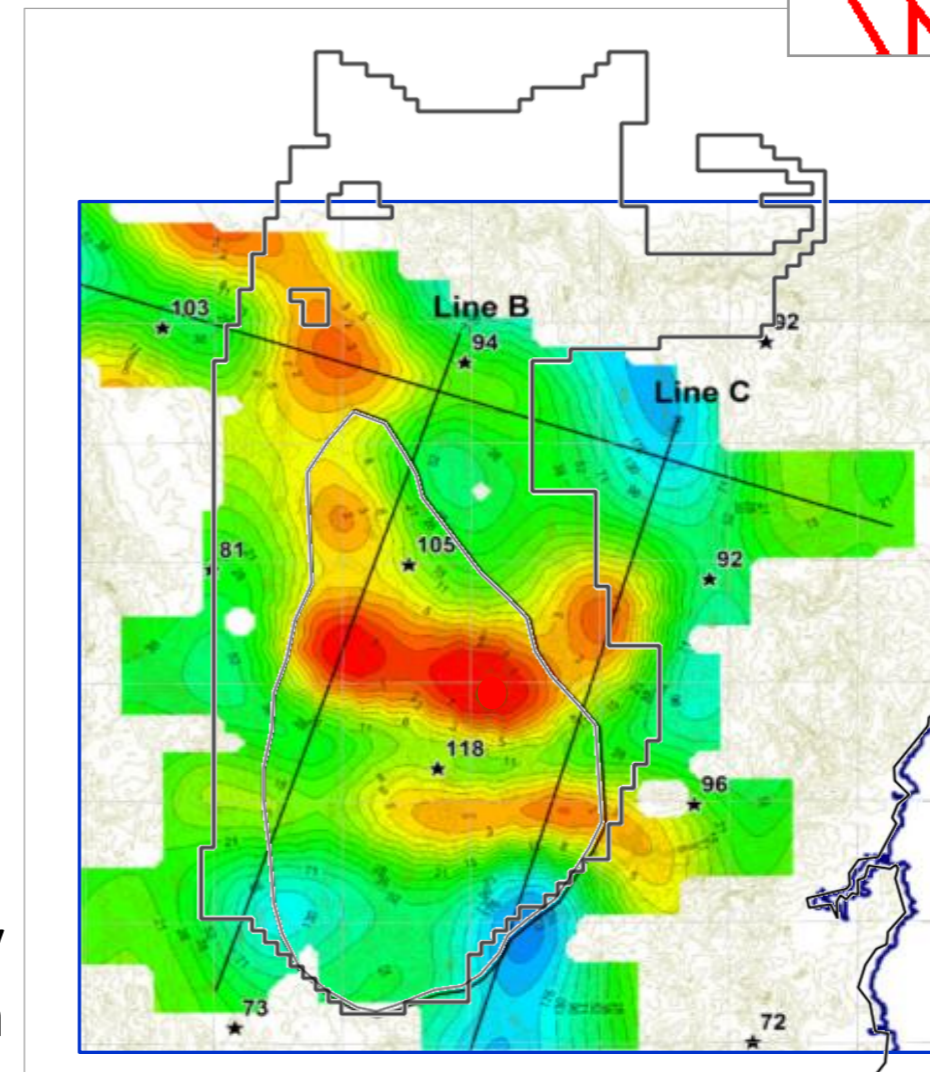
Stress
Model



Major faults



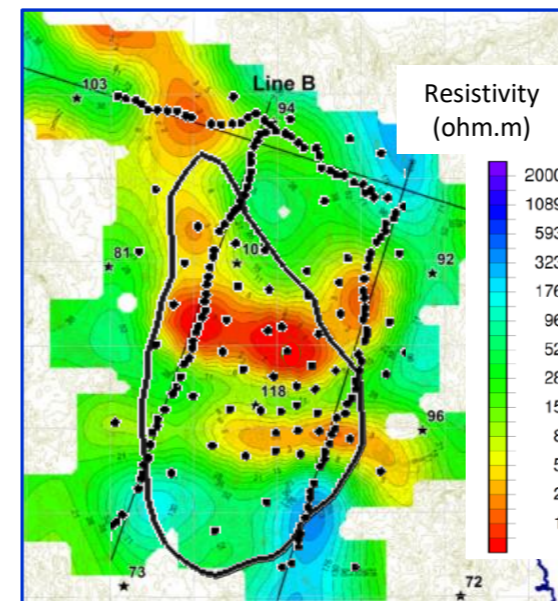
(Berry, 2019)



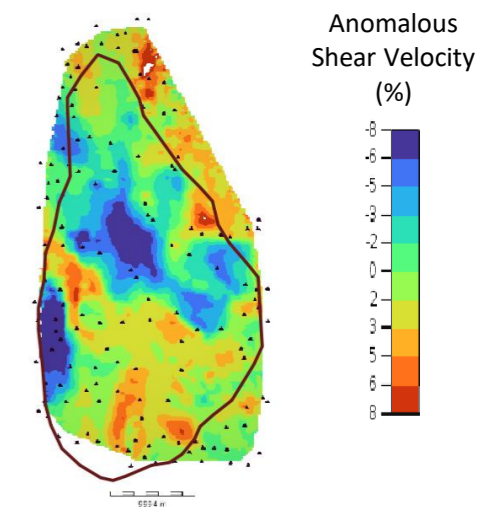
A. Heat B. Lithium C. Flow rate

- As previously noted, permeable zones are commonly associated with resistivity lows. This interpretation is enhanced if there is an associated seismic velocity low, since other sources of resistivity lows, such as sulphides or graphitic shales, would not produce low velocities.
- A passive seismic survey was carried out over Lemont in 2021. Tom Ostersen produced a 3D data set of regions with coincident low resistivities and seismic velocities ('Ostersen dots').

