HiSeis

Lynas Rare Earths

Multi-scale insights into the high-grade Mt Weld REE deposit from 2D and 3D active seismic survey data

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Co-authors: Greg Turner[1], Mohamed Megebry[1], Ganesh Bhat[2] and Brad Knell[2]
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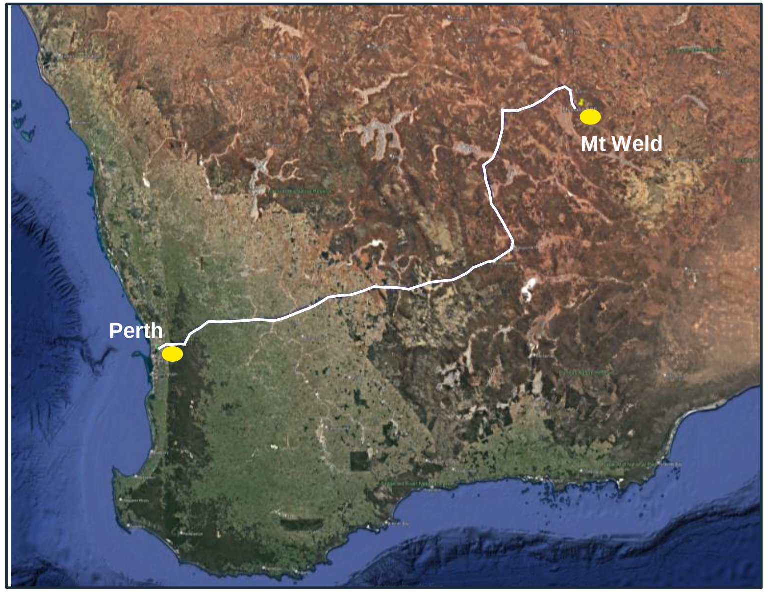
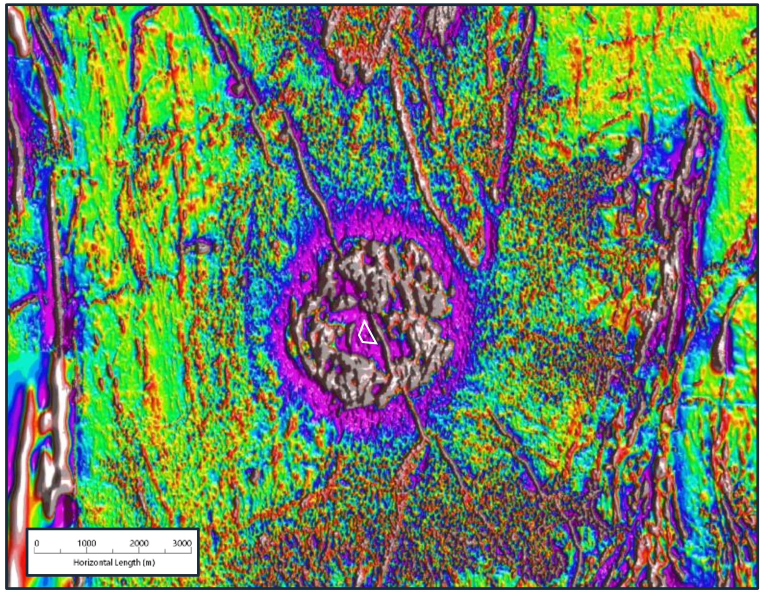
15th November, 2023

Lynas Rare Earth - Mt Weld Deposit

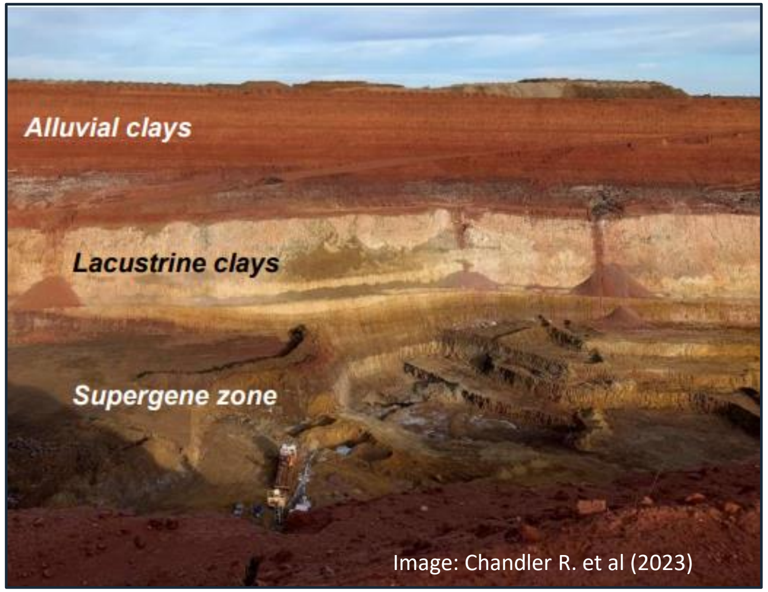
- A world class laterite/carbonatite rare earth deposit, Mt Weld has been in production since 2011 and remains one of the highest grade REE deposits globally
- Total Mineral Resource: 55Mt @ 5.2% TREO (Lynas Annual Report, 2023)



Seismic Program Location Map



Magnetics Intensity – Carbonatite Intrusive Profile

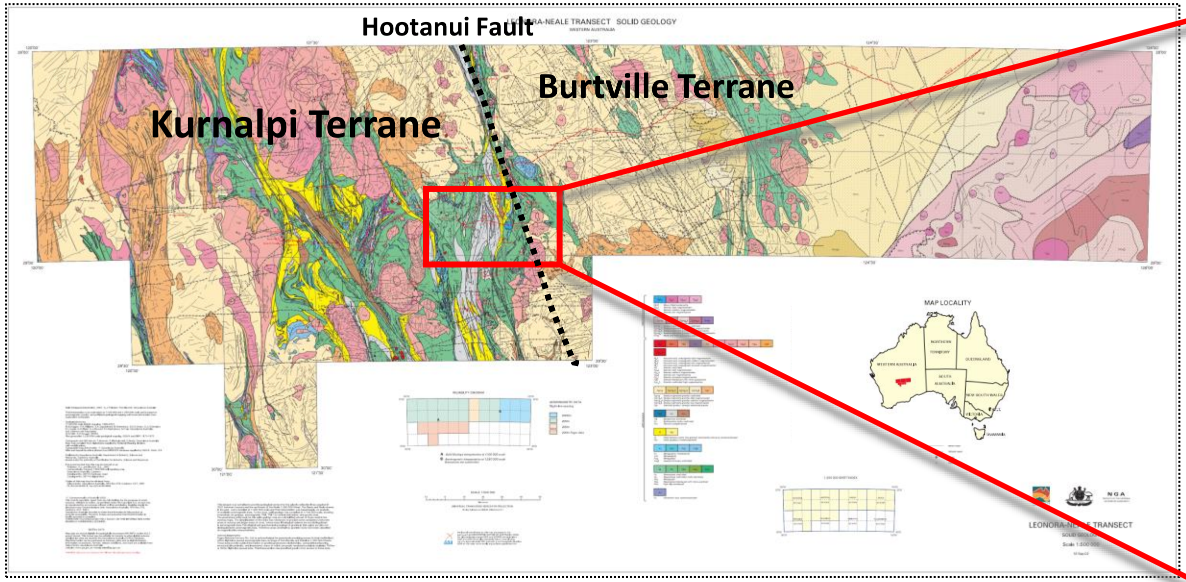


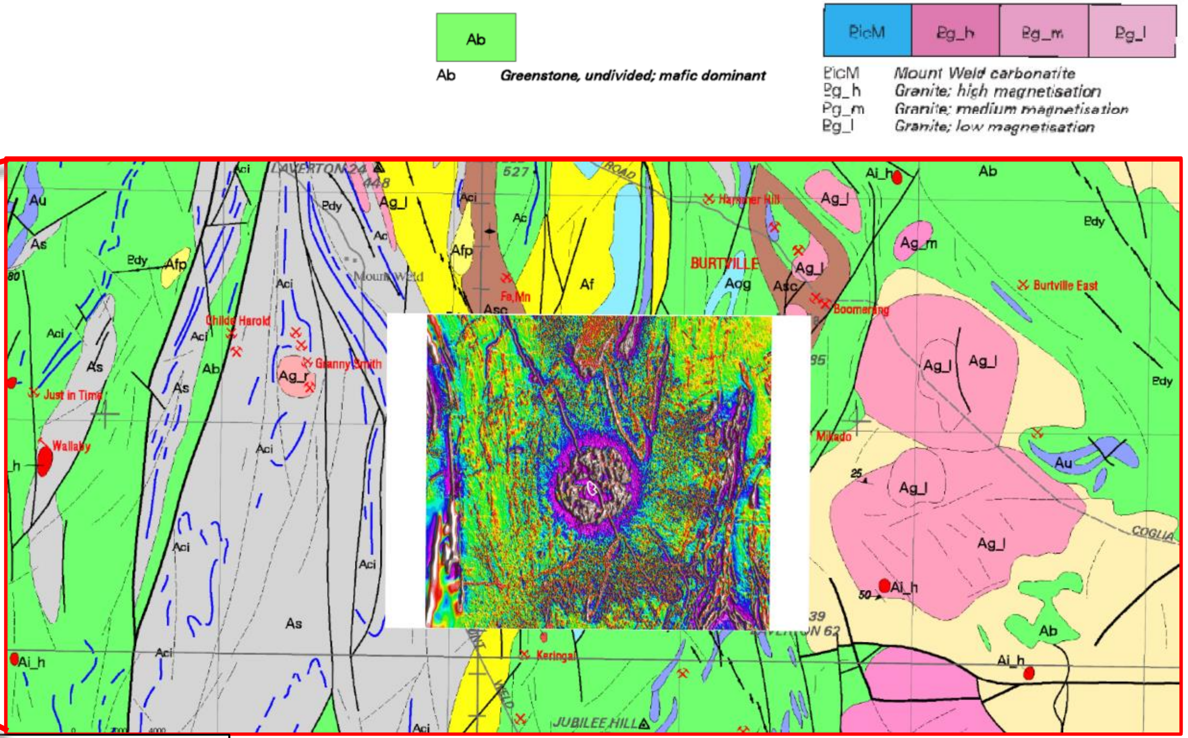
Photography of Mt Weld Pit Wall

- Ore extracted from 20-120m thick regolith profile derived a weathered Proterozoic carbonatite intrusive
- Regolith profile also behaves as an aquifer, important local water source for processing

Can seismic help narrow down prospective drilling targets to increase reserves and find more water?

Geological System





The Mt Weld Carbonatite – a **multi-phase** intrusive body (3 – 4km in diameter), intruding Neoarchean Laverton greenstones within the Eastern Goldfield Province

- **Variable chemistry** → *resulting in variable weathering profiles.*
  - Dominantly calcio-carbonatite intruded by magnesio to ferro carbonatite.
  - **Textures** are both ***Brecciated*** to ***Layered***.
- **Dolerite Dyke –** acting as baffles/barriers within groundwater aquifers?
- **Near surface weathering** (Permian to Eocene) resulted in highly enriched REE regolith profile.

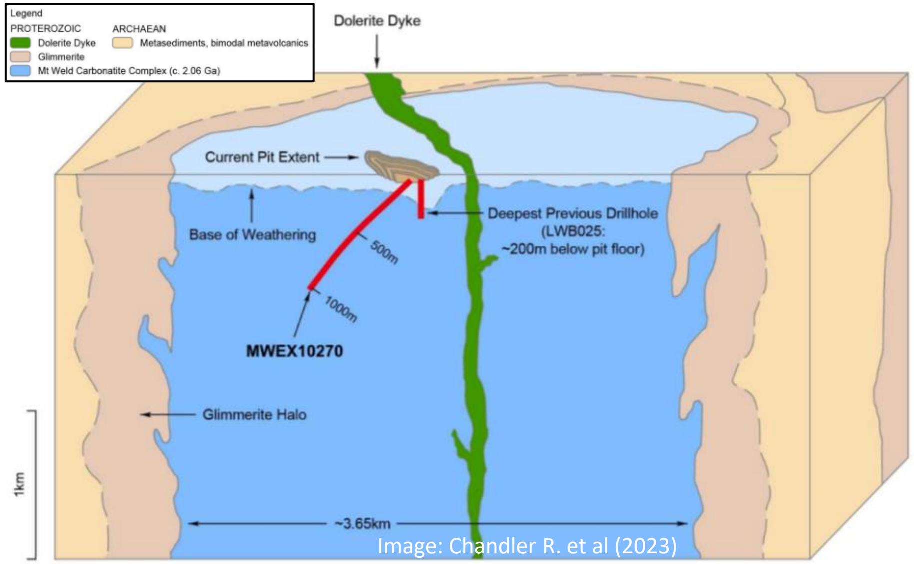


Image: Chandler R. et al (2023)

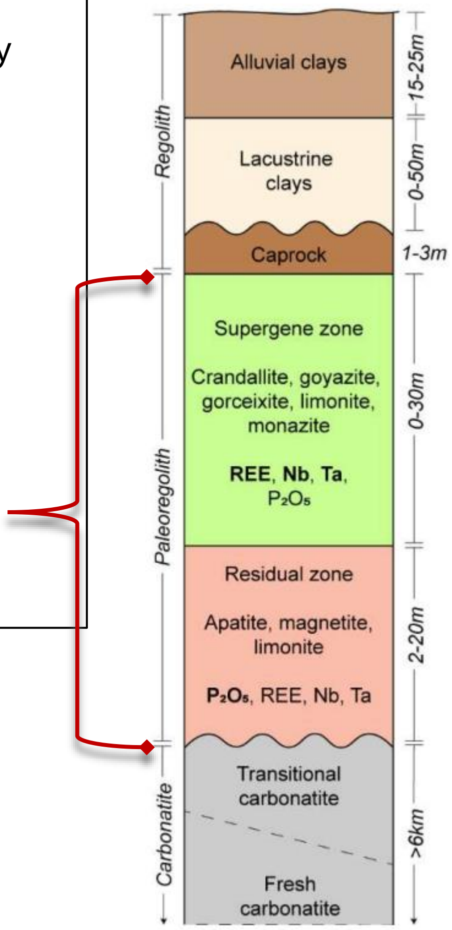
Seismic Program Objectives

1. **Define new drilling targets for additional REEs**

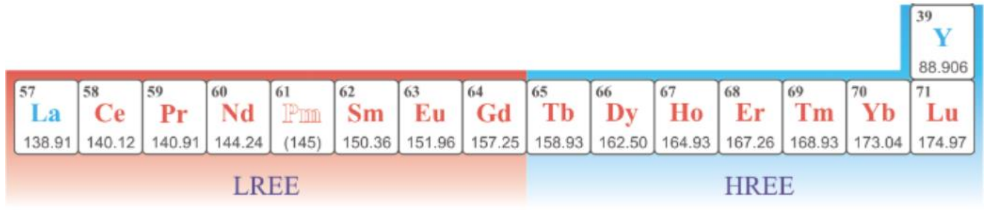
- Examine area on periphery of block, where current drilling is relatively shallow (dominantly AC holes, ~50-70m drilling depth)

2. **Exploration for groundwater resources**
   - Depressions in the weathering surface
   - Faults/fracture zones within the bedrock

3. **Provide insights into the structural setting**
   - Faulting may be controlling groundwater flow directions
   - Younger Dolerite intrusives altering the carbonatite.