3D MT resistivity model



3D passive seismic velocity model

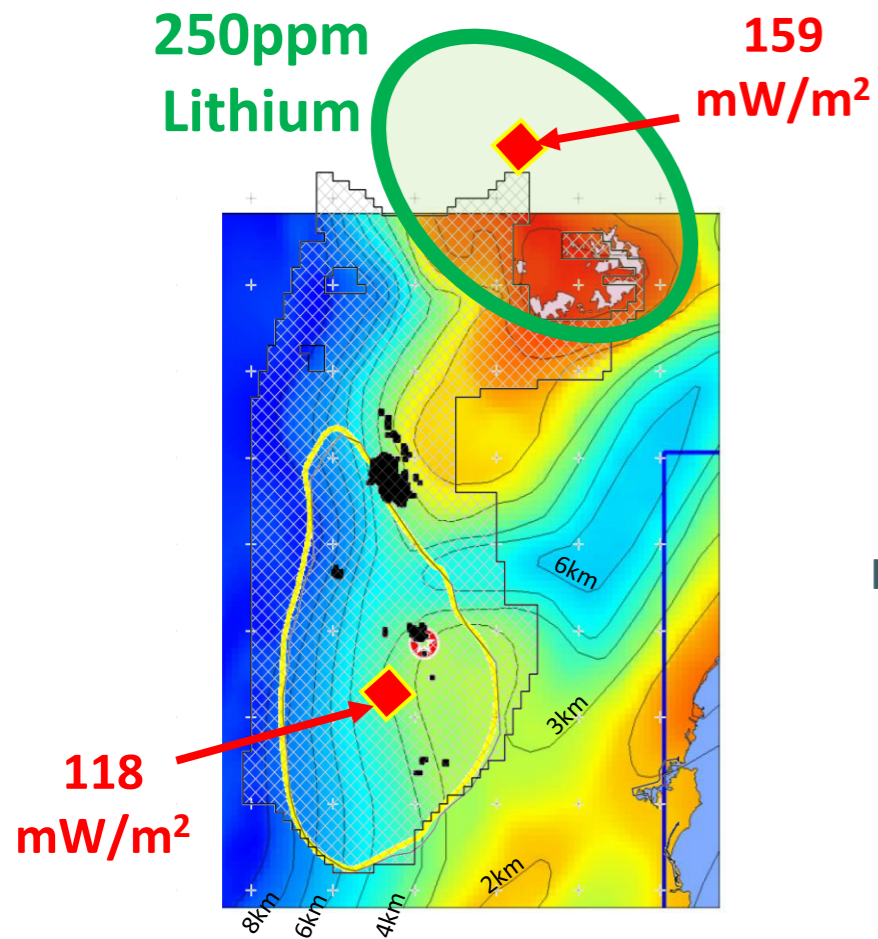


Depth slices at 3km below surface



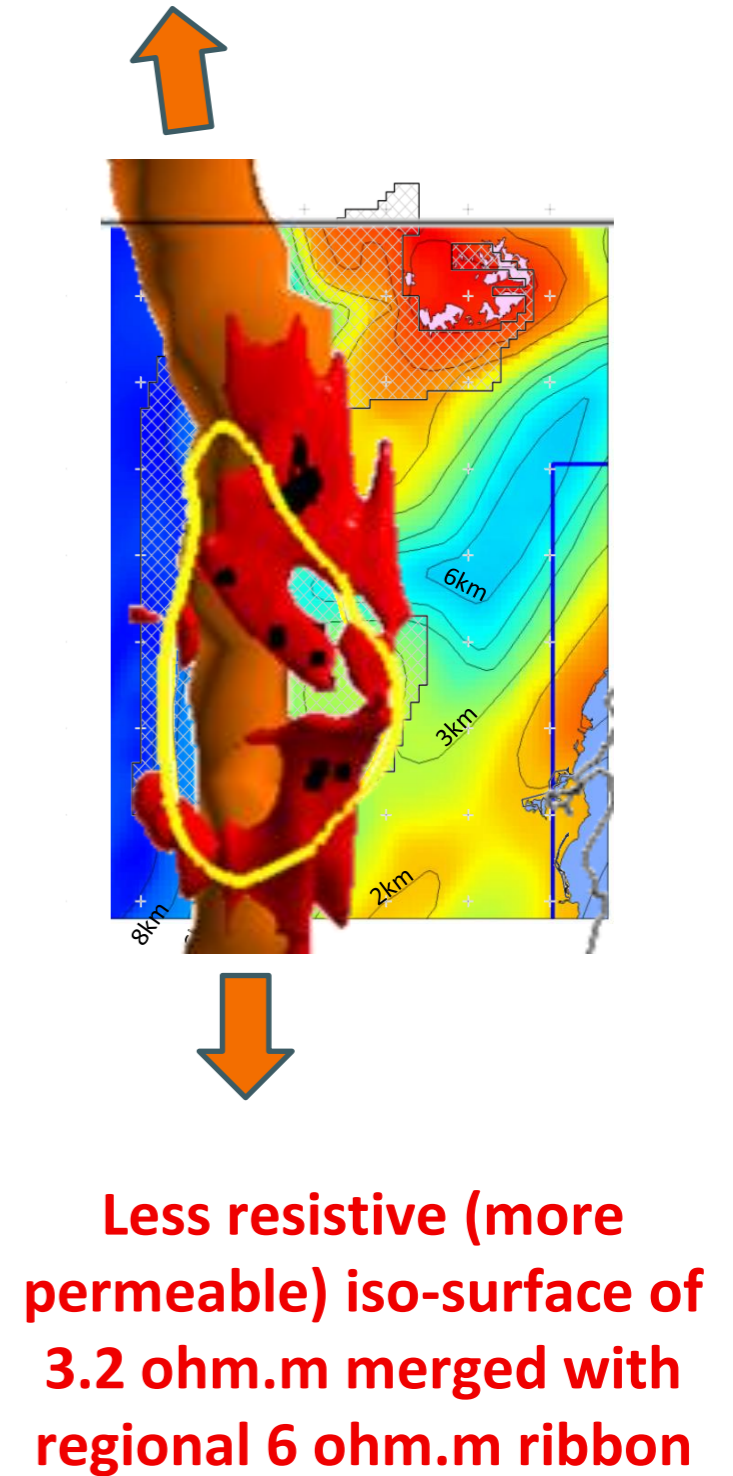
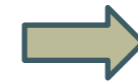
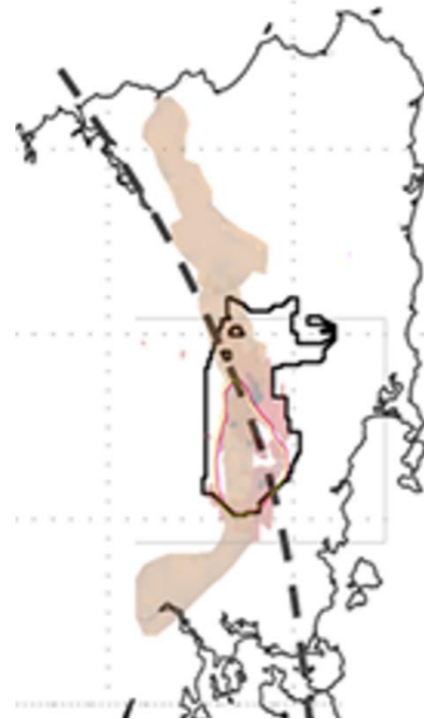
Coincident zones of low velocity and resistivity



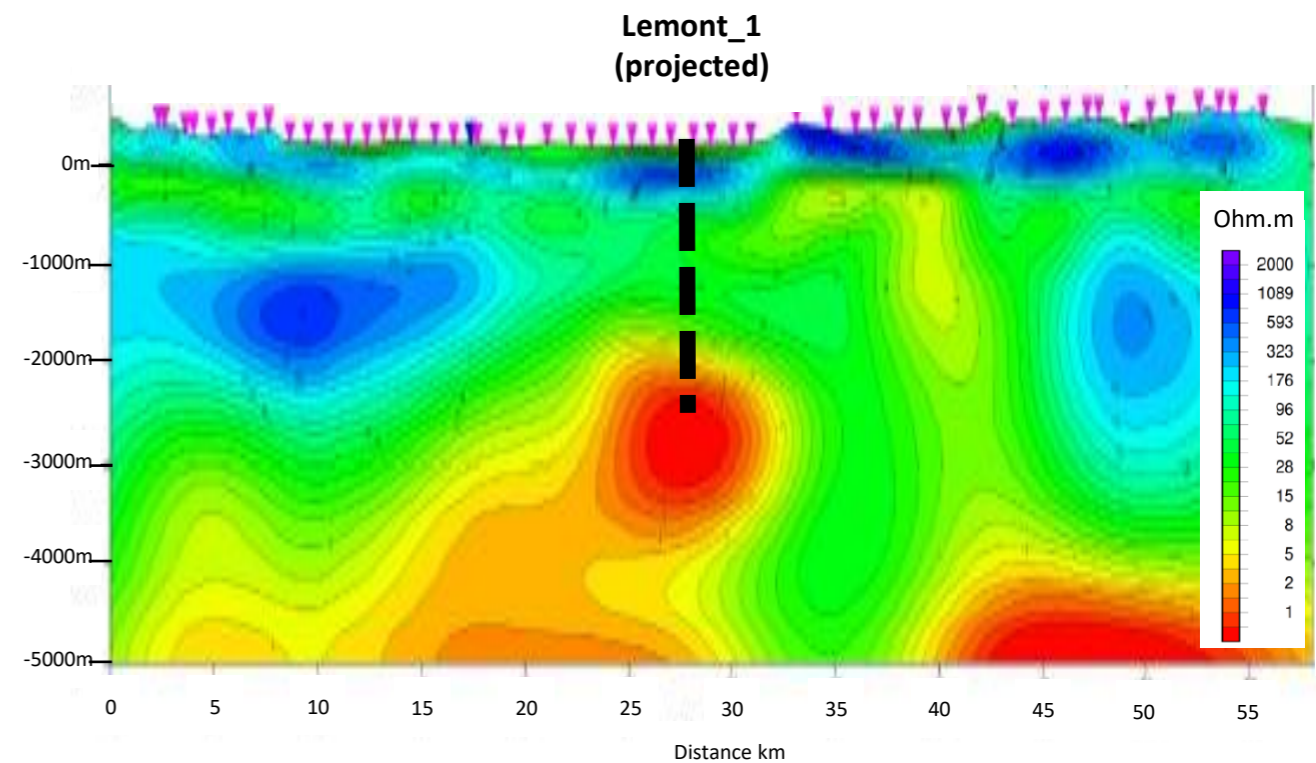
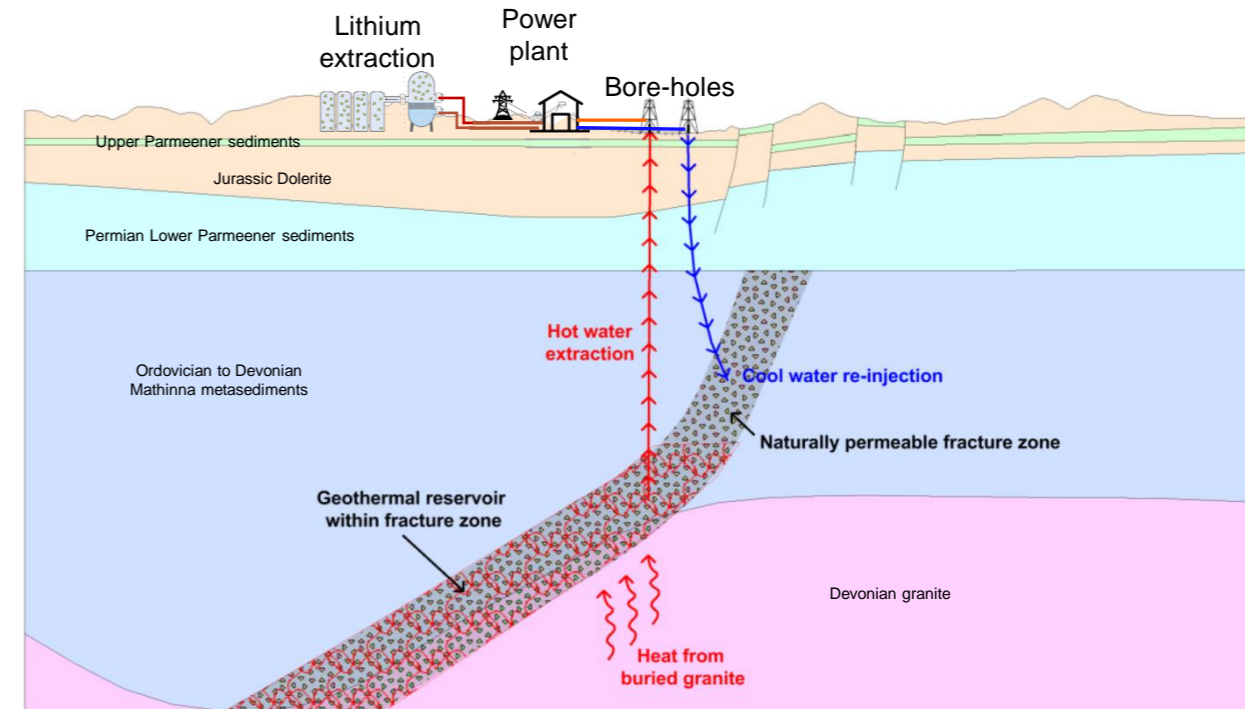


Depth to (hot) granite
1km contours to 9km

Regional iso-surface
of 6 ohm.m



- The immediate aim is to de-risk the project by drilling a test well. This would confirm the geology and structural interpretation and provide the chemistry of the brines, including lithium concentration, plus temperature and an indication of flow rate.