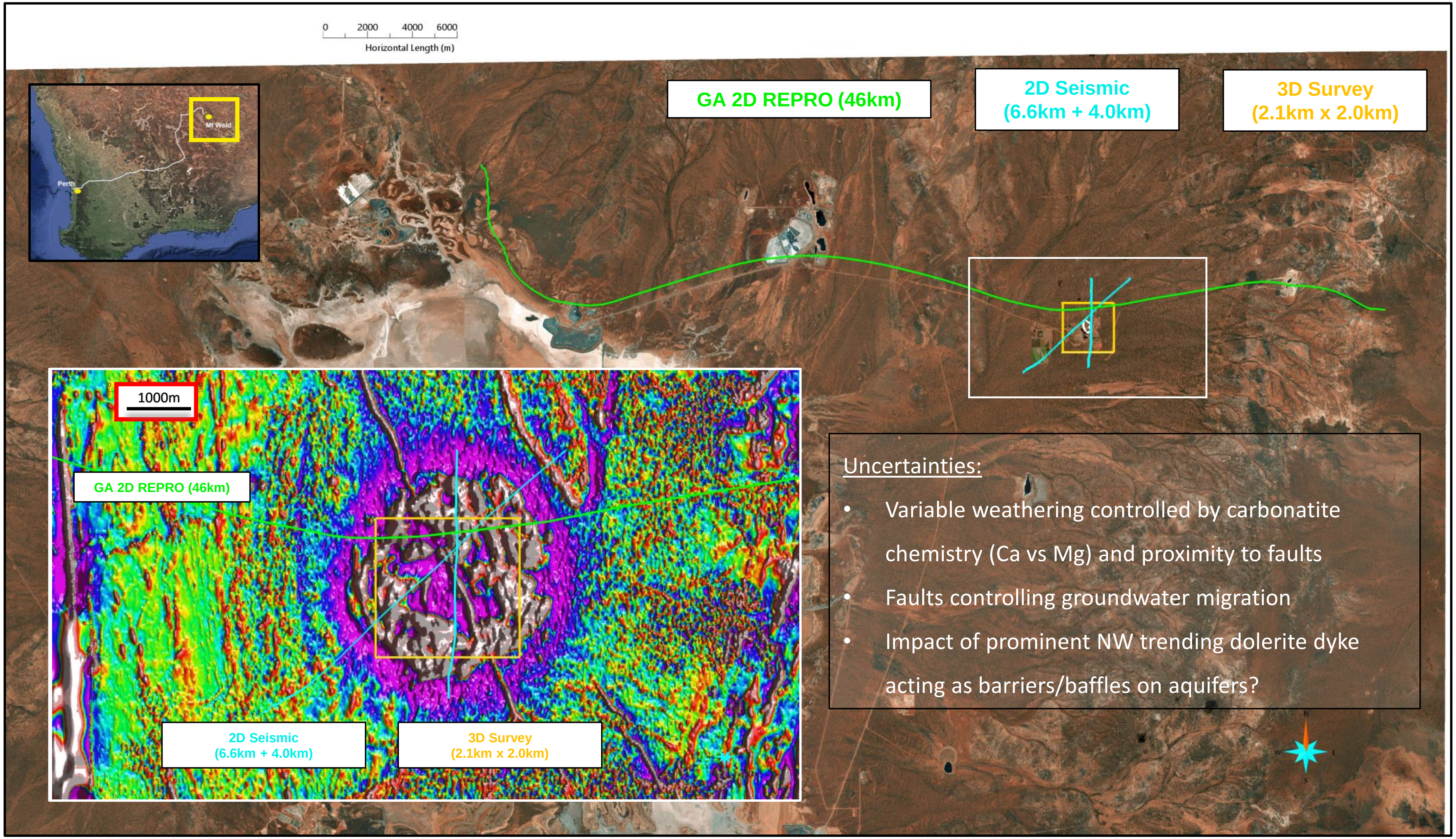
REE = Rare Earth Elements



Rare earths are a key enabler for the development of energy saving technologies

Seismic Surveys

Mt Weld Seismic – 3 Tiers of Seismic Data



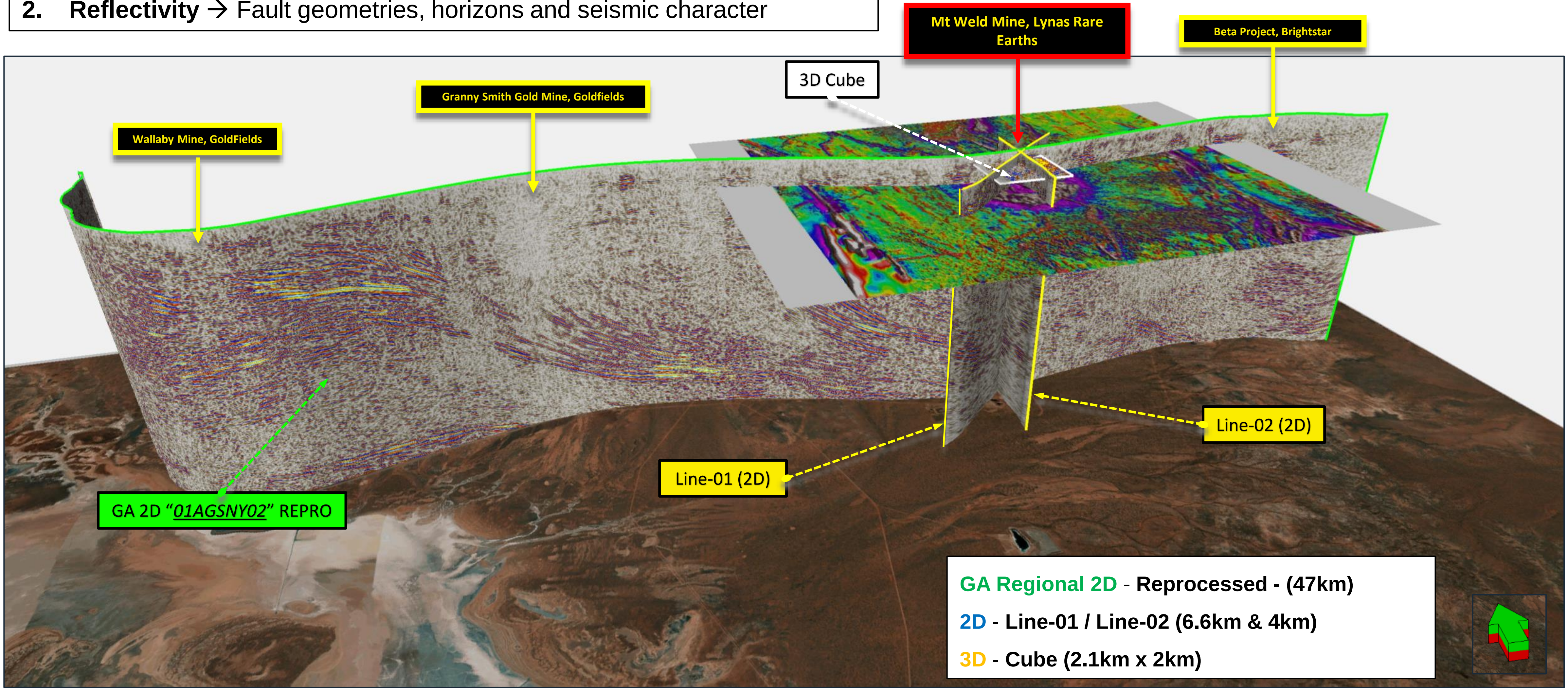
Uncertainties:

- Variable weathering controlled by carbonatite chemistry (Ca vs Mg) and proximity to faults
- Faults controlling groundwater migration
- Impact of prominent NW trending dolerite dyke acting as barriers/baffles on aquifers?

Mt Weld Seismic – 3 Tiers of Seismic Data

For each seismic dataset, HiSeis produces:

1. **Tomography** → Weathering profile / depth to fresh rock
2. **Reflectivity** → Fault geometries, horizons and seismic character

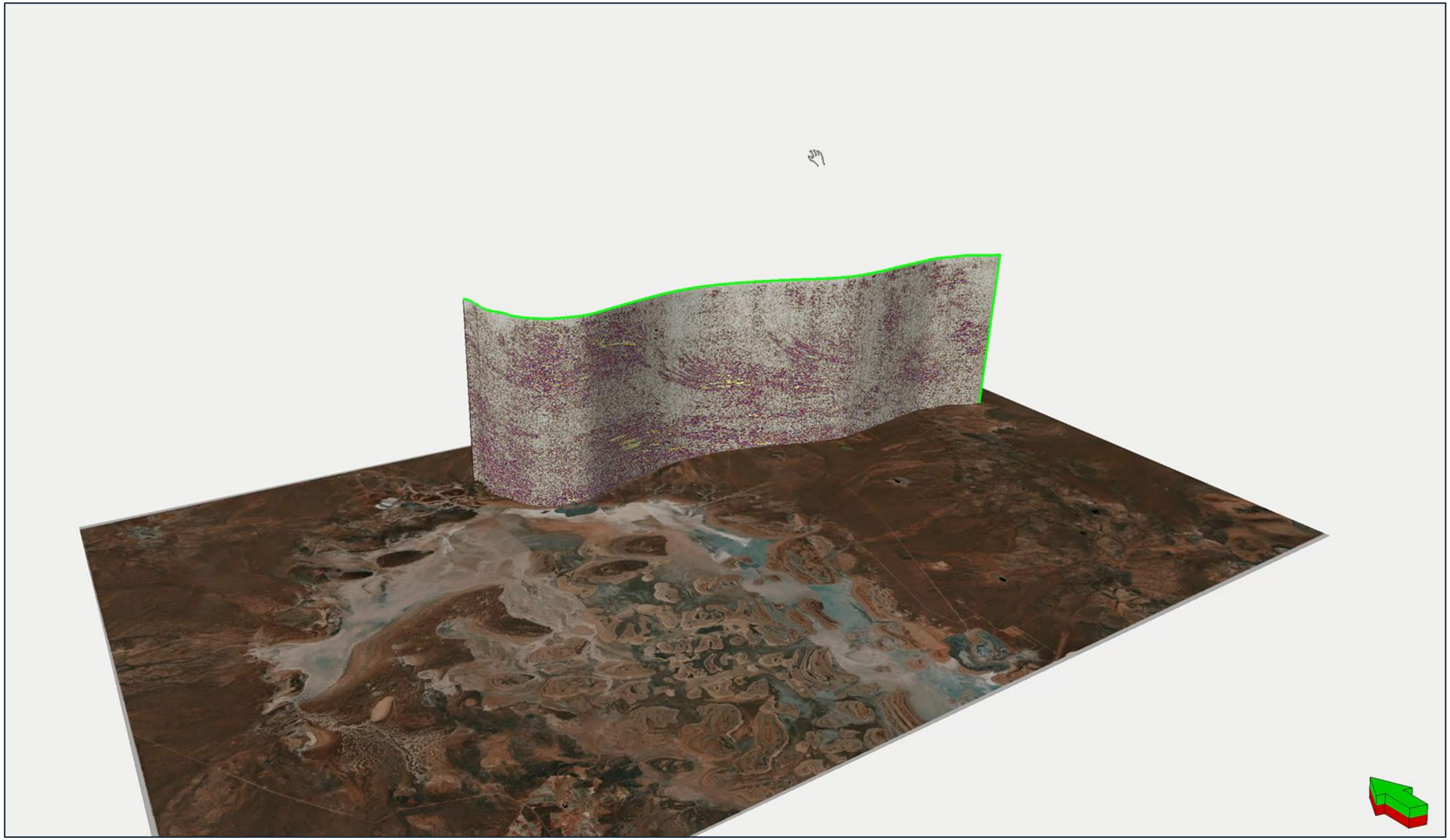


First Pass Observations

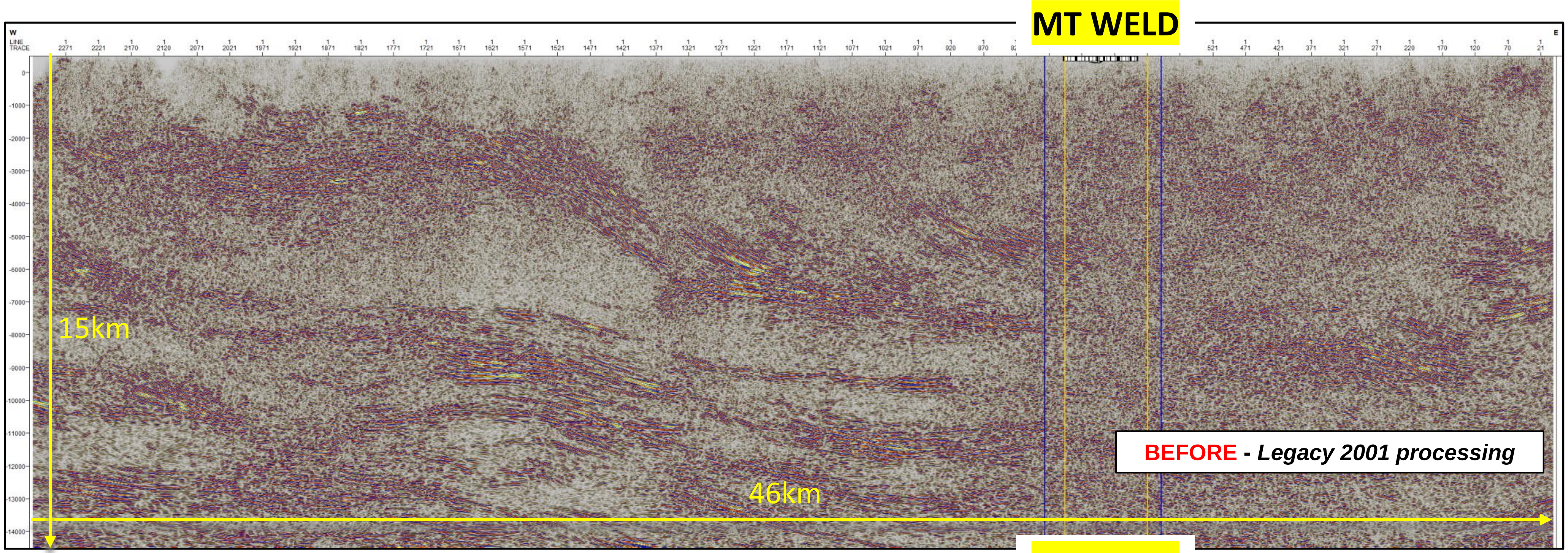
Mt Weld Seismic Datasets

(1) Regional GA Line (Reprocessed)