Electricity Generation:	Slide 15
Other Applications:	Slide 16
Case Histories:	Slides 17-19
Geological Setting:	Slide 20
The Data:	Slides 21-24

Disclaimer

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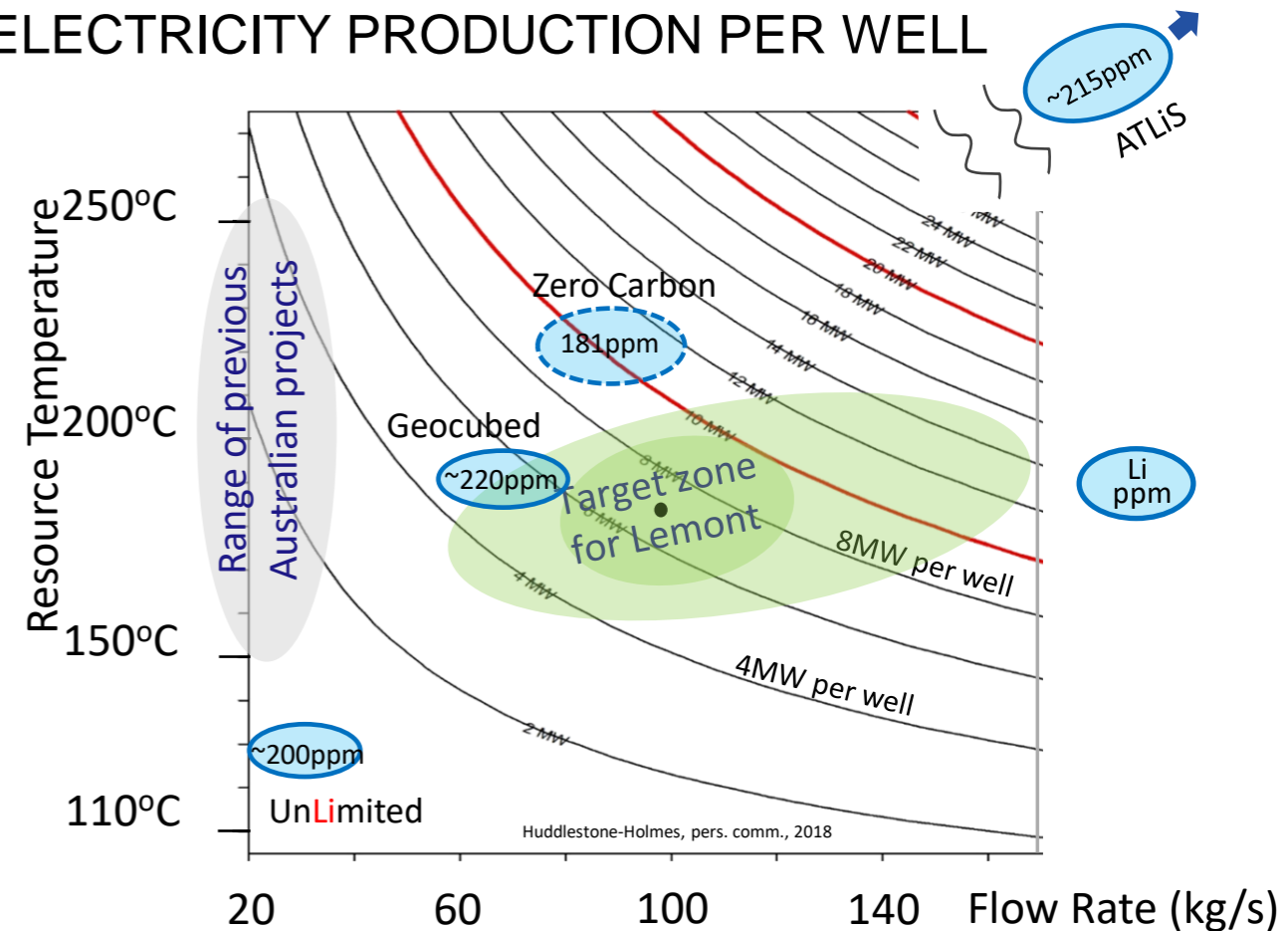
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- Temperature and flow rate determine how much electricity can be produced from a well. Initial estimates suggest that $\pm 7\text{MW}$ per well might be produced from Lemont; i.e., close to the global average.
- Superimposed on the nomogram are four leading geothermal DLE projects, showing a wide range of temperatures and flow rates, but similar Li concentrations. A similar value, of $\sim 200\text{ppm}$ Li, is expected for *Lemont*.

ELECTRICITY PRODUCTION PER WELL

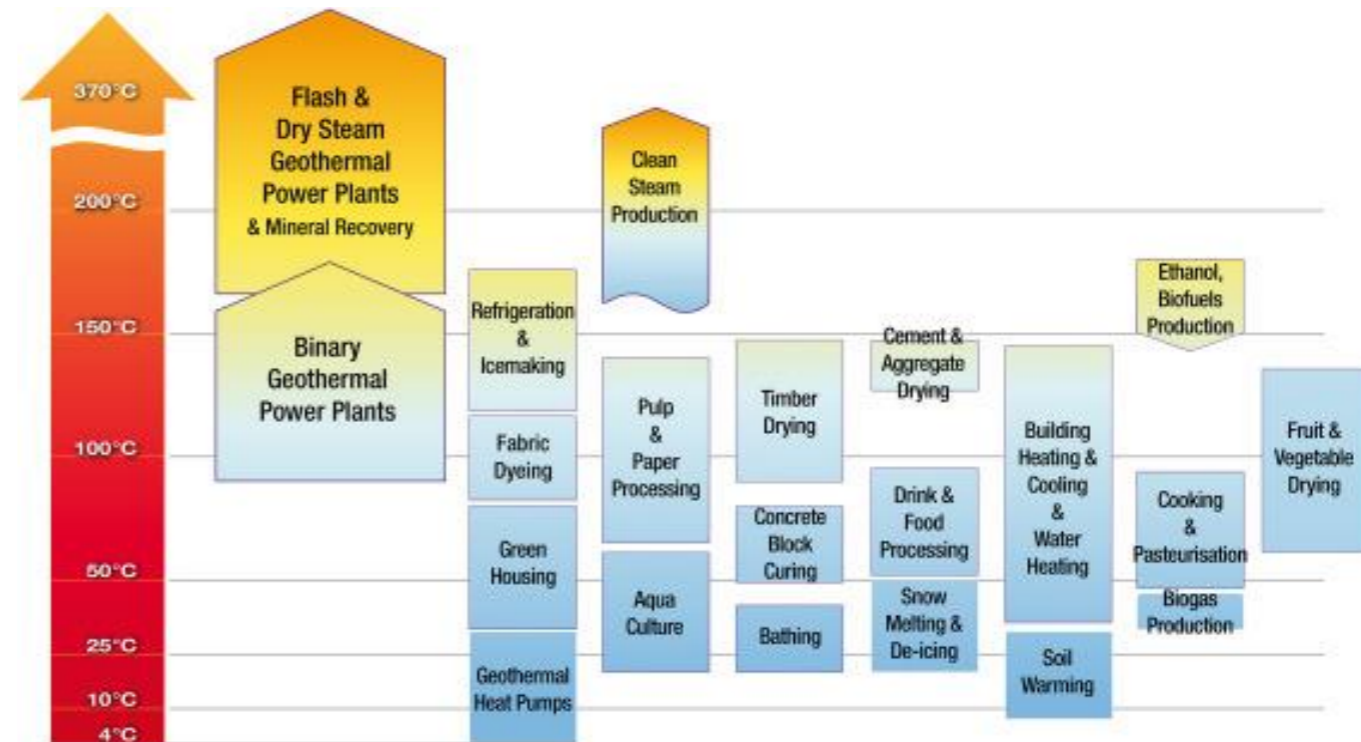


Tasmania is aiming to export at least 10TWh/yr of renewable energy by 2040, which will require doubling of the State's current capacity. Some of this will come from pumped hydro and wind, but more dispatchable power will be needed, thus providing an excellent opportunity for *Lemont*.