GA Line Repro → 2D Lines → 3D Cube



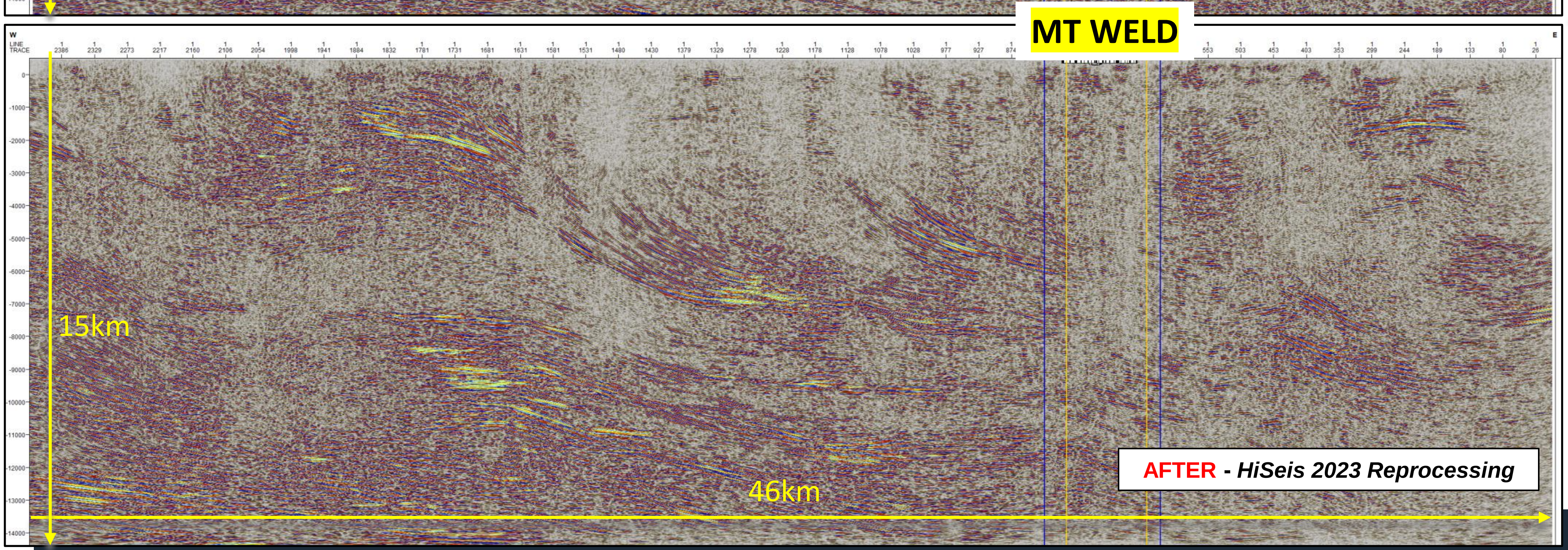
Play Video:



Regional 2D line

Legacy 2001 processing

Difficulty defining intrusive geobodies and reflector continuity



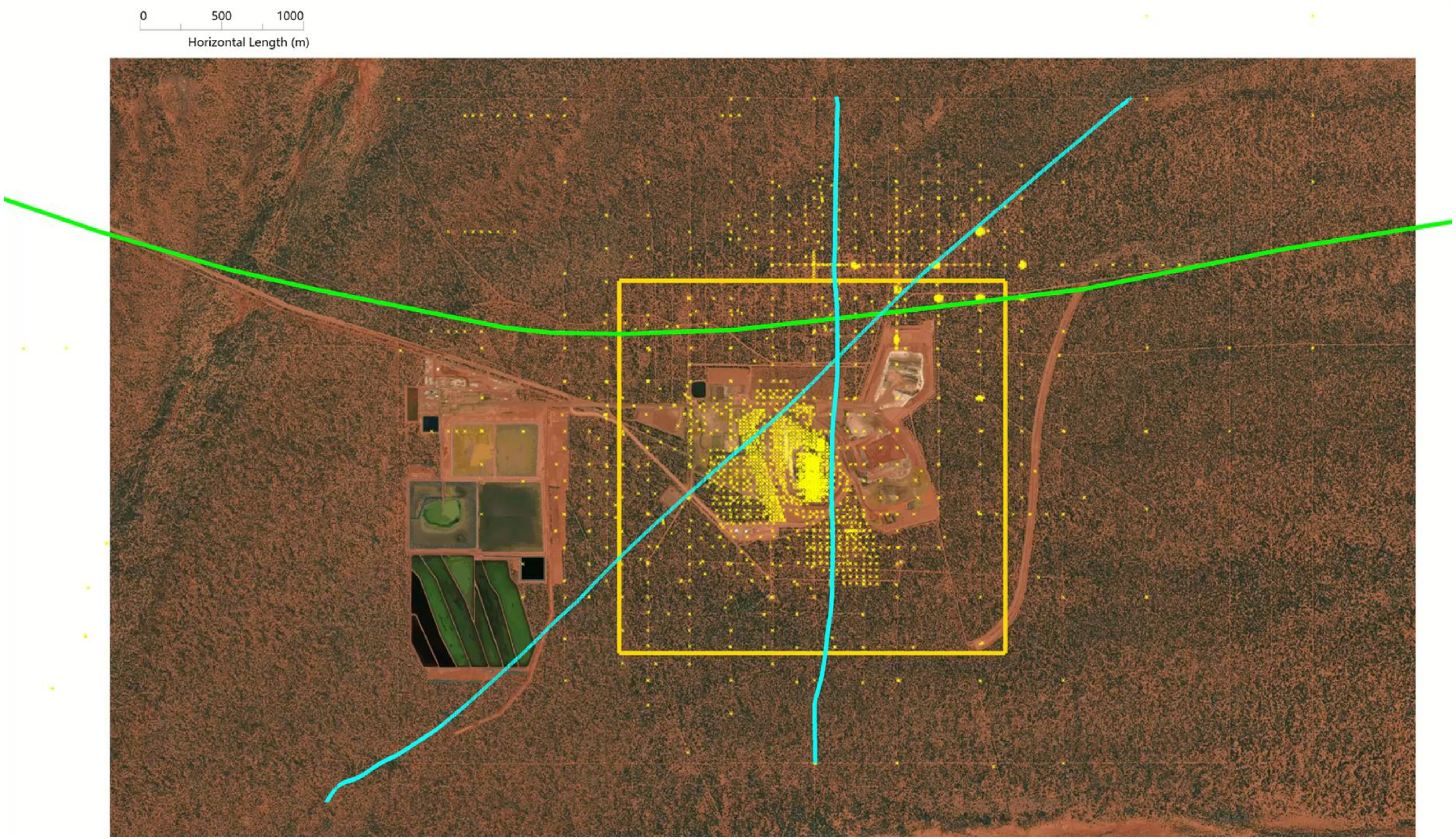
2023 Processing

- ✓ **Detailed velocity analysis**
- ✓ **Improved reflectivity in the top 3km**
- ✓ **Higher confidence interpretation**

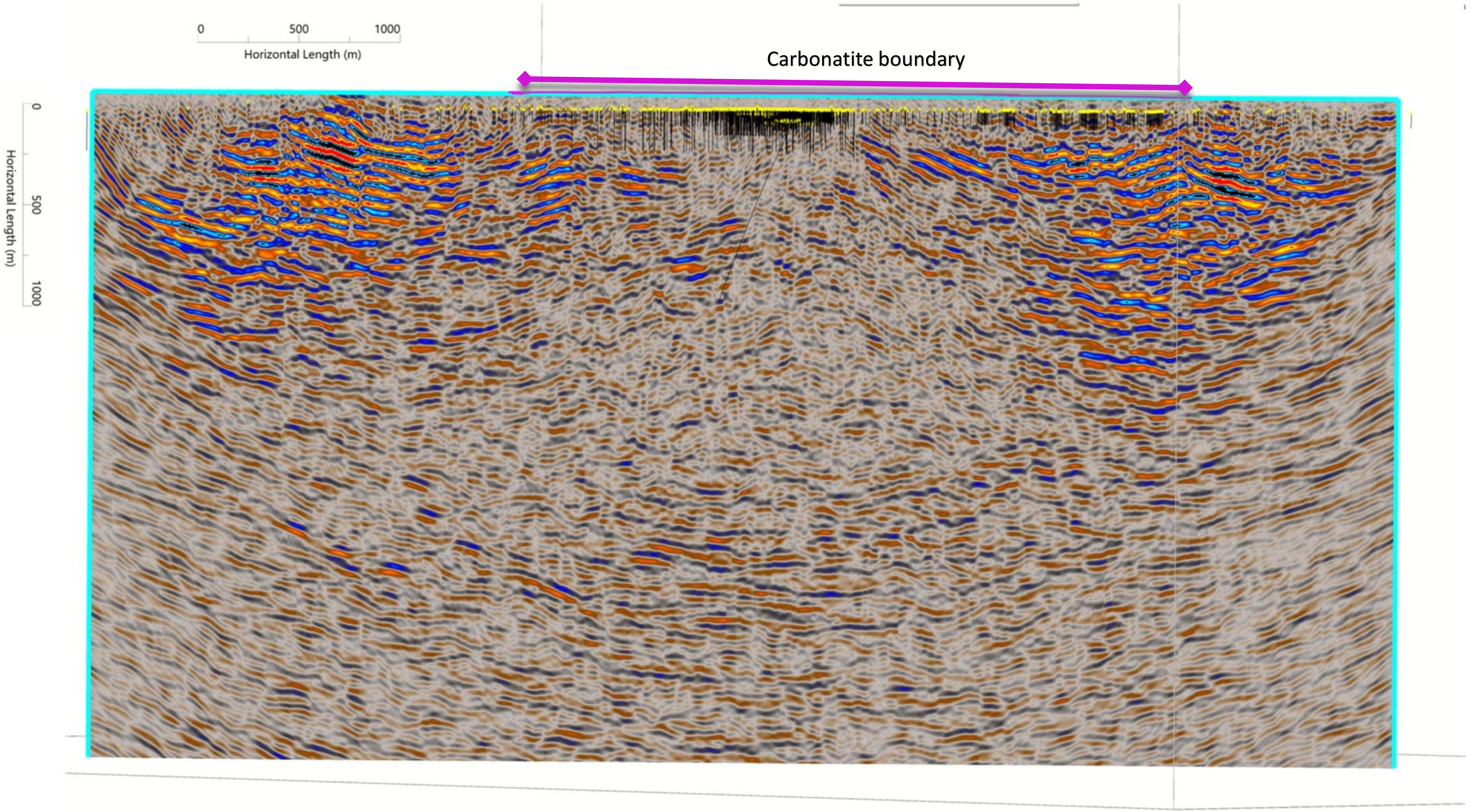
Lynas Rare Earths

HiSeis

2D Seismic Datasets



2D Seismic Datasets



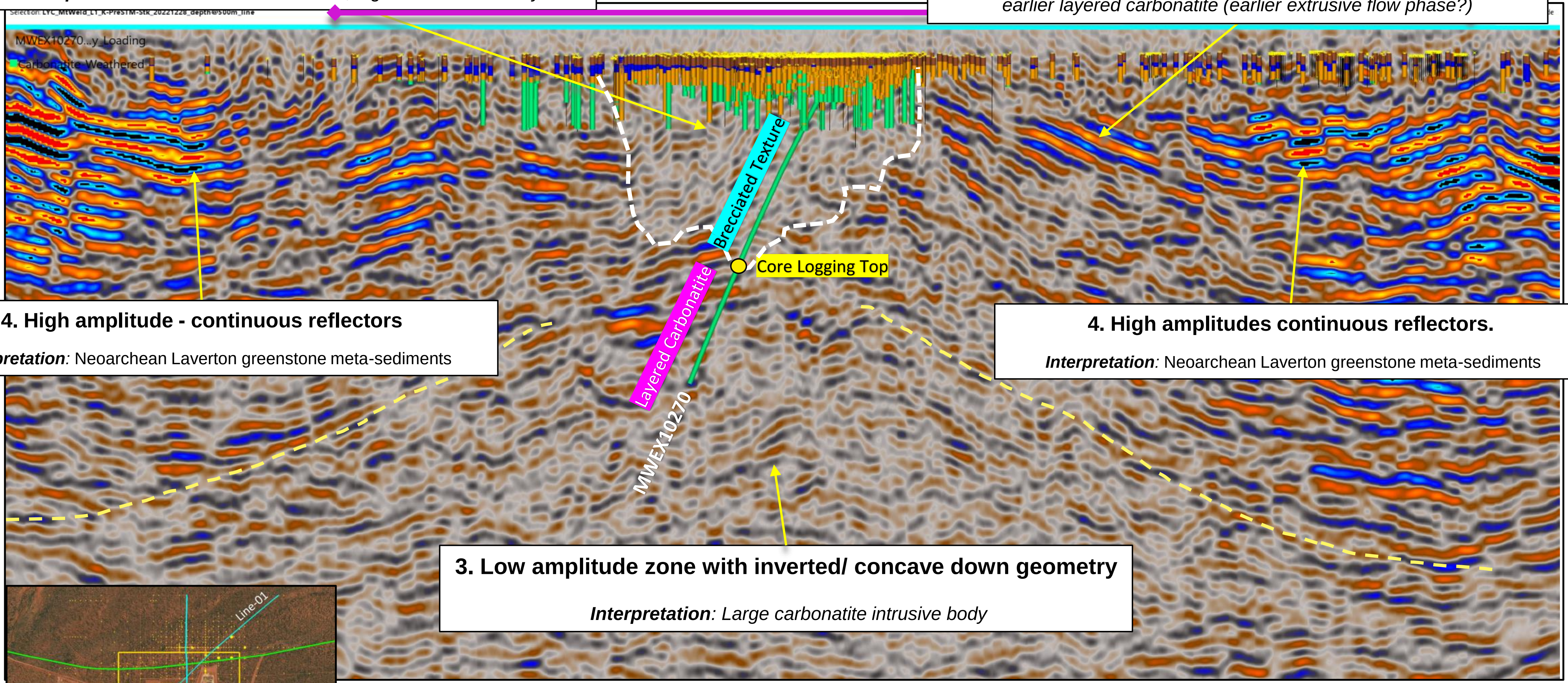
ations & Int

1. Low amplitude zone with discontinuous seismic reflectors

Interpretation: *Brecciated Carbonatite, higher fracture density.*

2. Moderate amplitude reflectors, laterally continuous & terminate against low amplitude contact.

Interpretation: *Neoarchean Laverton greenstone, or, earlier layered carbonatite (earlier extrusive flow phase?)*



4. High amplitude - continuous reflectors

Interpretation: Neoarchean Laverton greenstone meta-sediments

4. High amplitudes continuous reflectors.

Interpretation: Neoarchean Laverton greenstone meta-sediments

3. Low amplitude zone with inverted/ concave down geometry

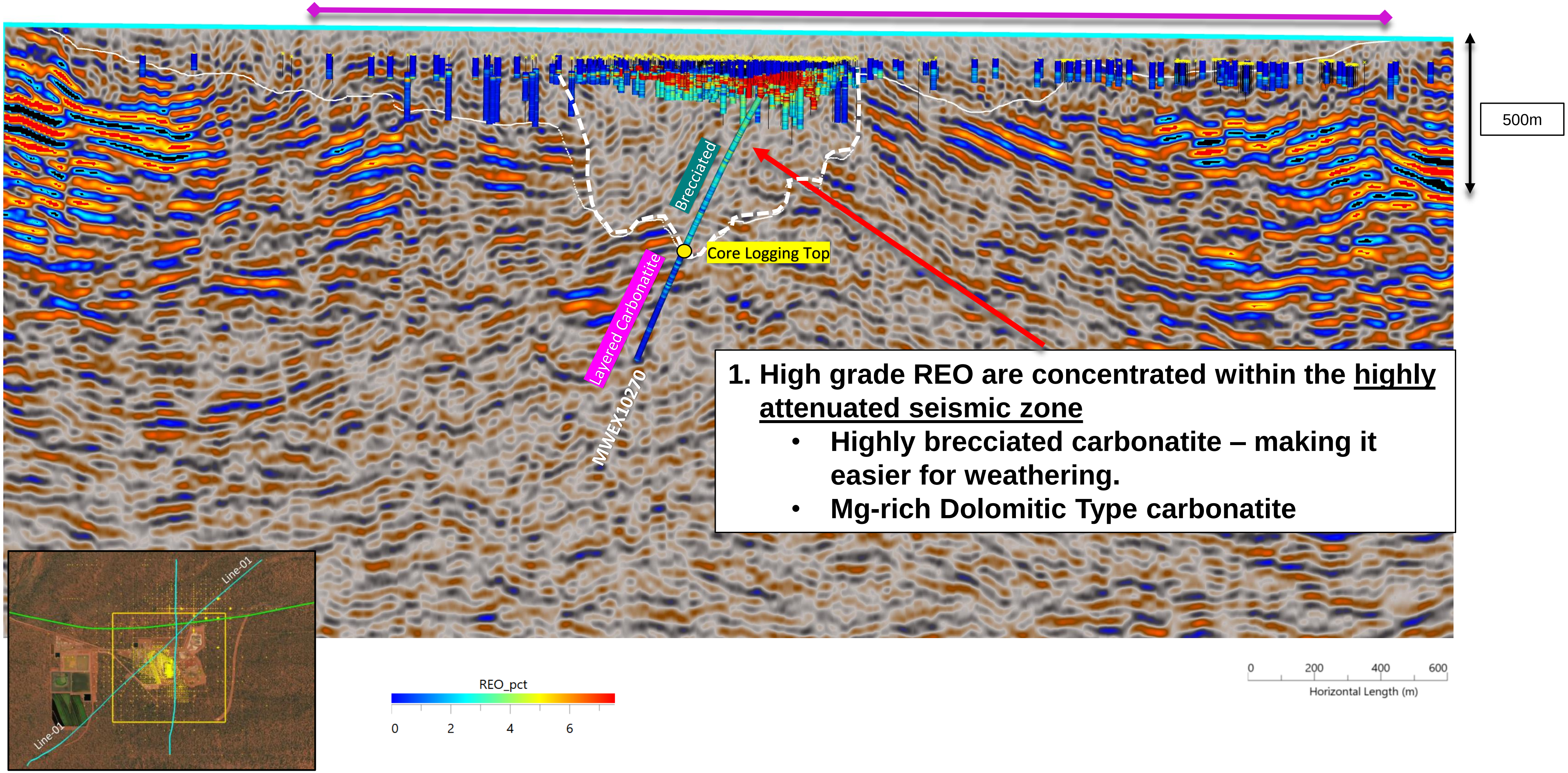
Interpretation: *Large carbonatite intrusive body*

Lithology Zones
- TRANSPORTED ALLUVIUM
- LACUSTRINE SEDIMENTS
- REGOLITH CARBONATITE
- FRESH CARBONATITE

* EIS funded diamond hole MWEX10270 total length 1020mMD

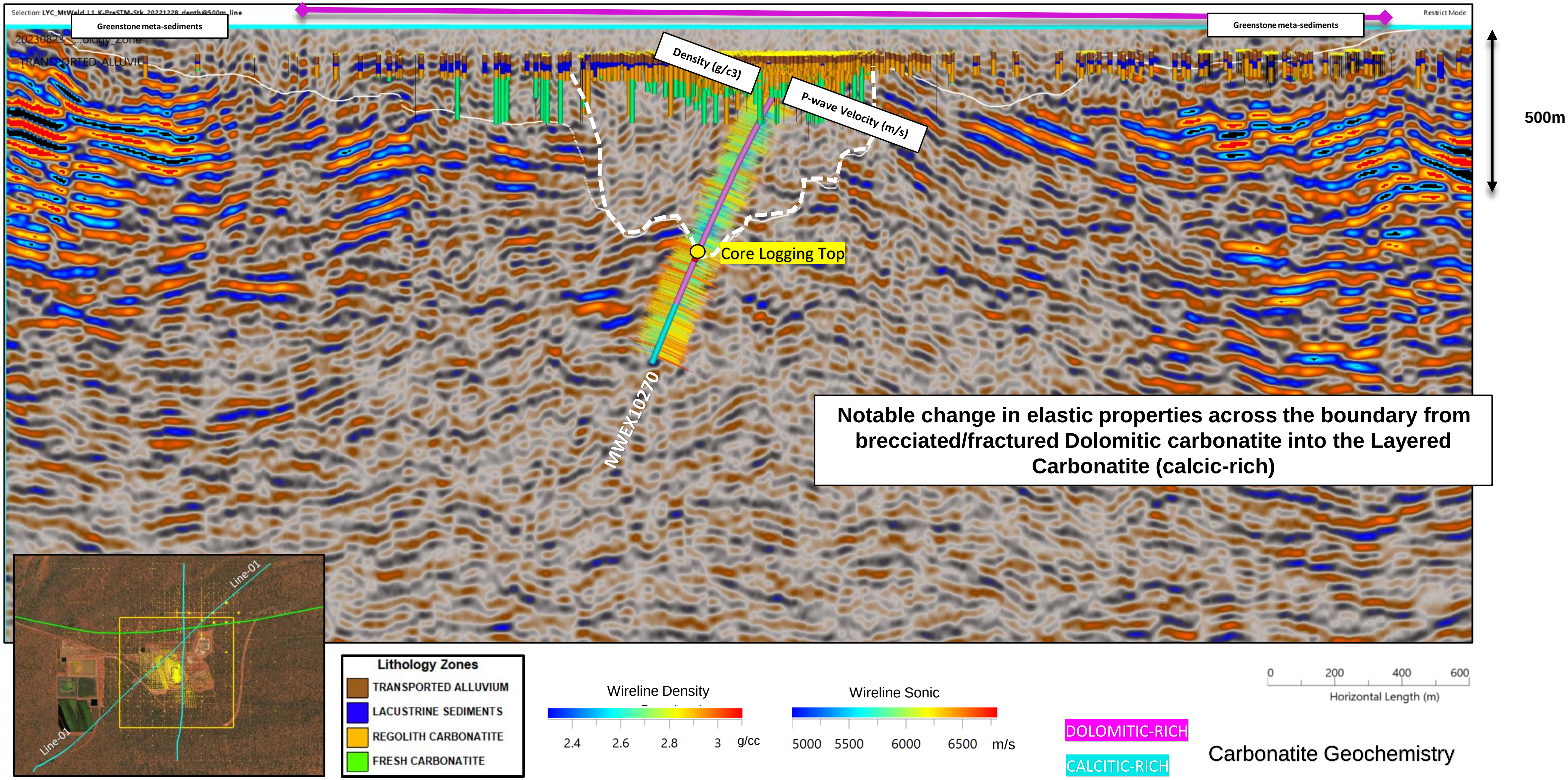
0 200 400 600
Horizontal Length (m)

Rare Earth Oxide % Grade

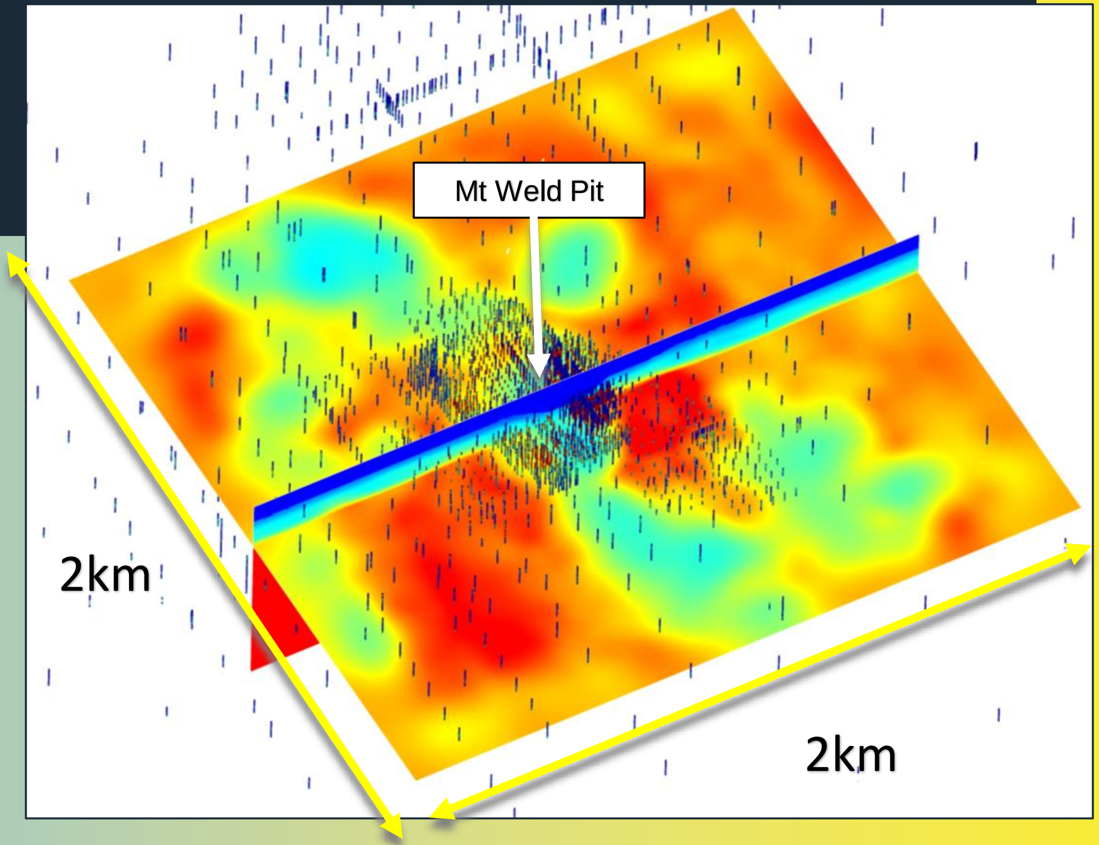


1. High grade REO are concentrated within the <u>highly attenuated seismic zone</u>
    - Highly brecciated carbonatite – making it easier for weathering.
    - Mg-rich Dolomitic Type carbonatite

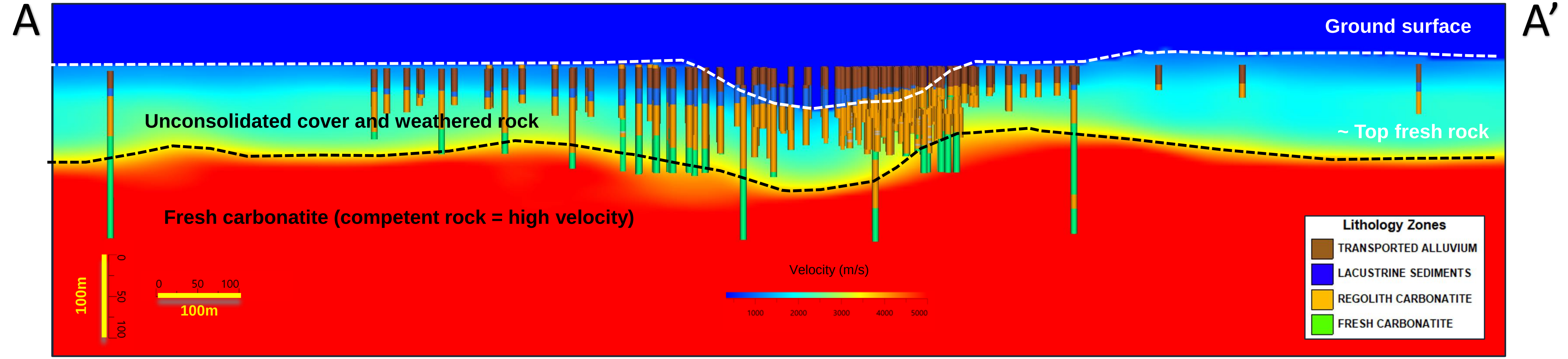
Wireline Logging – Density & Sonic

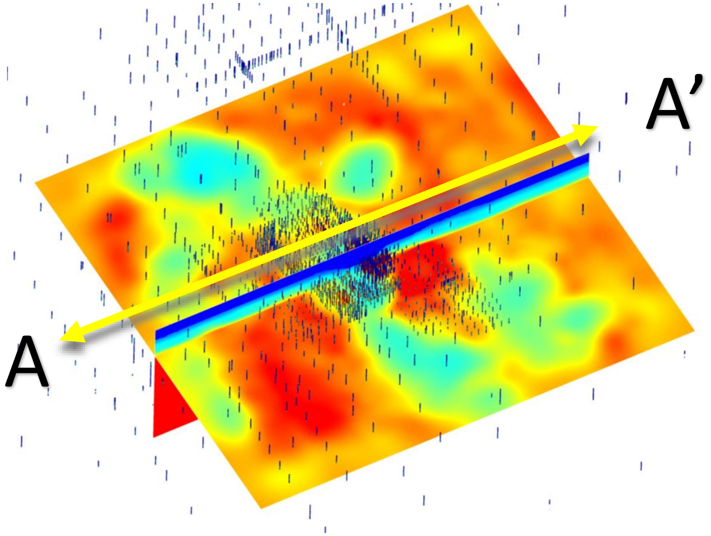


3D Seismic Results



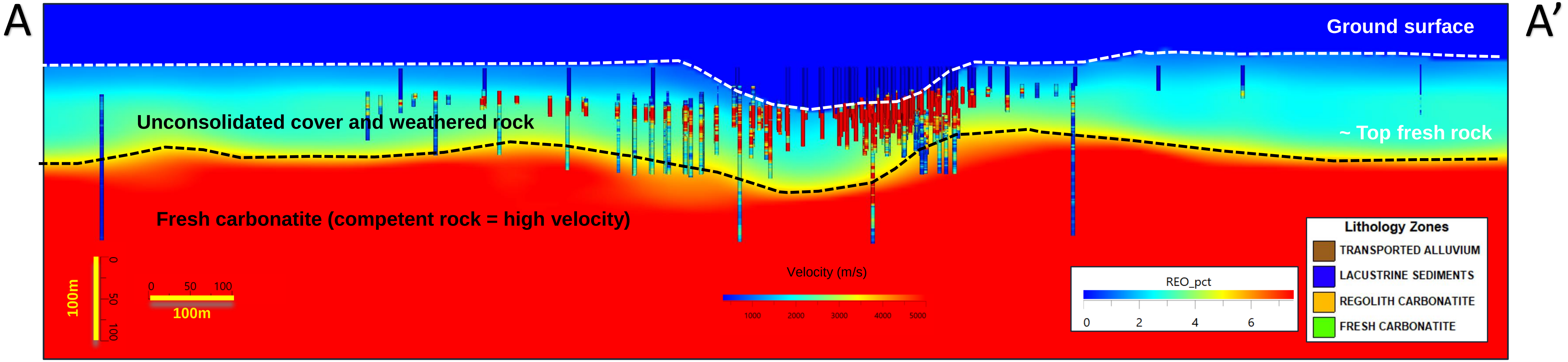
3D Seismic – Refraction Tomography
Finding Top of Fresh Rock