- The brine on the outlet side will still contain significant heat and, based on global geothermal plants, could be used for a range of activities, including:

- Spas / Hot springs
- Greenhouse industries
- Aquaculture
- Timber drying
- Fruit and vegetable drying

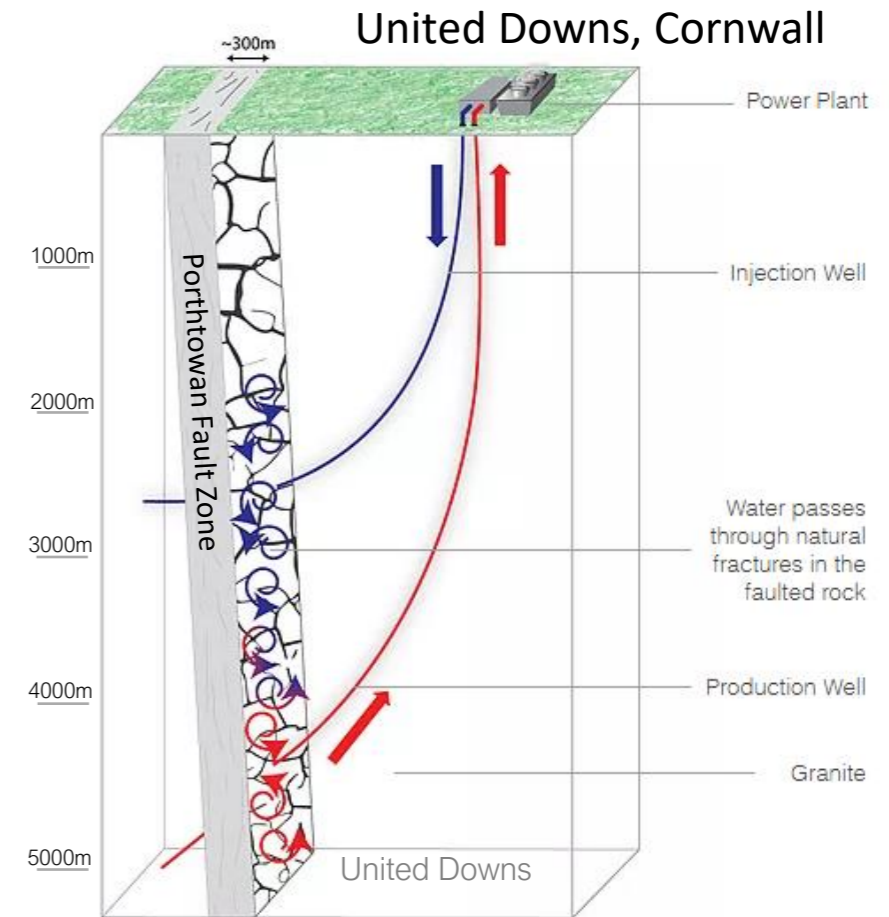
- A similar enterprise is envisaged to Iceland's *Resource Park* where different industries use the geothermal energy co-operatively, maximising efficiency and minimising waste.



Geothermal energy has numerous uses, many of which are applicable to Tasmania.

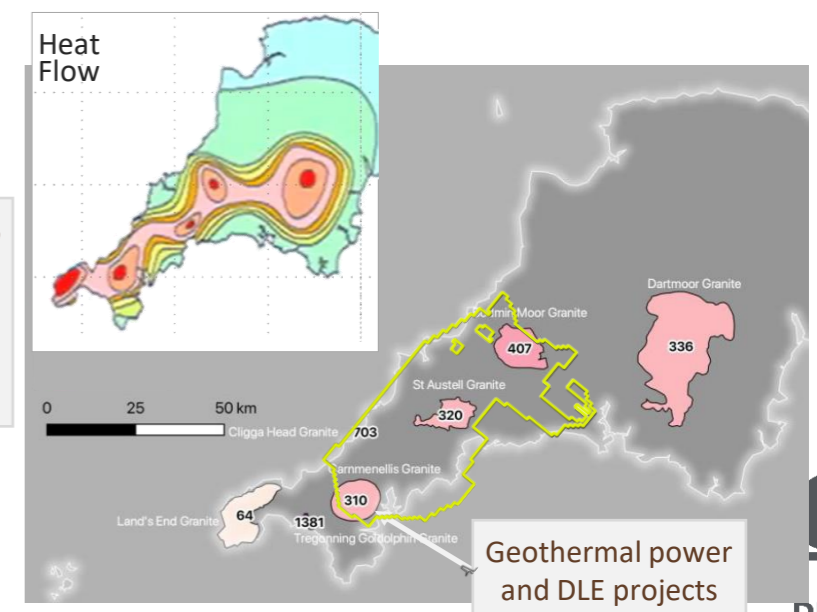


- Cornish Lithium’s *Geocubed* project is poised to extract lithium from GEL’s ‘United Downs’ geothermal power plant under construction (with two completed wells) in Cornwall UK.²²
- Cornish Li are also looking at drilling shallower holes, 1.5-2km deep. Although lithium grades improve with depth, this study may show the extra drilling cost isn’t justified. No electricity generated, but direct heating would be possible.²³
- The *Geocubed* brine has a ~220ppm Li and a pilot plant using GeoLith’s *Li-Capt* DLE technology is operating with high recoveries. The target is 4000tpa Li from 2026 with the possibility of other metals.²⁴
- The geological setting is very similar to Lemont, with mineralised (tin, tungsten) granites; the resource in a major (extensional) transfer fault and comparable heat flows (120mW/m² compared to Lemont’s 118). The granites also have comparable assays: 310ppm Li at Carnmenellis compared with 253ppm Li in the Royal George Granite at *Midlands*.
- More Case Histories in the Appendices.



Brines at ~190°C from a ~5km deep borehole will power turbines to produce electricity. Lithium to be extracted via a DLE plant, prior to re-injection.

Main: Lithium hard-rock assays (in ppm), Cornwall and Devon, UK. SELA 21/2022 superimposed for scale. Inset: Heat flow to 120 mW/m².



²² 193°C at ~4.8km depth; targeting ~80 l/s flow rate. Expected to produce ~3MW_e.

²³ Presentation by Cornish Lithium’s Lucy Crane to IMMM, 9jun22: <https://www.youtube.com/watch?v=I0hIAMEQKJ8>

²⁴ <https://cornishlithium.com/>

- Vulcan Energy Ltd (ASX: VUL) is developing a 'Zero Carbon Lithium' project in the URV. Total resource >15Mt LCE in geothermal brine with an average grade of 181mg/l Li. The operation will produce LiCl using sorption technology³⁵ which will go to a Central Lithium Plant to be converted to LiOH by electrolysis. The project will also generate geothermally driven electricity.
- A Jan 2020 pre-feasibility study (with a 100mg/l Li cut-off)³⁶, gives robust financials for both Lithium and electricity.³⁷ The forecast CAPEX is US\$1.3B with an OPEX of €2,640/t LHM for a 40ktpa LiOH.H2O plant,³⁸ and 74MW geothermal power plant. To be built in 2 stages: first production in 2024. The Li plant on a stand-alone basis has a 33% IRR with a 4yr payback.
- The Table below compares Vulcan's project with some operating DLE plants and other planned projects.

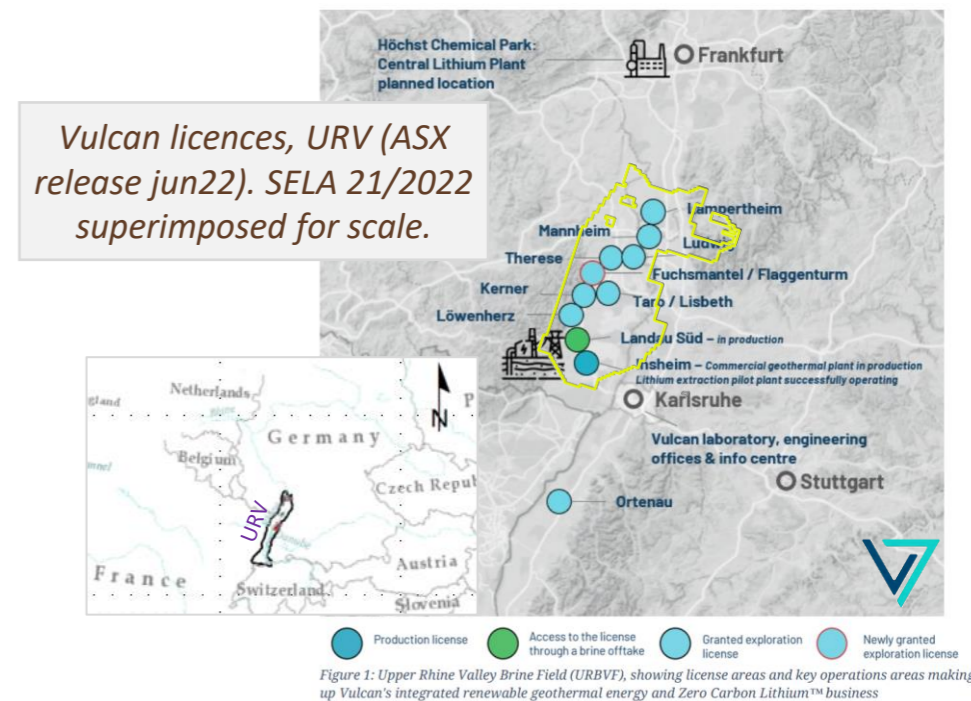


Figure 1: Upper Rhine Valley Brine Field (URV), showing license areas and key operations areas making up Vulcan's integrated renewable geothermal energy and Zero Carbon Lithium™ business

DLE comparisons. Extracted from VUL corp. presentation Jul-Aug, '22. References for the other projects are listed in the presentation
<https://www.investi.com.au/api/announcements/vul/fa49dc9c-01a.pdf>