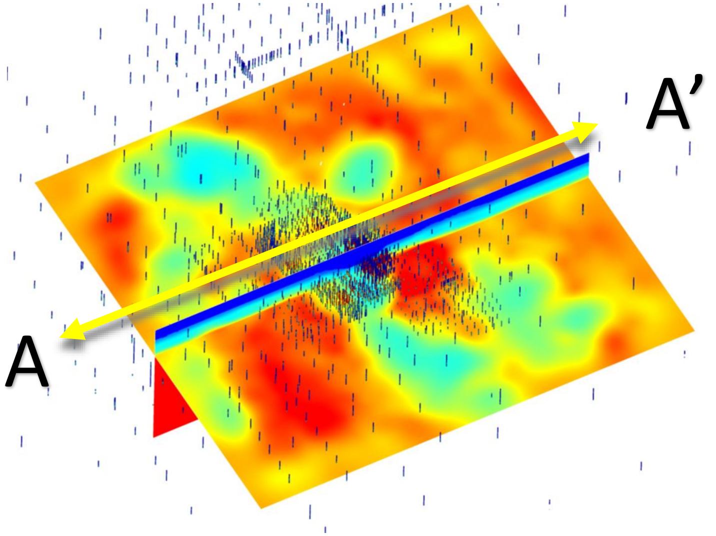




- Lynas' mineral systems model: ***A thicker regolith profile increases the probability of encountering REE ore concentrations***
- Weathering reduces competency of rocks → ***reduces seismic velocity***
- HiSeis 3D seismic refraction tomography cube revealed high variability in shallow seismic velocity → ***Identify weathering profile drilling targets***

3D Seismic – Refraction Tomography
Finding Top of Fresh Rock





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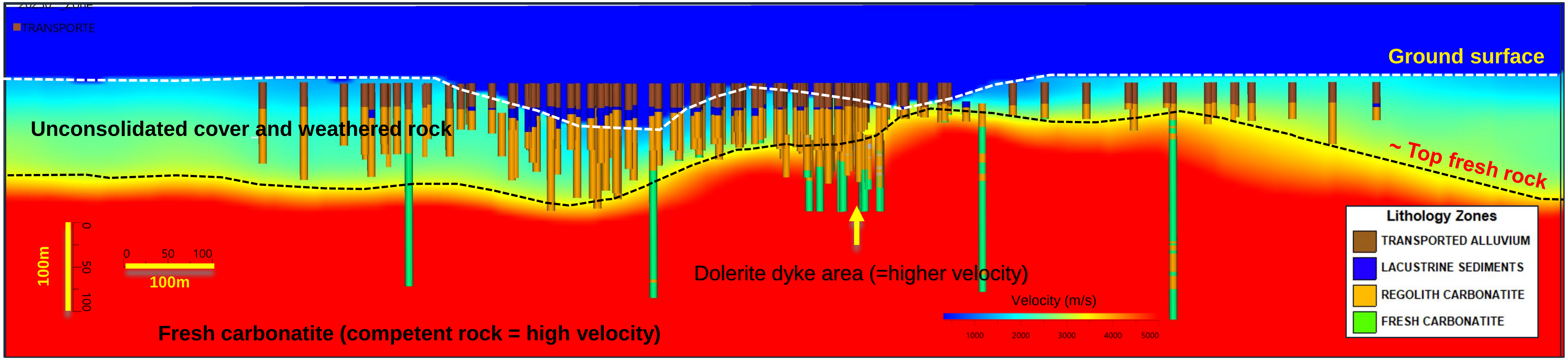

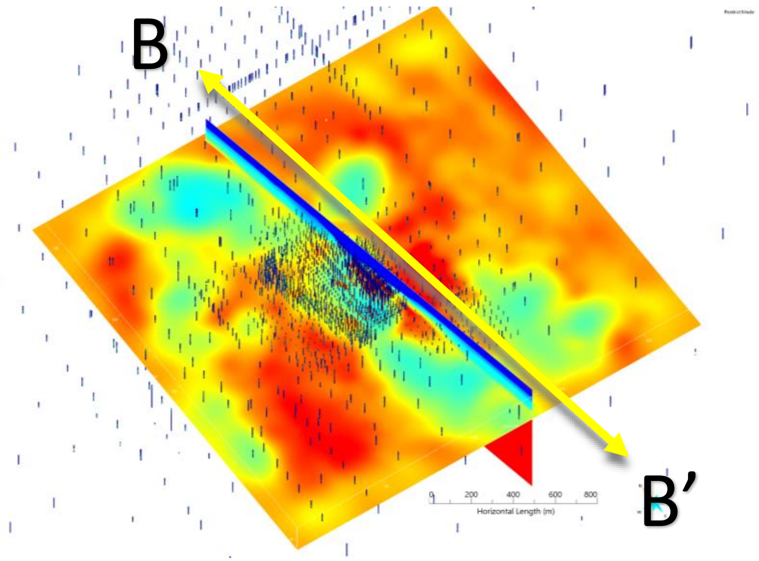

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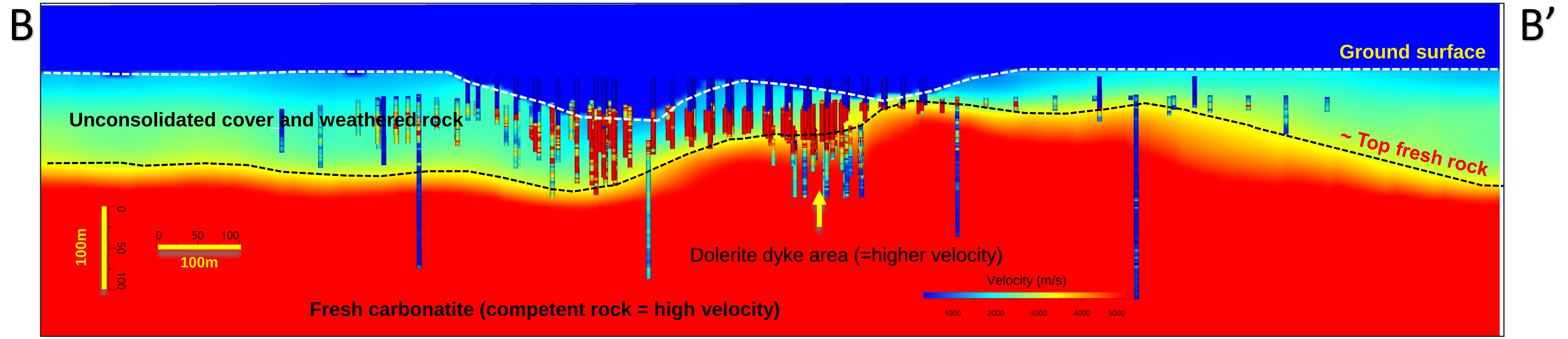

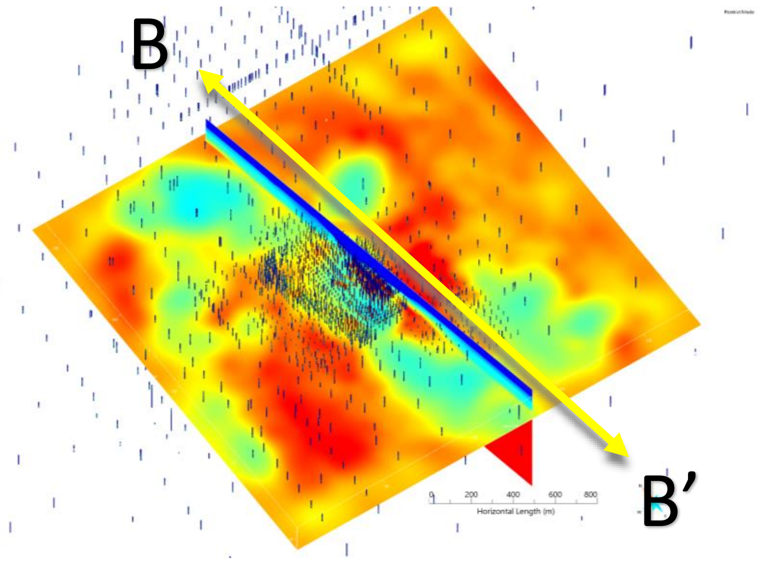

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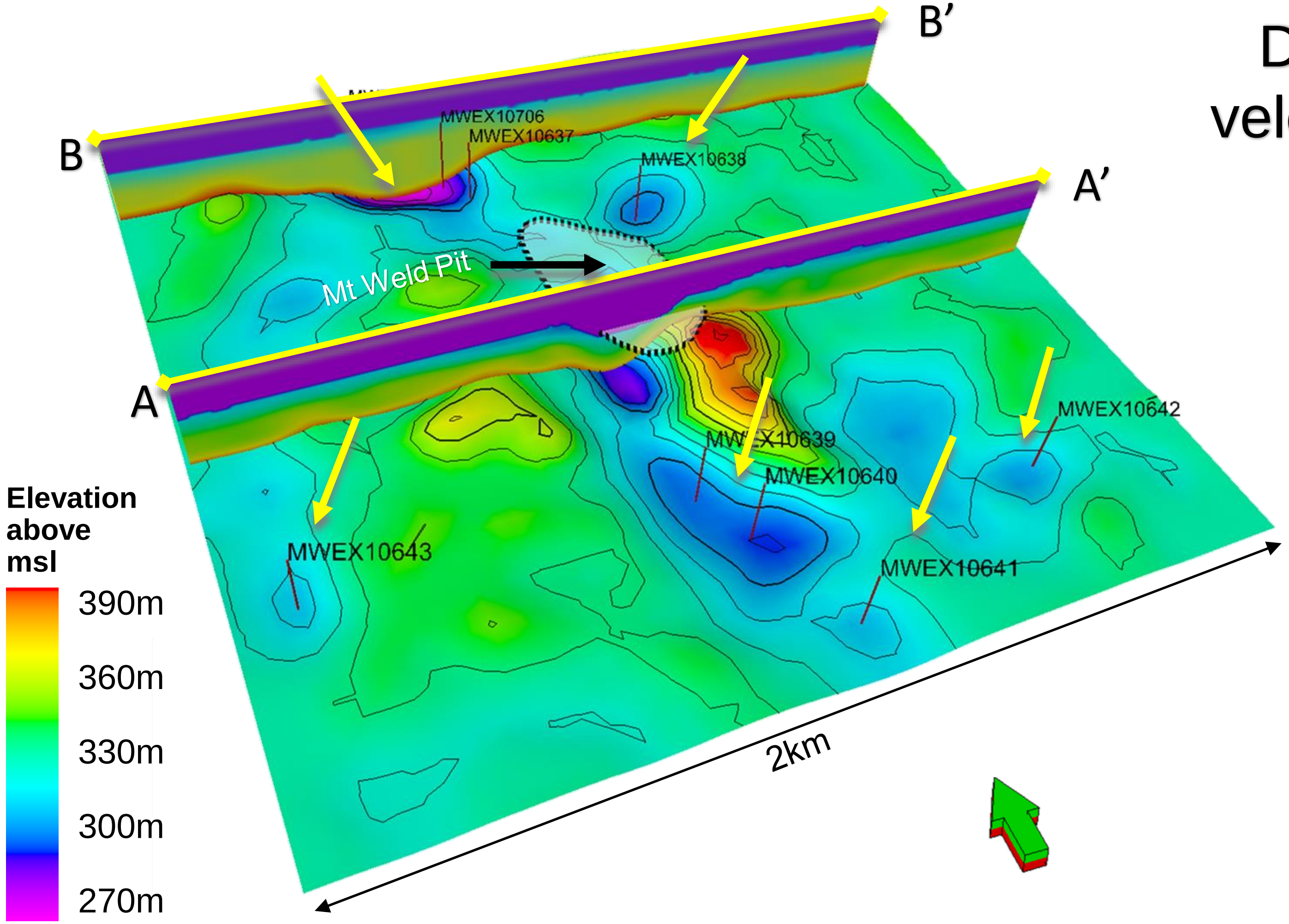
3D view of 3200m/s velocity contour



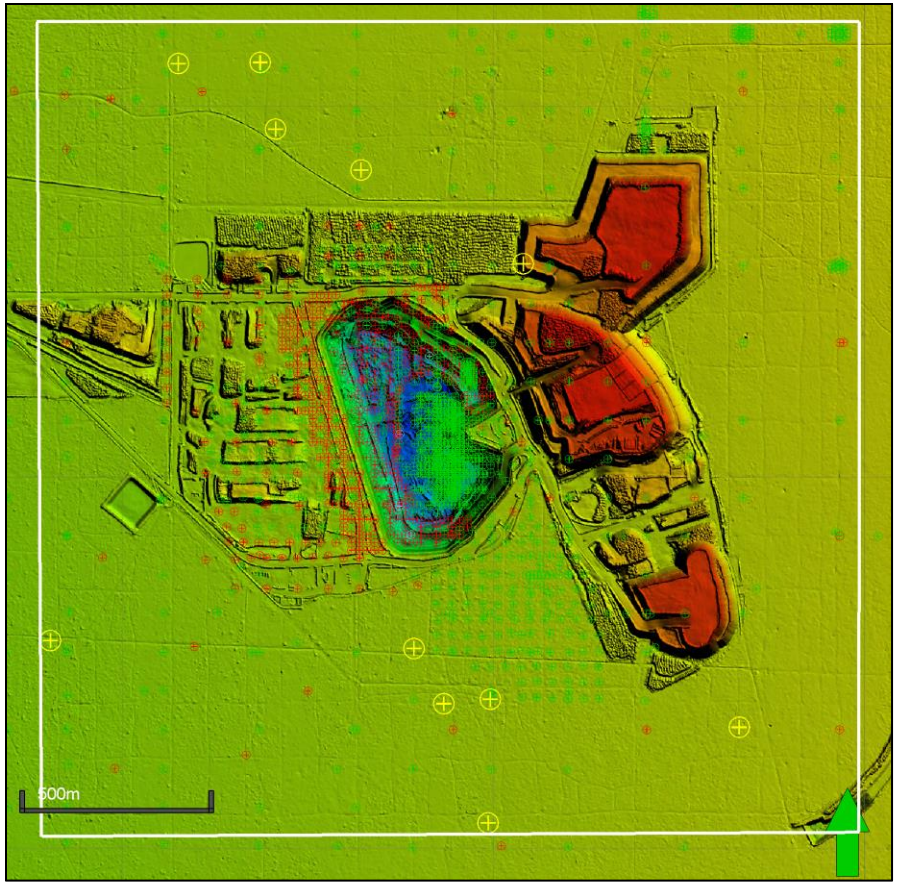
Drill testing zones where low velocity is deeper identified from 3D Seismic

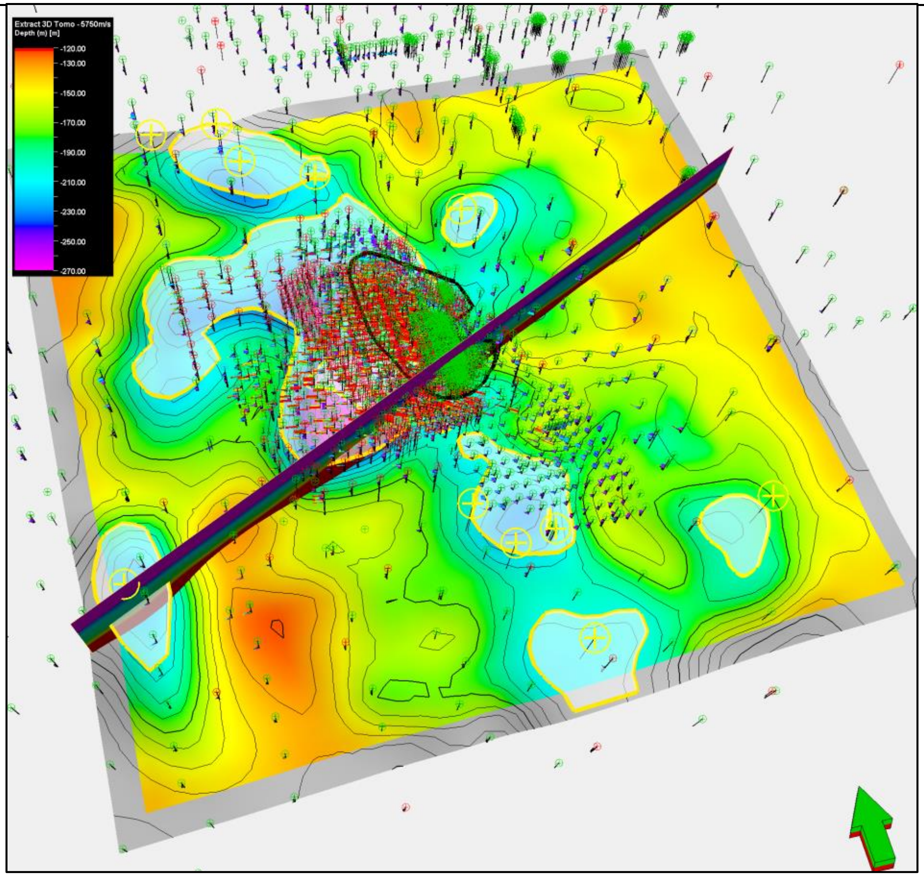
- **11 holes targeted to evaluate deeper zones of weathering for REO% and water resources**

Key Results

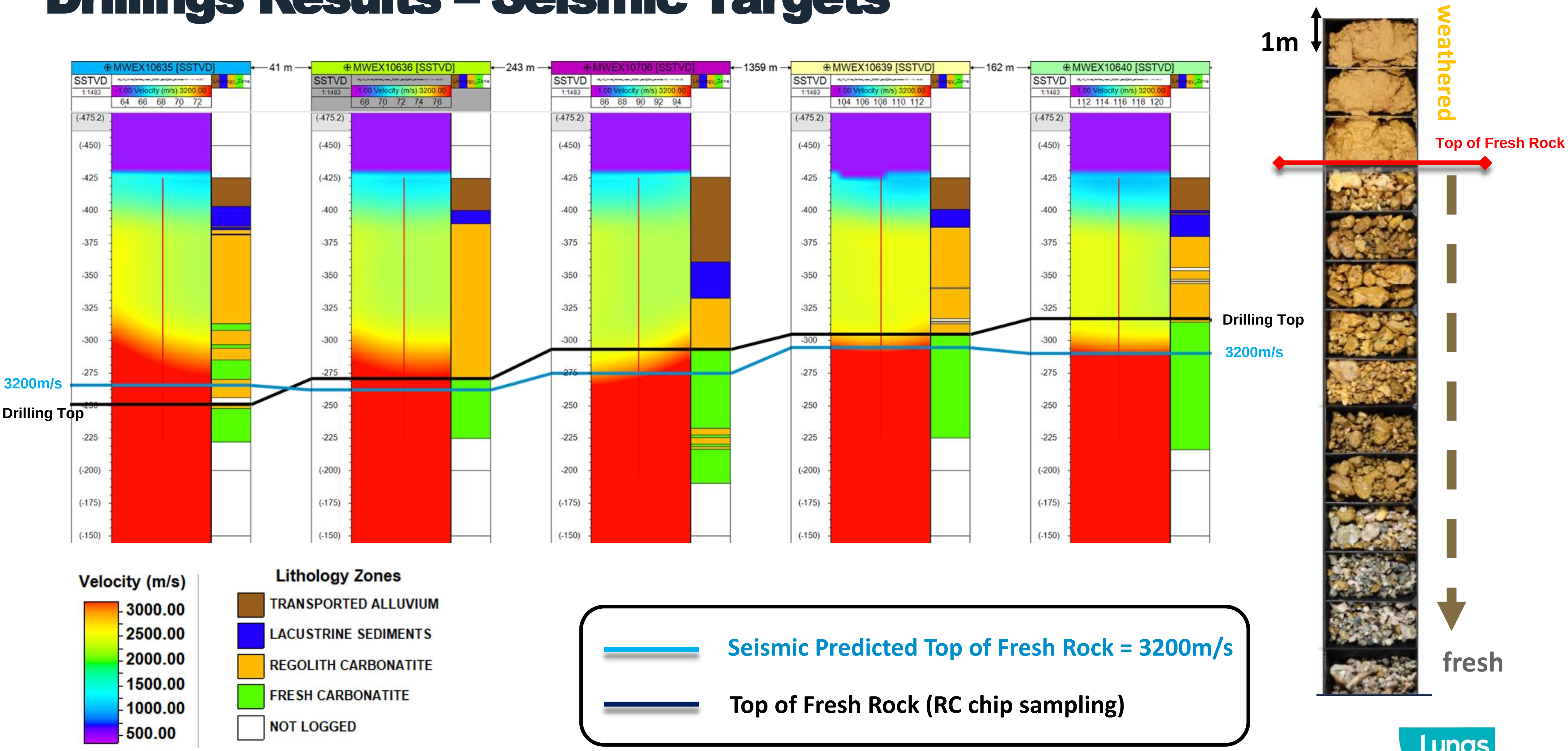
(1) Targets for REE and aquifers

- **Several undrilled areas around the Mt Weld pit area showed positive indications for well-developed weathering profiles based on anomalous tomography trends.**
- **Eleven drillholes have been planned by the Mt Weld Geoscience Team to test the seismic anomalies and validate for the presence of enriched rare earth oxides or groundwater resources.**



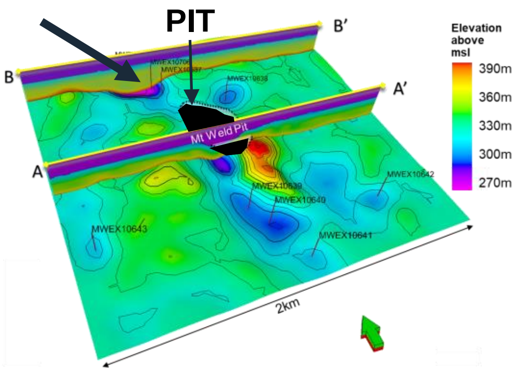


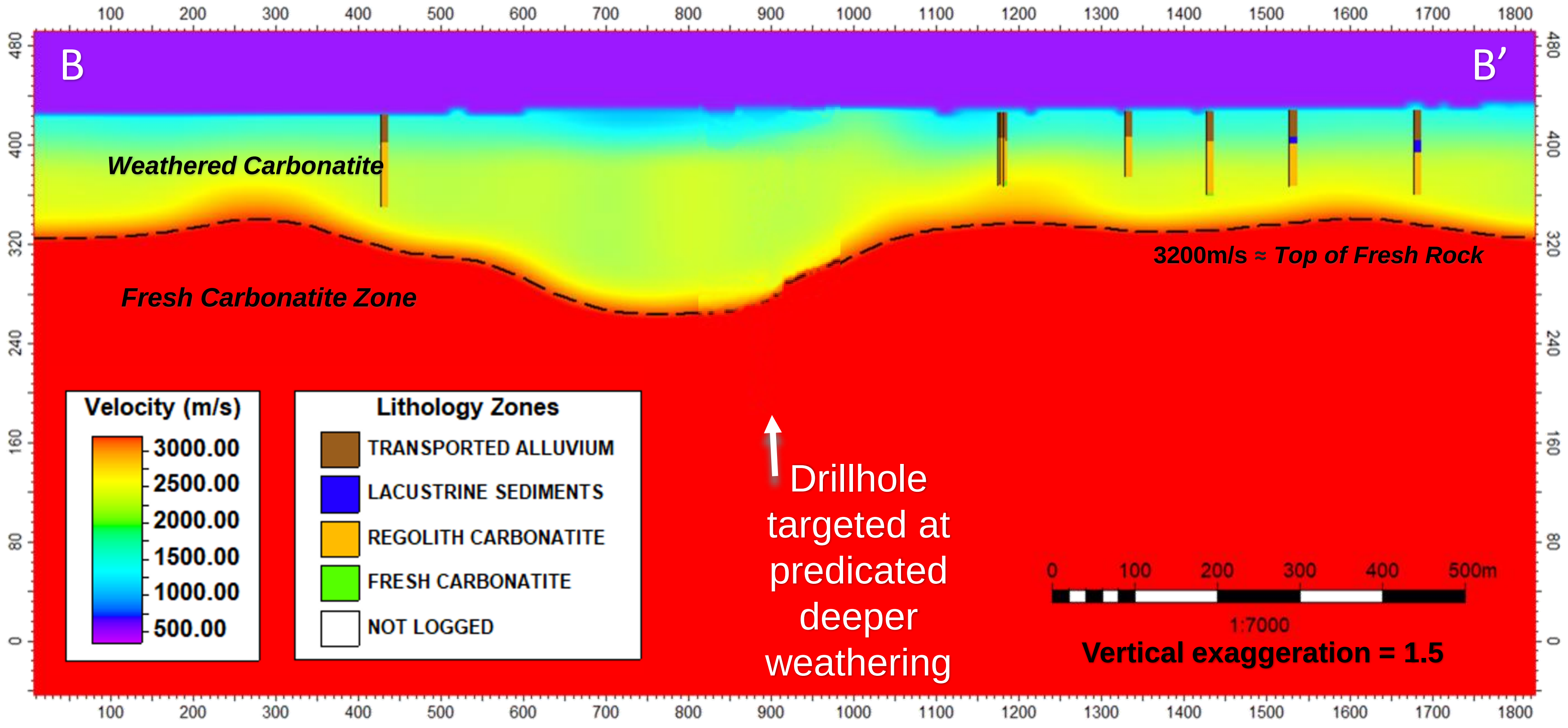
Drillings Results – Seismic Targets



Drillhole validation

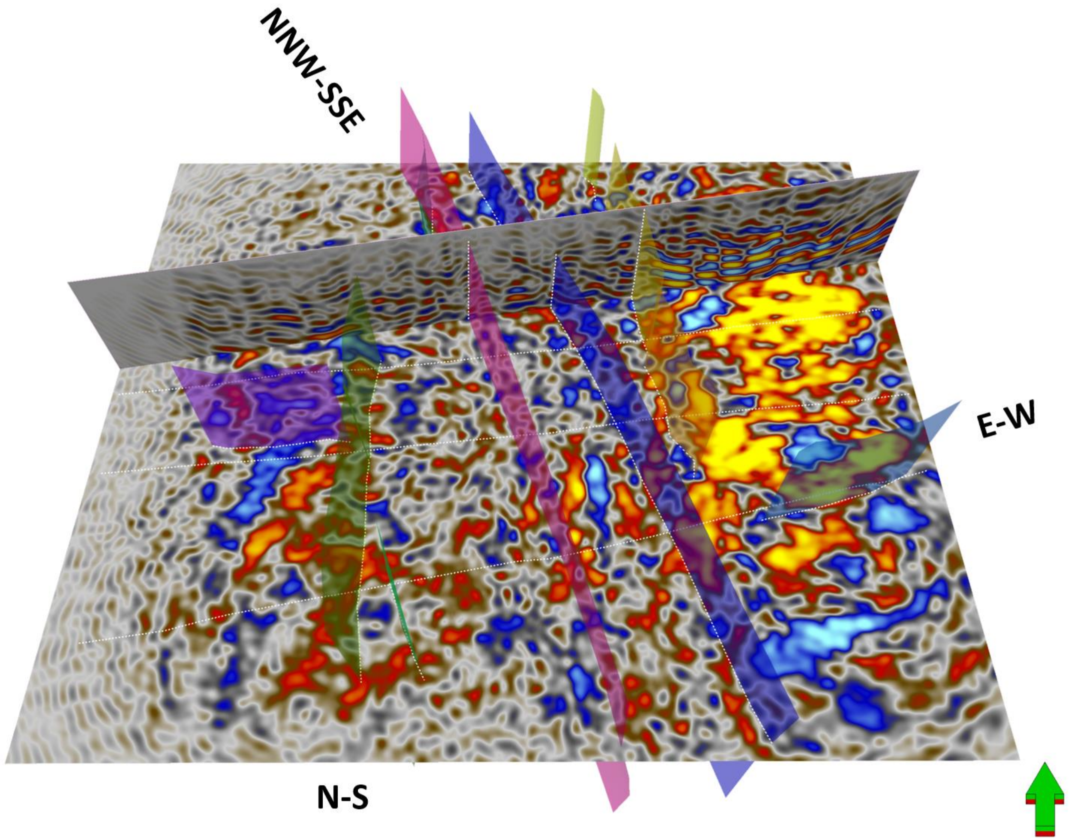
- 11 areas with potential deep weathering identified – 11 drilling (RC)
- Targets tended to fall along the NW structural trend.