Company	Livent	Lanke Lithium	Zangge Lithium	Jintai Lithium	Eramet/ Tsingshan	Standard Lithium	Vulcan Energy	Rio Tinto	CTR	Energy Source Minerals	Berkshire Hathaway	Lake Resources/ Lilac	Compass Minerals	E3 Metals
Asset name	Hombre Muerto	Qinghai	Qinghai	Qinghai	Centenario-Ratones	Smackover	Zero Carbon Lithium™	Rincon	Hell's Kitchen	ATLiS	Salton Sea	Kachi	Great Salt Lake	Clearwater Lithium
Country														
DLE technology	Sorption	Sorption	Sorption	Sorption	Sorption	IX	Sorption	Sorption	IX	Sorption	IX	IX	IX	Ion Exchange
DLE provider	Proprietary	Undisclosed	Undisclosed	Undisclosed	Proprietary	Proprietary LiSTR	Undisclosed	Axion	Lilac	Proprietary ILiAD	Proprietary	Lilac	Undisclosed	Proprietary
Stage	Production	Production	Production	Production	Construction	Demo	Pilot	Pilot	Offsite pilot	Pilot	Pilot	Offsite pilot	Pilot	Pilot
Resource (Mt LCE)	Undisclosed	Undisclosed	Undisclosed	Undisclosed	10	3	16	12	3	Undisclosed	Undisclosed	4	2	7
Geothermal	✗	✗	✗	✗	✗	✗	✓	✗	✓	✓	✓	✗	✗	✗
Start date	1998	2017	2018	2019	2024	tbc	2024	2025	2024	2024	tbc	2024	tbc	2025
Capacity (ktpa LCE)	20	20	20	7	24	21	40	50	20	20	90	25	20-25	20
Ownership	Public	-	-	-	Public	Public	Public	Public	Private	Private	Public	Public	Public	Public
Significant Investments					Tsingshan \$375M 11/2021	Koch \$100M 11/2021	Institutional Investors \$320M 2021 Stellantis \$76m	Rio Tinto \$825M 12/2021	GM \$?M 07/2021			Lilac Up to \$50M 09/2021		
Offtakes (announced publicly)		✗	✗	✗	✗	✗	 	✗		✗	✗	✗	✗	✗

³⁵ See Vulcan's Technical Update, 12nov21
<https://v-er.eu/wp-content/uploads/2021/11/Direct-Lithium-Extraction-technical-update-FINAL.pdf>

³⁶ ASX announcement 15jan21 https://cdn-api.markitdigital.com/apiman-gateway/ASX/asx-research/1.0/file/2924-02330867-6A1015607?access_token=83ff96335c2d45a094df02a206a39ff4

³⁷ Geothermal power in Germany has a high, long-term, feed-in-tariff. See:
<https://www.nortonrosefulbright.com/en/knowledge/publications/3e005a80/opportunities-geothermal-energy-in-germany#:~:text=The%20German%20Renewable%20Energy%20Sources,25.20%20cents%20per%20kilowatt%20hour.>

³⁸ Aus-based Ekosolve state an all-in OPEX of US\$2,500/t with 80% recoveries for playa brines <http://www.ekosolve.com.au/technology.html>.

Note 1: Resources are rounded to Op. Refer to Appendix 7: DLE Projects and Assets - References



- The Salton Sea Geothermal Field in southern California is exceptional. Individual wells typically produce $>20\text{MW}_e$ with the highest $>40\text{MW}_e$. Temperatures reach 389°C at $\sim 2\text{km}$ depth and the brine is up to 28% salts by weight. However, the lithium content is comparable to the URV and Cornwall, at 211mg/l Li .³⁹
- At least three companies are developing DLE plants. BHER has 10 geothermal power plants producing 345MW. In 2021 they received a US\$15M matched grant and have successfully trialled an ion exchange process.
- EnergySource has a 55MW power plant with an associated pilot trialling their own *ILiAD* sorption technology. The third company, CTR, plans to build a 140MW power plant of which two-thirds will be sold.⁴⁰ It is trialling *Lilac Solutions* ion exchange technology and is planning to produce up to 35ktpa of LCE by 2025.⁴¹

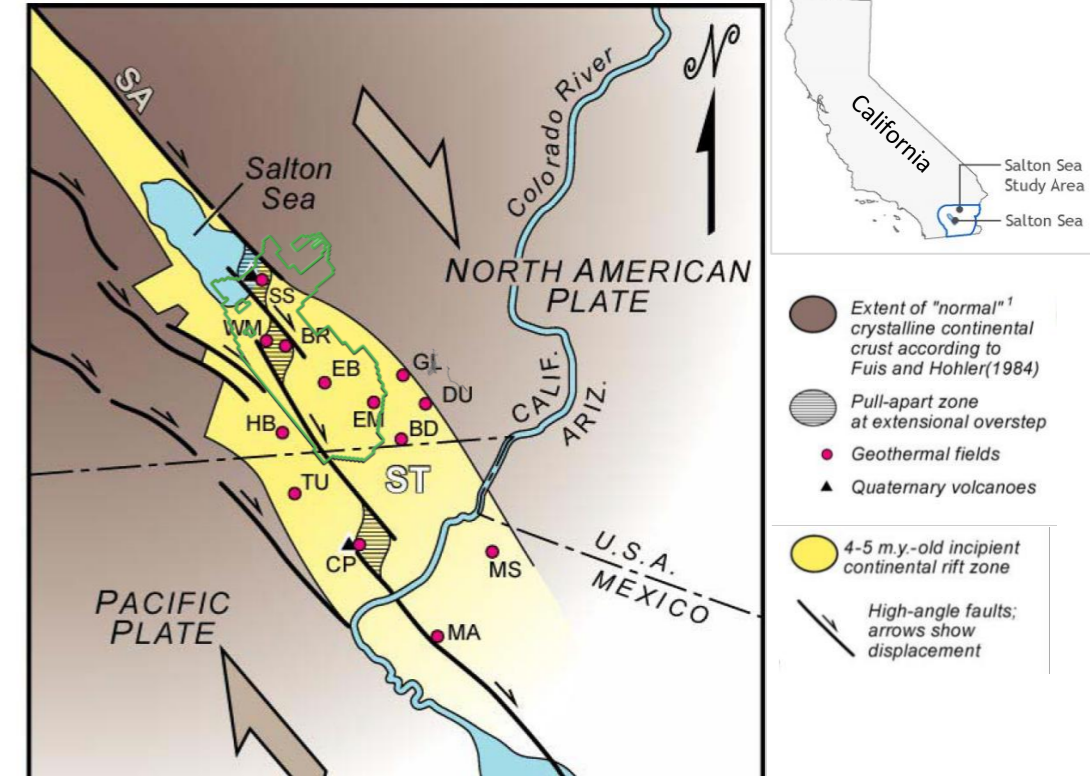
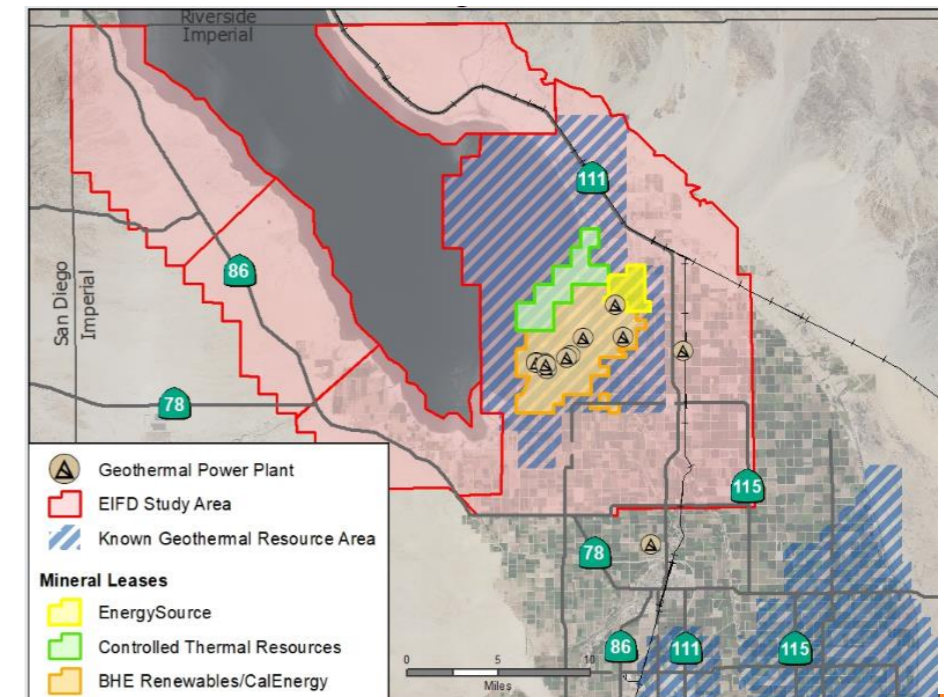


Fig. 1, Kaspereit et al, 2016.⁴²

Upper: Greater Imperial Valley geothermal fields associated with the San Andreas Transform Fault. SELA 21/2022 superimposed for scale (green line).⁴²
 Lower: Salton Sea Geothermal Field where at least three companies are developing DLE operations.⁴³



Salton Sea Geothermal Field from Lockhart, 2019.⁴²

(EIFD: Enhanced Infrastructure Financing District)

³⁹ Ventura, S. et al, 2020. *Selective Recovery of Lithium from Geothermal Brines*. SRI Int. report for the CEC. <https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2020-020.pdf>

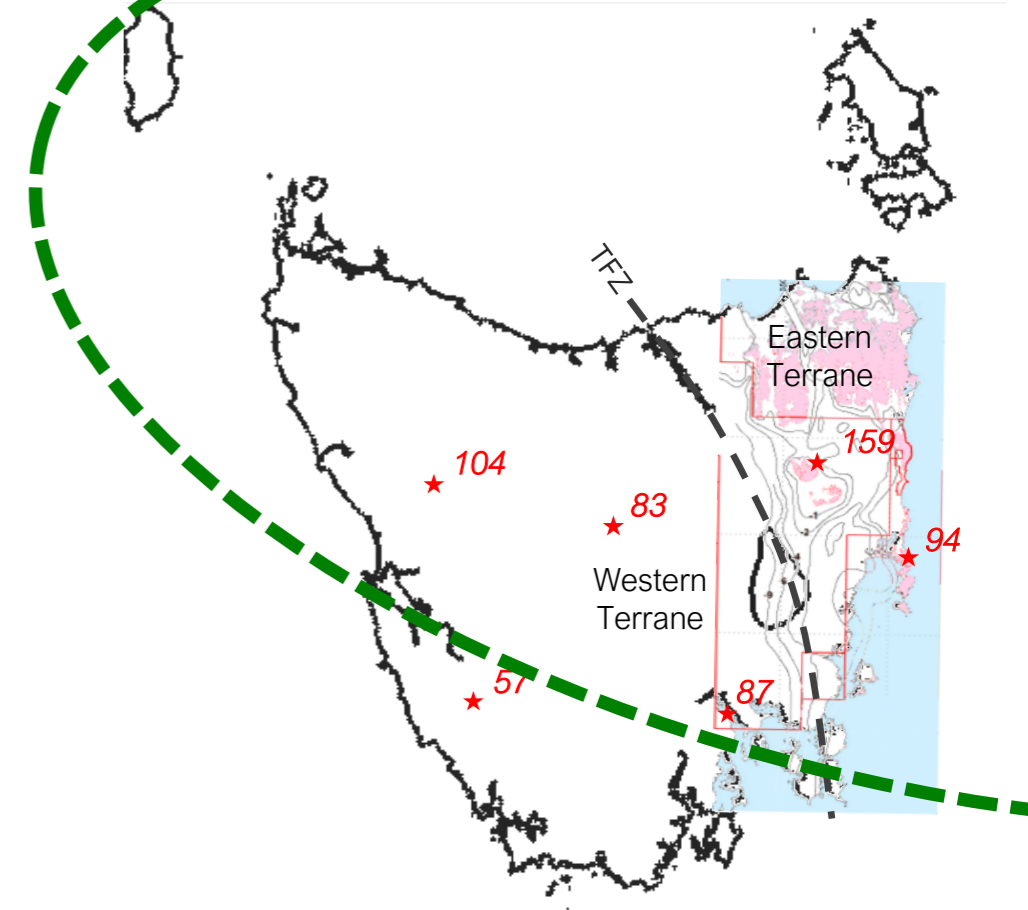
⁴⁰ <https://www.cthermal.com/>

⁴¹ Lithium Valley Commission, Presentation 29jul21 Updated. <https://efiling.energy.ca.gov/getdocument.aspx?tn=239067>

⁴² Kaspereit, et al, 2016. Updated conceptual and (power) reserve estimate for the Salton Sea Geothermal Field. <https://publications.mygeoenergynow.org/grc/1032308.pdf>

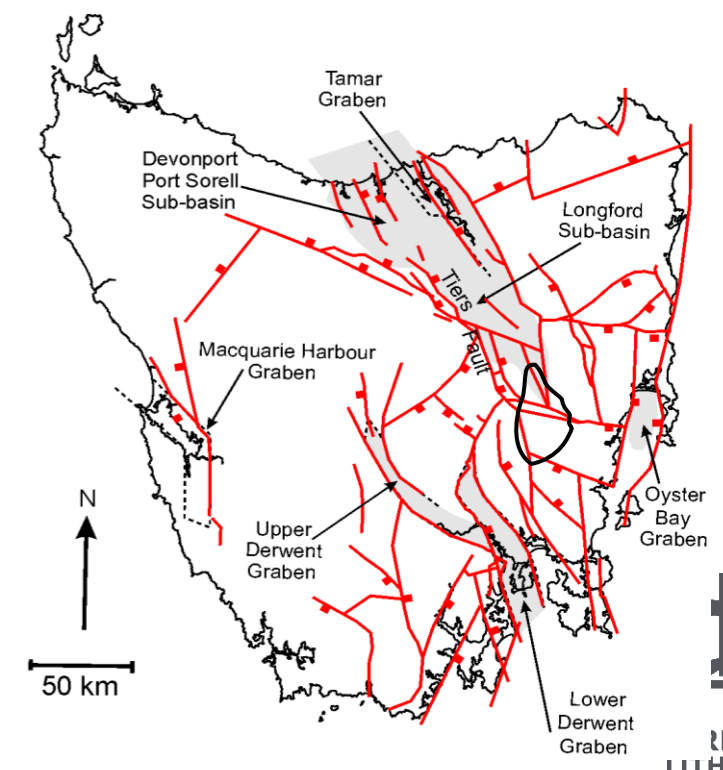
⁴³ Lockhart, B., 2019. Possible Sites for Lithium Mining in the Salton Sea Geothermal Area. https://ic.arc.losrios.edu/~veiszep/36fall2019/Lockhart/G350_Lockhart_Project.htm (accessed 14oct22).

- Several heat-producing granites were emplaced (mostly) in eastern Tasmania during a period of tectonic compression ~400Mya, which joined Eastern and Western Tasmania terranes along the largely concealed Tamar Fracture Zone (TFZ): upper figure.
- Many of these granites are strongly mineralised, including with lithium.
- ~50Mya Tasmania became part of an extensional regime associated with the separation of Australia and Antarctica, with several grabens developing. In the Lemont region the bounding faults “*form a complex transfer zone that is expected to have high fracture permeability*” (Berry, 2019: lower figure).¹³
- Lastly, Tasmania is located over an interpreted hot spot, the *East Australia Plume System* (upper figure), which may explain some of the legacy high heat flow measurements scattered across the State: upper figure. (Continental crust averages 65mW/m².)

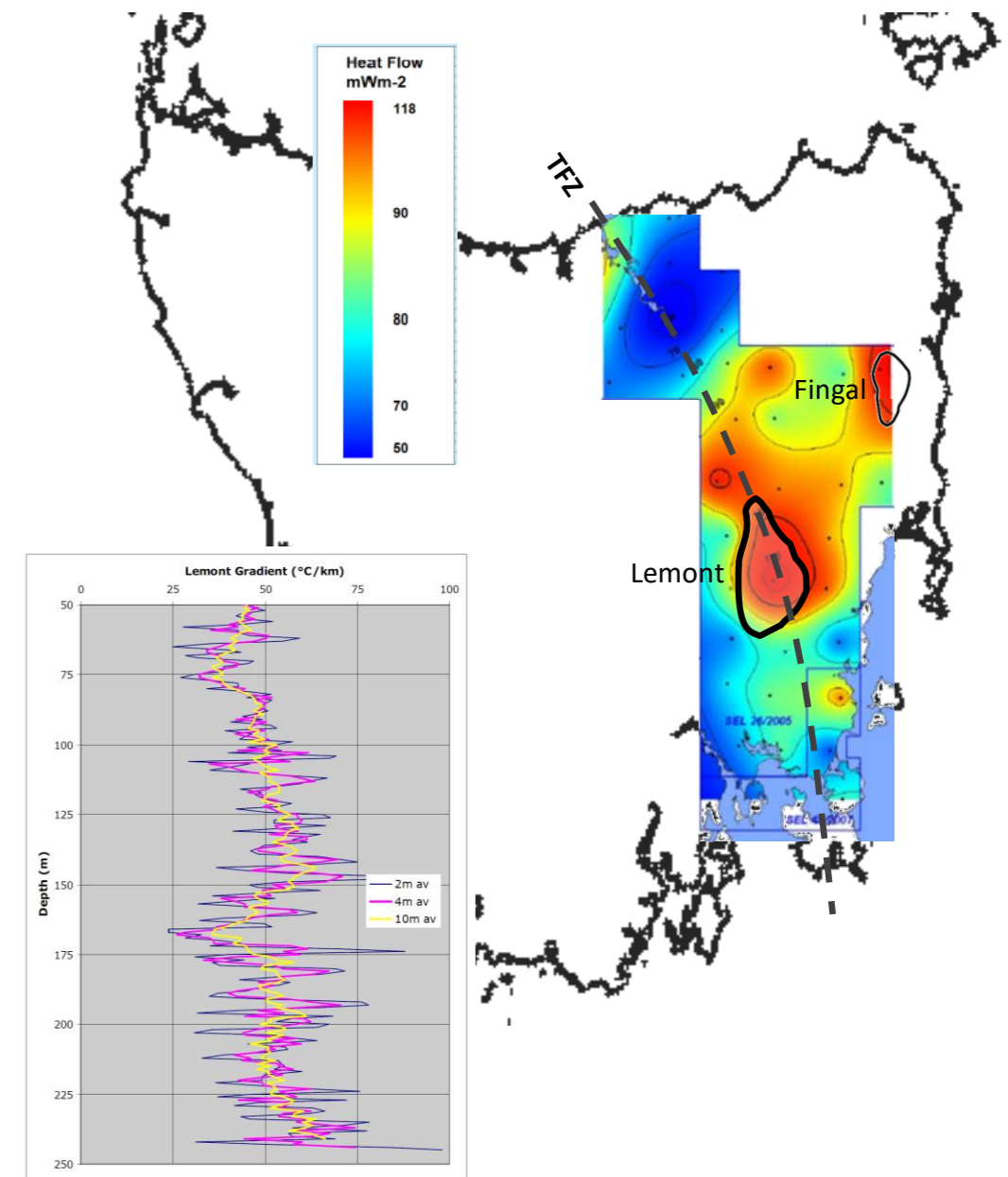


Upper Figure: *Radio-isotope enriched granites were emplaced during the Devonian, associated with a compressional regime bringing Tasmania’s Western and Eastern Terranes together. (Eastern outcropping granites in pink: Western ones not shown). Legacy high heat flow measurements support the hypothesis of a ‘hot spot’ beneath Tasmania (green dashed line from Davis et al, 2015). The TFZ marks the approximate location of the paleo-plate boundary, Also shown are legacy heat flows and depth contours to the granite surface in 1km intervals.*