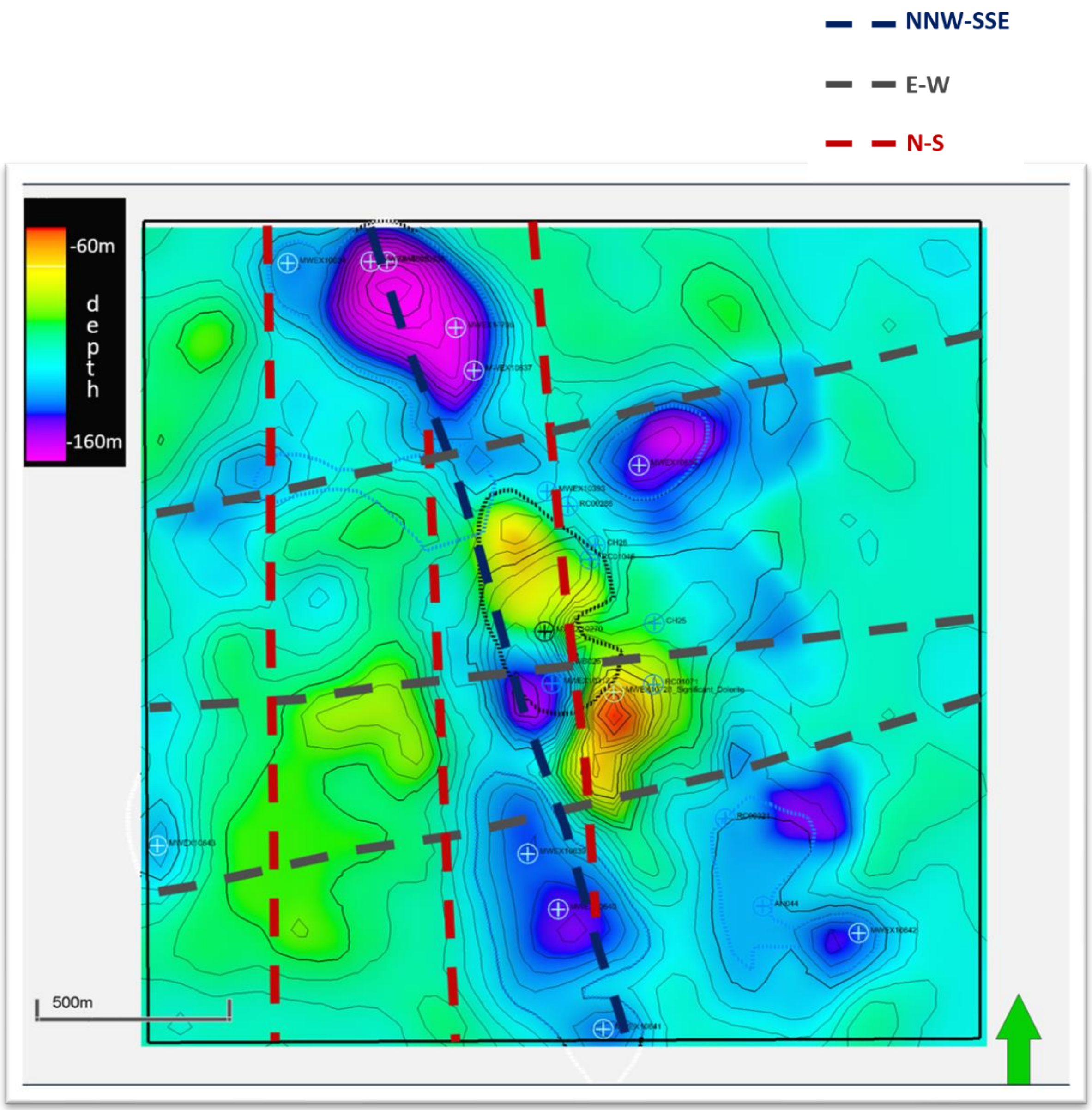




- **All 11 holes intersected deeper weathering**
- **Initial assay data '*very encouraging*' – higher grade REO% encountered**
- **2 groundwater extraction wells planned**

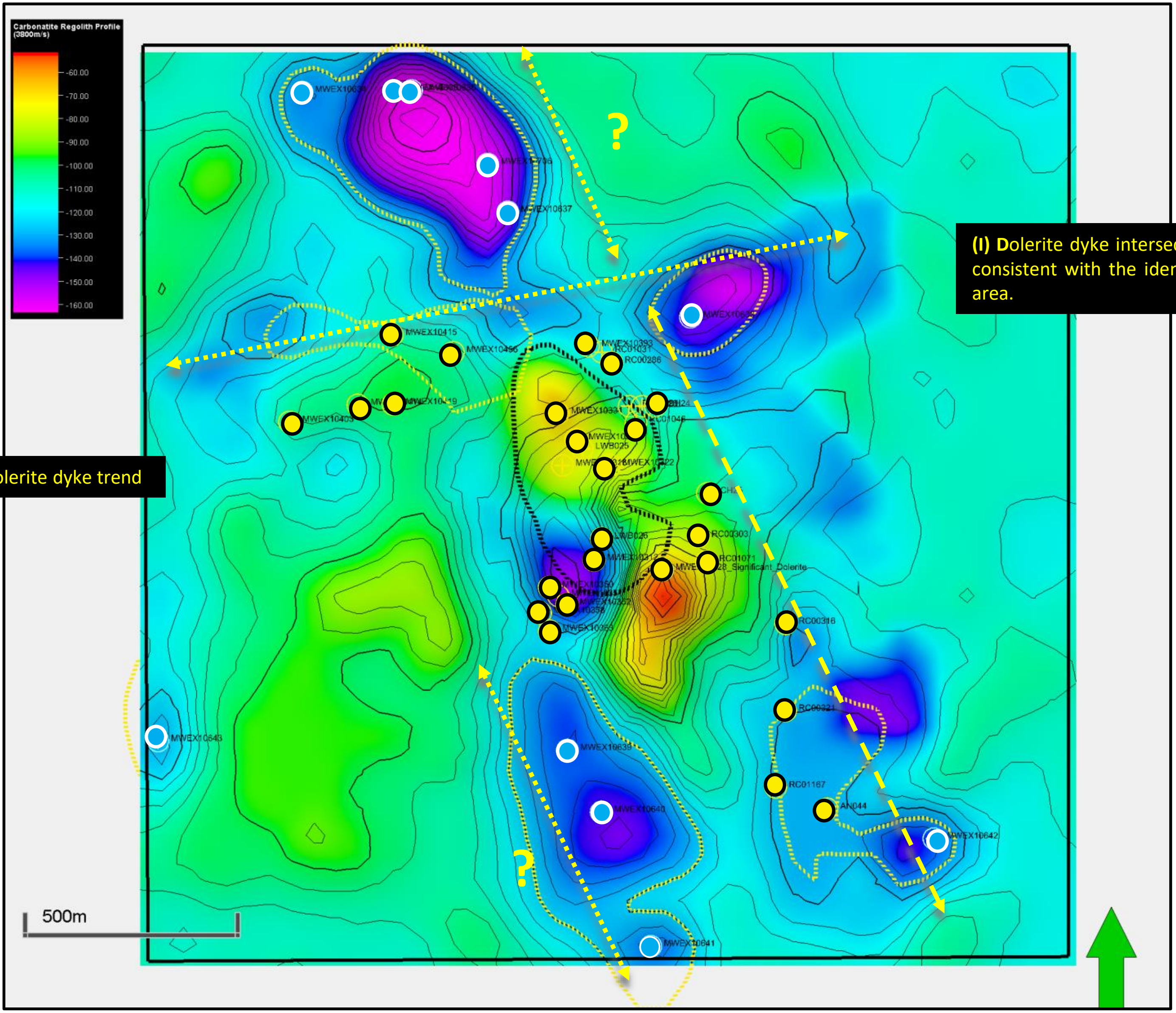
Fault Interpretation





- 3 main fault orientations
- Subvertical breaks in reflectivity
- Faulter intersections for greater fracture permeability
- Faults allow conduits for Dolerite Dykes intrusions – a potential key part to enriching ore zones due to thermogenic alteration.
- Faults and fault intersections are bedrock aquifer targets

Seismic Response to Dolerite Dyke Intrusives



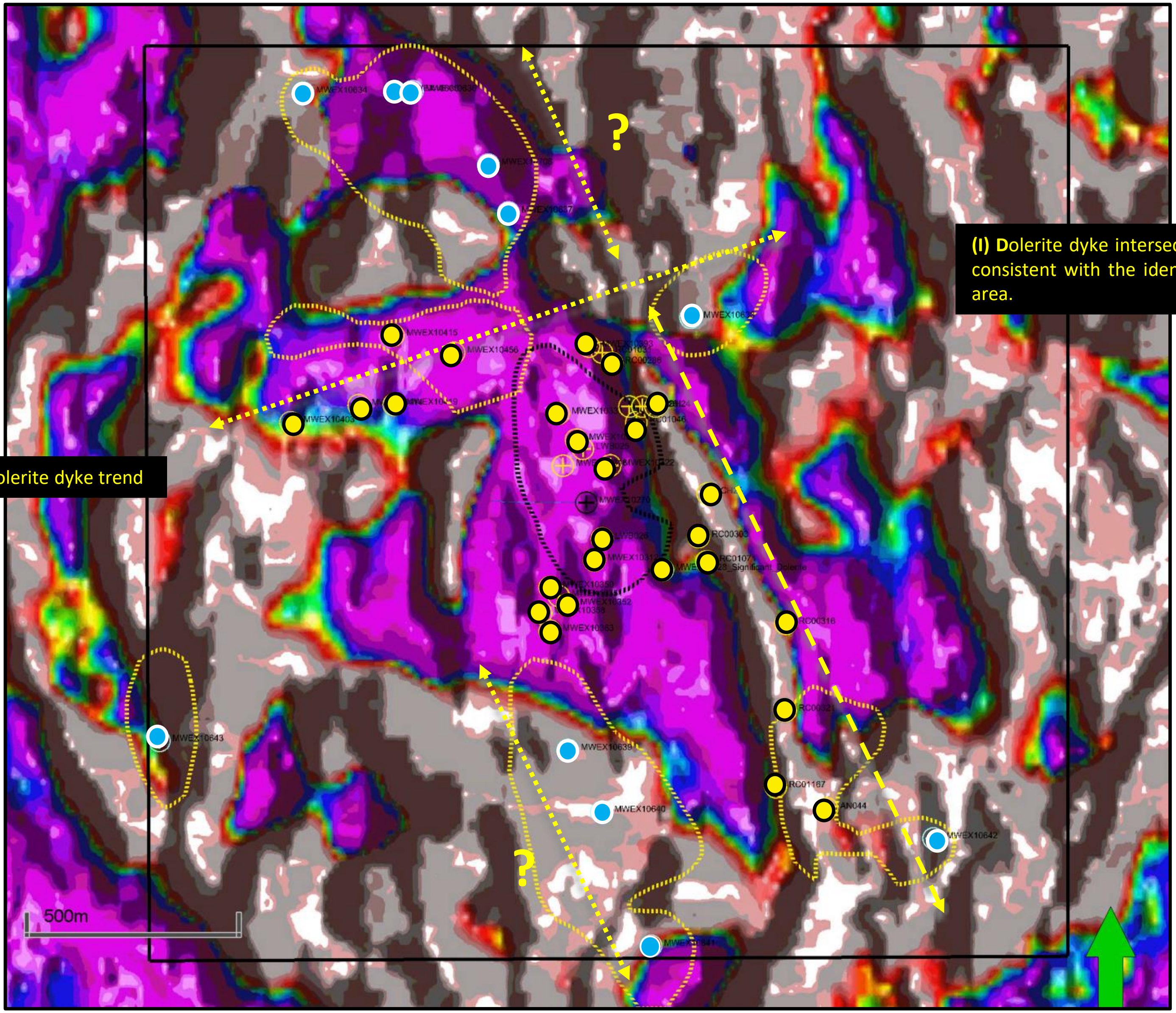
(I) Dolerite dyke intersections occur along a NW trend, consistent with the identified structural control in the area.

(II) Inferred EAST-WEST dolerite dyke trend

Drillholes which intersected of dolerite dyke

Seismic Drillhole Targets

Seismic Response to Dolerite Dyke Intrusives



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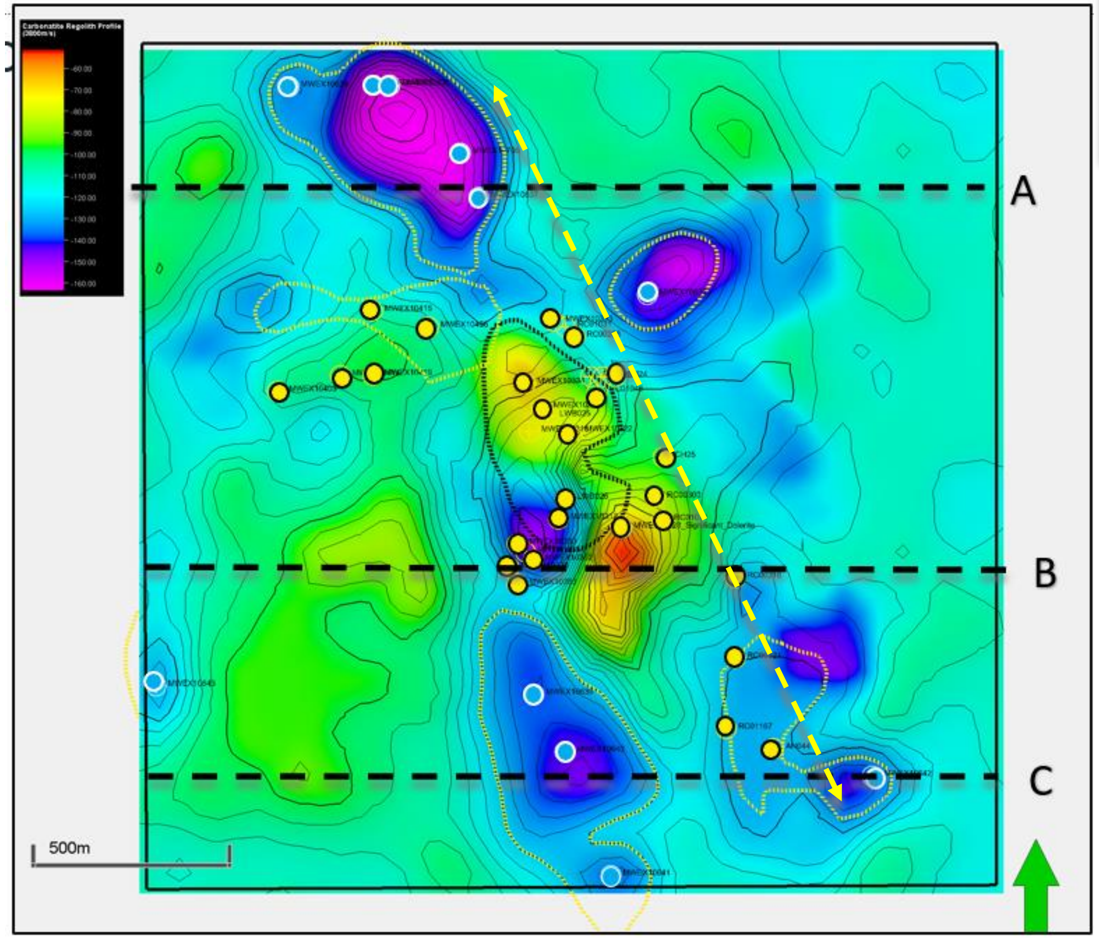
(II) Inferred EAST-WEST dolerite dyke trend