Lower Figure: *Major Tertiary faults from Berry (2019). Tasmania was an extensional regime during this period (Australia separating from Antarctica) with several grabens opening up. Berry (2019) regards the “complex transfer zone” within the Lemont outline as likely to have high permeability.*



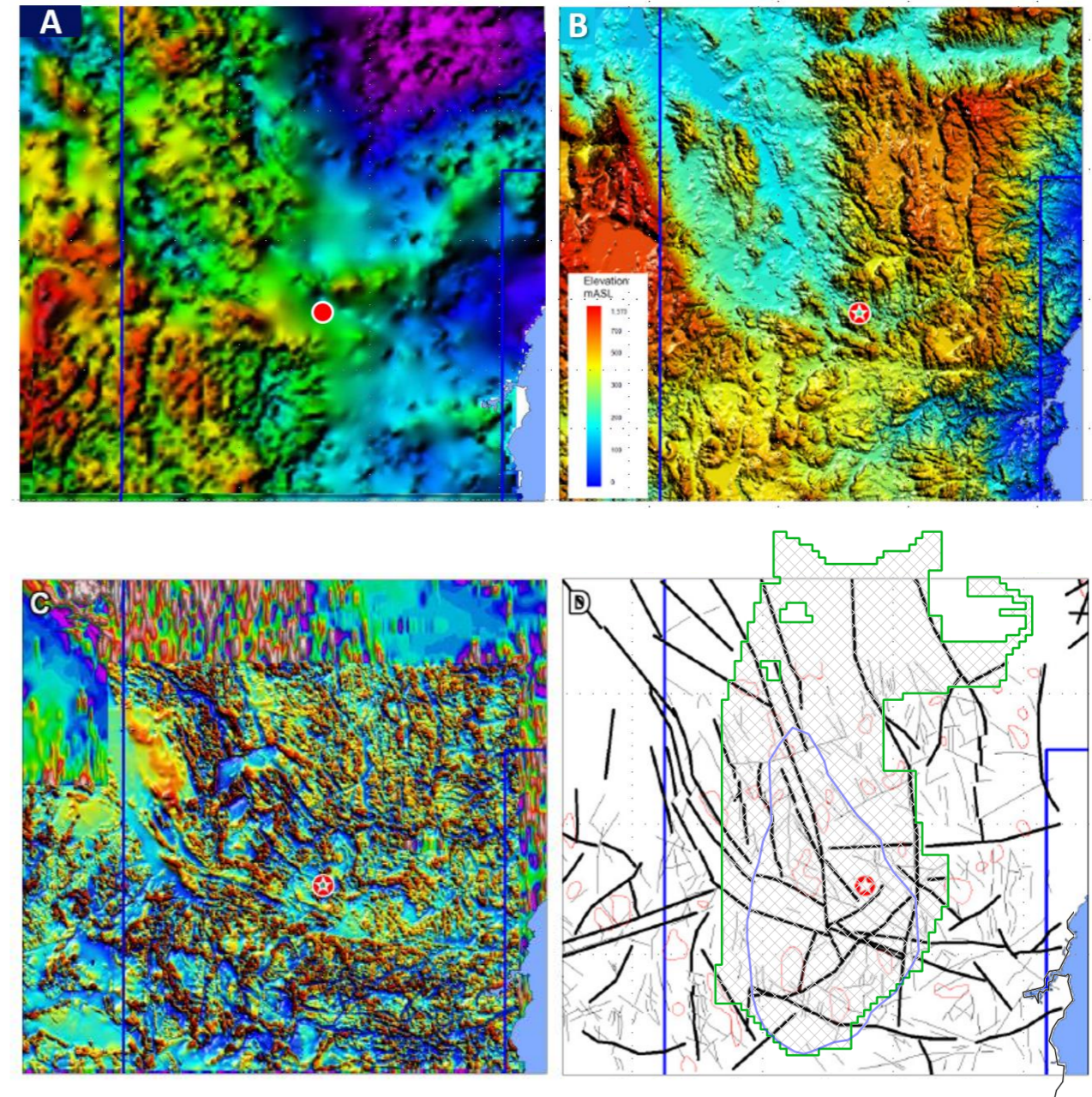
- KUTh's TFZ-focused exploration started with a systematic heat flow program of 37 deep (~250m) cored holes on a ~20km x ~20km grid. Temperatures were taken down equilibrated holes and physical properties including thermal conductivity measured from a representative suite of cores.
- The northern, known-to-be-conductive end of the TFZ proved to be relatively cool but further south some of Australia's highest heat flows were recorded (to 118mW/m²). The Inferred Geothermal Resources of Lemont and Fingal were the result.
- Fingal had a higher geothermal gradient (due to more coal); however, Lemont was larger, had a higher heat flow and was considered more likely to have associated permeability²⁸ and subsequent surveys concentrated there.
- KUTh then carried out a series of MT surveys which showed a close correlation between faults and low resistivities suggesting permeable structures at depth. Subsequent surveys supported and refined this interpretation (next slides).



Some of Australia's highest heat flow measurements were recorded over 'hot' granites in E. Tas. Modelling of these data was used to produce the Lemont Inferred Geothermal Resource outlined. Inset: Geothermal gradient of ~50°C/km for Lemont; i.e., twice global average.

²⁸ A conclusion supported by the later AusLAMP survey.

- Permeable zones are often associated with faults and fractures. Such structures can often be interpreted from potential field data and sometimes from topography.
- This figure shows the detailed data used to interpret the structure within the Lemont geothermal resource. They cover most of SELA 21/2022. Other data sets, not all as detailed, cover all of the SELA and surrounding area.
- The red dot in all four images is a drill target defined by KUTh Energy. Holgate¹⁰ noted that a hole placed here would test a region of “structural convergence” where east-directed basement thrusts on the western side met west-directed thrusts on the eastern side.

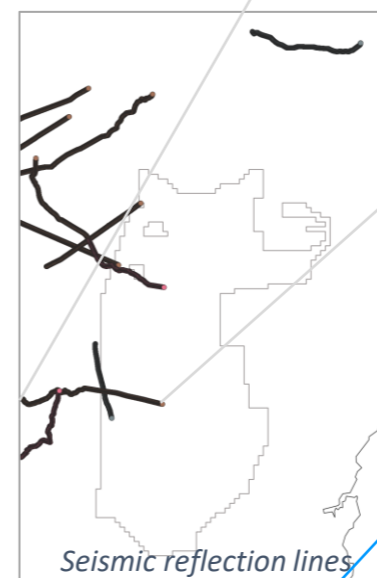
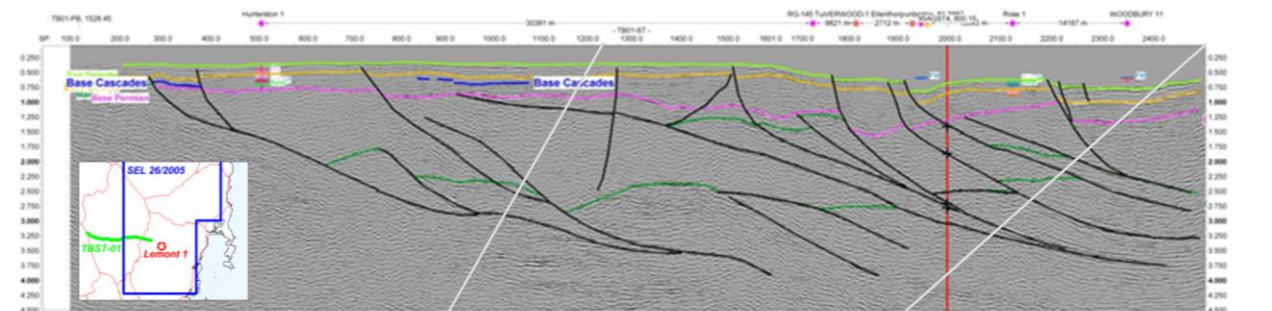


A. Residual Bouguer gravity: Low values (cold colours) reflect regions where (low density) granitic basement is closer to the surface. Some regional structures are also evident. These data were also used to refine the granite topography modelling.

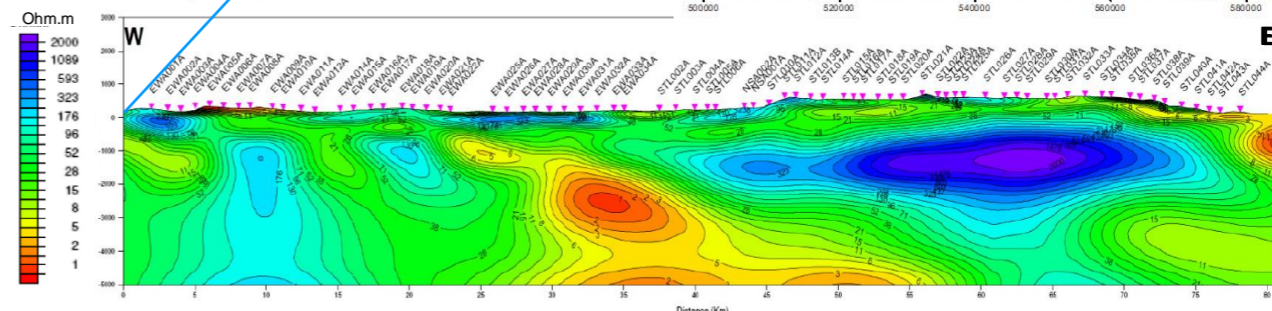
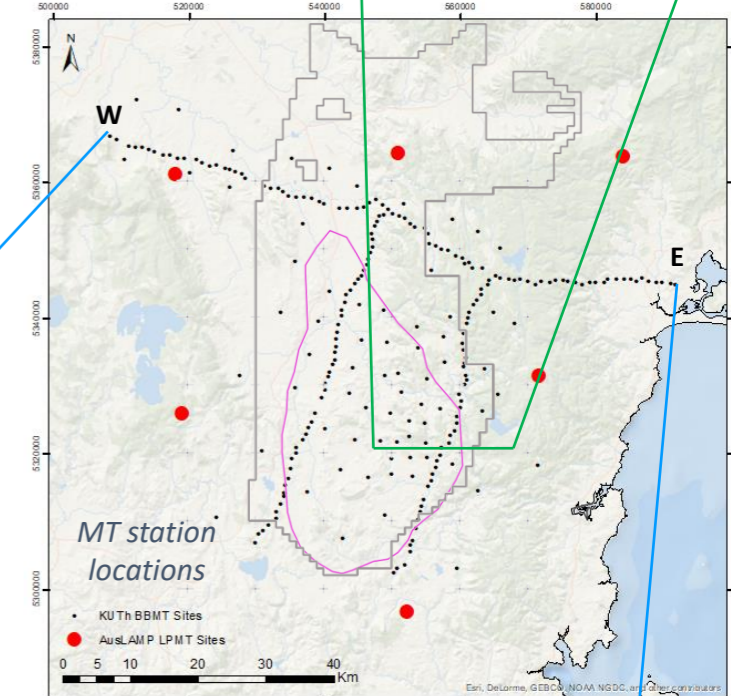
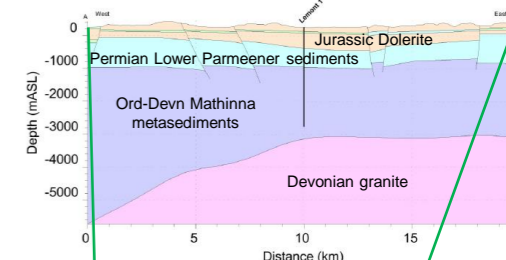
B. Digital terrain model. Again showing some major structures, including a prominent arcuate structure also discernible in the magnetics (C) and gravity (A).

D. Interpreted major and minor structures and possible dolerite intrusion centres (red)

- East-directed thrusts on the western side of the TFZ, described by Holgate (Slide 20), can be seen in the seismic reflection cross-section (top).
- The MT resistivity cross-section (bottom: from 3D inverse-modelling for KUTh Energy) shows a strong resistivity low which coincides with a major interpreted shear (see Slide 11).
- Ostersen (2020)¹⁴ remodelled the KUTh data with the addition of six AusLAMP stations. This significantly improved the resolution, as well as giving better depth information (Slides 9 & 11).
- Joint inverse-modelling of the gravity, passive seismic and MT data is planned, following further surveys to complete the coverage of SEL 21/2022. This will help constrain the main lithological boundaries, including the granite surface, and Mathinna-Parmeener unconformity, and possibly the dolerite centres, as well as highlighting the major structures.



Residual gravity

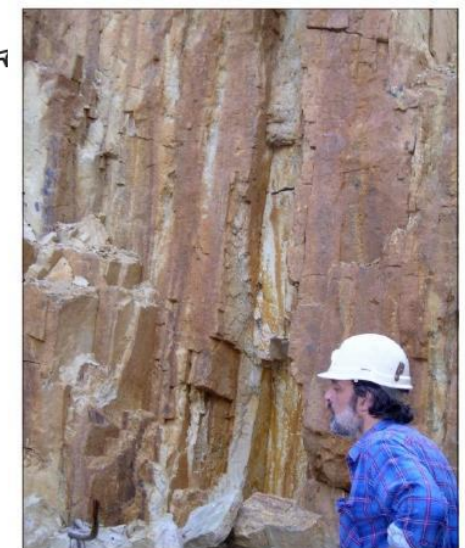
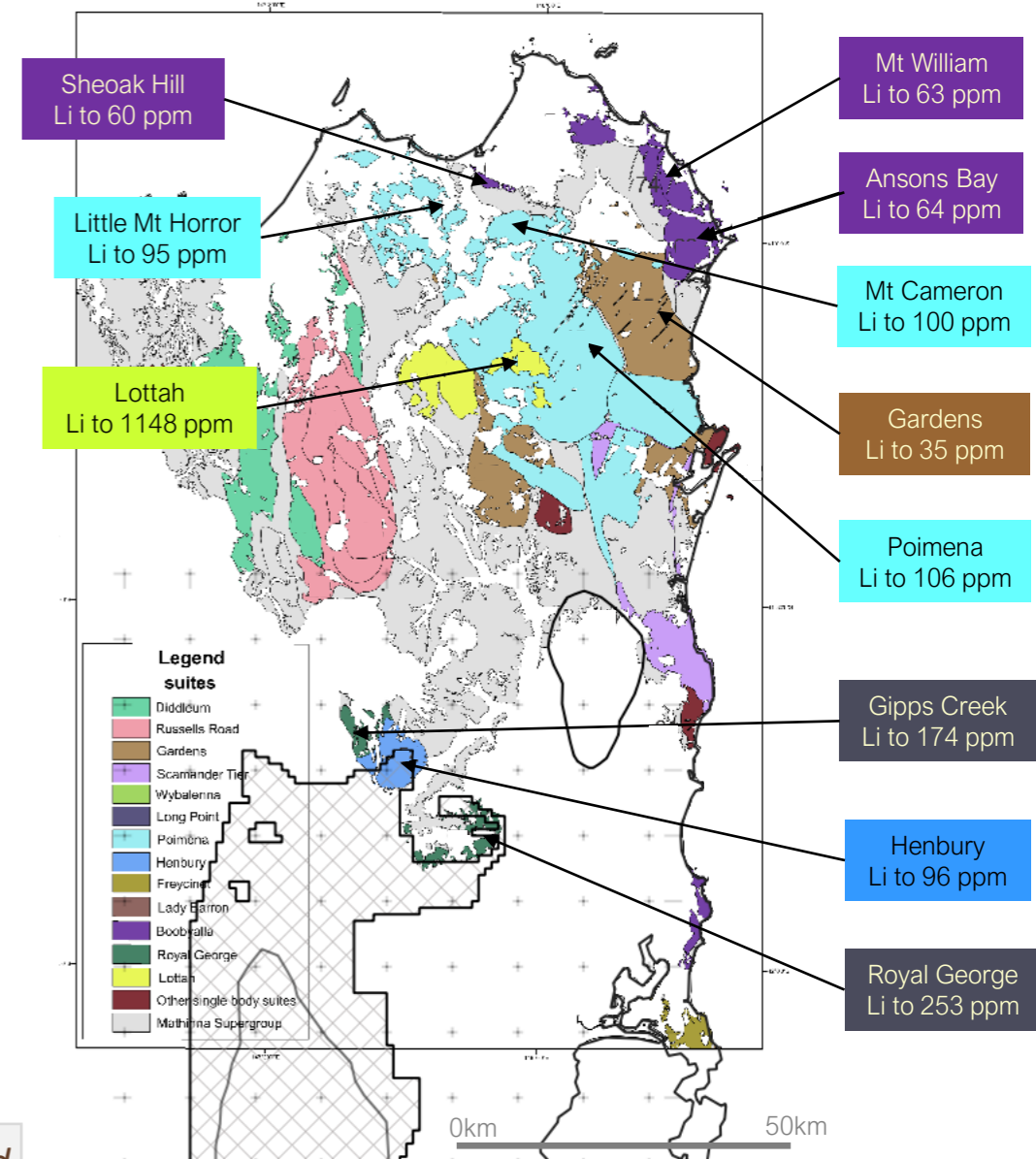


Sources: Holgate (2013)¹⁰, MRT, Ostersen (2020).¹⁴

- Prior to drilling a deep hole, we must rely on indirect evidence of lithium-in-brine. Many of the granites in NE Tas are highly mineralised and contain significant levels of Li, including the ~100-250ppm Li hard-rock assays²⁹ in the Henbury, Gipps Ck and Royal George granites in the northeast corner of the licence. These values are comparable to (e.g.) the 310ppm of the Carnmenellis granite which hosts the Geocubed project in Cornwall, UK: see Slide 17.
- Dr Francis Wedin, CEO of Vulcan Energy with its Upper Rhine lithium project has noted: “Key will be flow rate from the granite. I doubt that lithium will be an issue.” (Wedin, pers. comm., 2021) That is, permeability will likely be the critical factor and, as previously explained, Direct Lithium considers it has this covered.
- Extensive, hot, and highly mineralised granites are interpreted to be the source of heat for the Lemont (and Fingal) resources, and lithium-in-brine concentrations comparable to the global high-grade average of ~200ppm Li are anticipated.

Top: SELA 21/2022 superimposed on Tasmania’s north-east granites with assayed lithium values (from A. McNeill, pers. comm. and Corbett et al, 2014). Maximum values quoted where there are multiple samples; granites with zero lithium not quoted. Assays overlaid on figure from Geological Evolution of Tasmania (Corbett et al, 2014).

Bottom: The Royal George tin mine contains “sub-vertical and sub-parallel porphyritic aplite dykes, alkali feldspar granite with some pegmatitic segregations, and cassiterite-sulphide-uranium bearing, quartz-rich greisen” (MRT Record 2005/03).



²⁹ These hard-rock assays are coincidentally comparable to the expected lithium-in-brine values,