The seismic targets correspond to areas of magnetic lows

Drillholes which intersected of dolerite dyke

Seismic Drillhole Targets

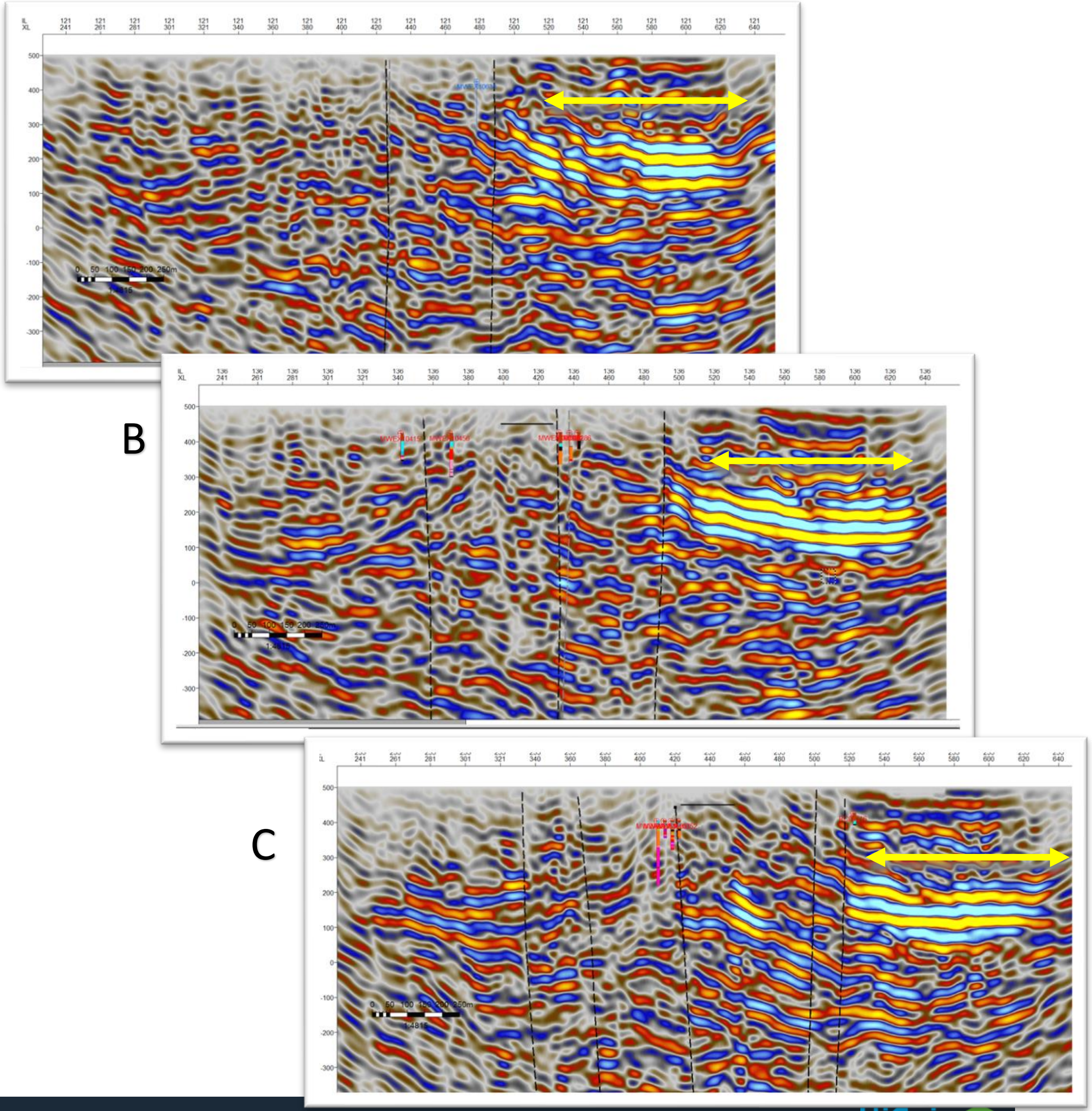
Seismic Reflectivity variation across NW trending Fault



A

B

C



Key takeaways from active seismic at Mt Weld

- Seismic Tomography successful at mapping weathering depth
  - ➢ Focussed targets for additional REE
  - ➢ Optimised groundwater extraction

- Mapped bedrock faults and domains
  - ➢ Additional groundwater sources in fault zones
  - ➢ Geotechnical input

- Provided first direct insights into carbonatite pathway from deep in crust
  - ➢ Reprocessing has dramatically improved image quality
  - ➢ Detailed overall geometry and revealed internal heterogeneity of carbonatite
  - ➢ Identified exploration sites

References

References

Irina A Zhukova, Aleksandr S Stepanov, Shao-Yong Jiang, David Murphy, John Mavrogenes, Charlotte Allen, Wei Chen, Ralph Bottrill. (2021)
Complex REE systematics of carbonatites and weathering products from uniquely rich Mount Weld REE deposit, Western Australia,
Ore Geology Reviews, Volume 139, Part B.

Ross Chandler, Ganesh Bhat, John Mavrogenes, Brad Knell, Rhiannon David, Thomas Leggo.
The Geology of the Paleoproterozoic Mt Weld Carbonatite Complex, Western Australia
The Research School of Earth Sceiences (RSES), Australian National University (ANU), Lynas Rare Earths Ltd.

Lynas Rare Earth (2023) Annual Report – ASX **https://wcsecure.weblink.com.au/pdf/LYC/02724575.pdf**

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Complex REE systematics of carbonatites and weathering products from uniquely rich Mount Weld REE deposit, Western Australia

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[b] Queensland University of Technology, 2 George St, QLD 4000 Brisbane, Australia
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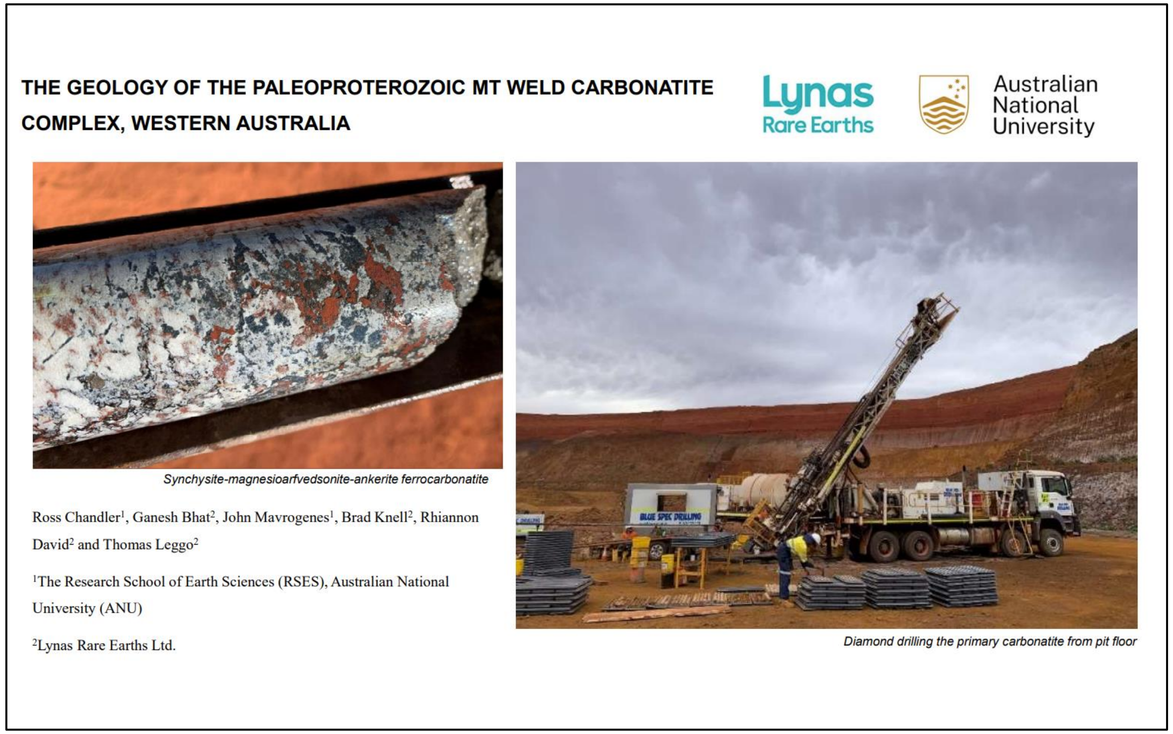
Bio-assisted weathering
high-REE carbonatitic melt

ABSTRACT

Carbonatite intrusive complexes are important hosts for Rare Earth Elements (REE) deposits and are commonly affected by surficial weathering processes. Mount Weld REE deposit of Western Australia is one of the world's richest REE deposits and here we present whole-rock and REE mineral geochemical data on compositions of primary and weathered carbonatites. The REE concentrations in magmatic carbonatites at Mount Weld vary by two orders of magnitude, suggesting a significant role of magmatic processes in REE enrichment in the carbonatite complex. The Th-Pb age 2056±67 (2σ) Ma of monazite-(Ce) from the carbonatite obtained by *in situ* LA-ICP-MS analyses confirm Paleoproterozoic age of the mineralization. The regolith samples preserve a detailed record of evolution from carbonatite to products of intensive weathering. The silica-cemented regolith (silcrete) contains monazite-(Ce) and apatite chemically identical to their carbonatite-hosted equivalents. The high-REE regolith containing 51.8 wt% $\sum REE_2O_3$ has some of the highest REE concentrations found to date, negative Ce anomaly and contains lithogenic monazite within matrix of florencite-(Ce) and rhabdophane-(Nd) and rhabdophane-(Nd) tubes resembling casts of plant material. The pronounced negative Ce anomalies in the ferruginous cap rock (ferricrete) and the high-REE regolith indicate intensive weathering, where Ce^{4+} was preferential removed relative to the REE^{3+}. The presence of paleo-plants in the high-REE regolith implicates bio-assisted processes involved in the extreme REE fractionation. The diverse REE enrichment processes, which occurred in supergene environment of Mount Weld, have implications for the understanding of the genesis of REE deposits worldwide.



THE GEOLOGY OF THE PALEOPROTEROZOIC MT WELD CARBONATITE COMPLEX, WESTERN AUSTRALIA

Synchysite-magnesioarfvedsonite-ankerite ferrocarbonatite

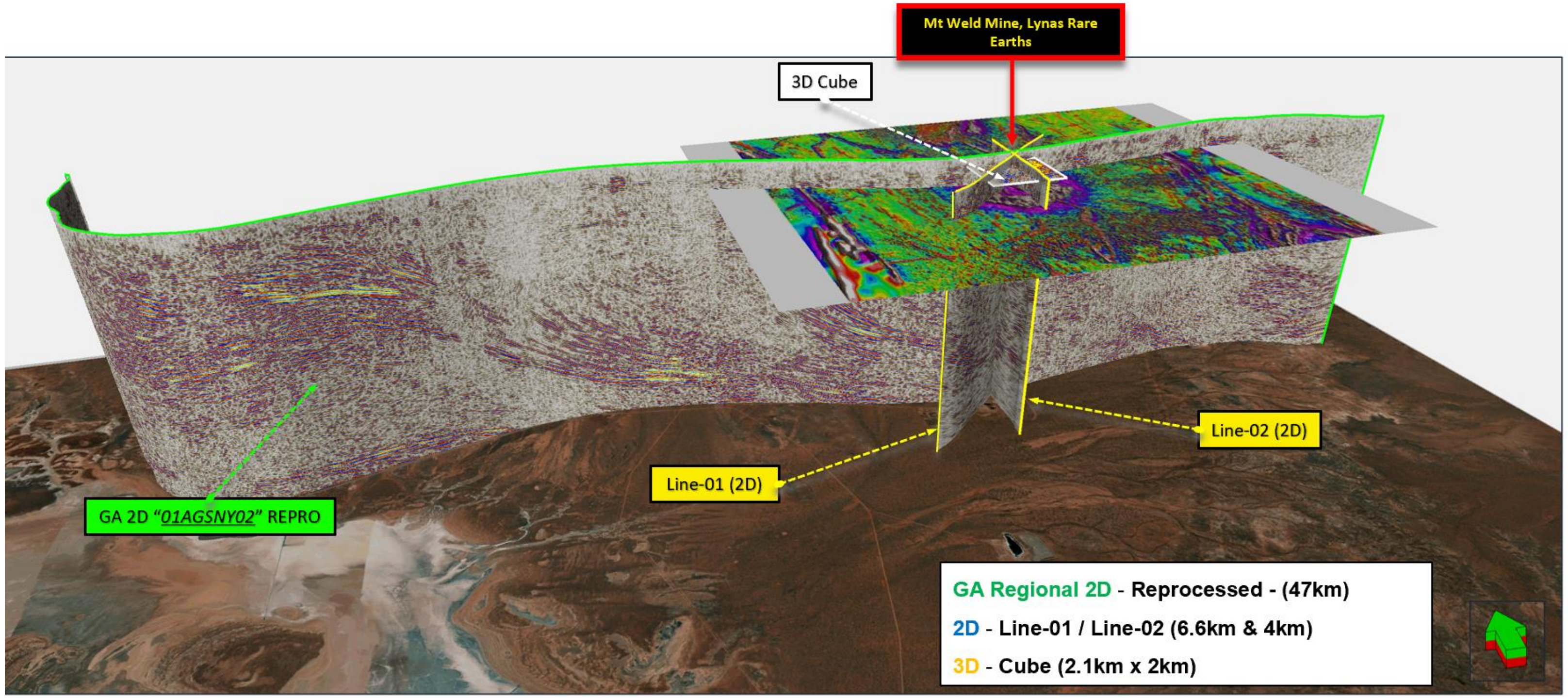
Diamond drilling the primary carbonatite from pit floor

Ross Chandler[1], Ganesh Bhat[2], John Mavrogenes[1], Brad Knell[2], Rhiannon David[2] and Thomas Leggo[2]

[1]The Research School of Earth Sciences (RSES), Australian National University (ANU)

[2]Lynas Rare Earths Ltd.

Questions?


Mt Weld Mine, Lynas Rare Earths
3D Cube
Line-02 (2D)
Line-01 (2D)
GA 2D "01AGSNY02" REPRO
GA Regional 2D - Reprocessed - (47km)
2D - Line-01 / Line-02 (6.6km & 4km)
3D - Cube (2.1km x 2km)

Backup Slides

What is a Carbonatite?

TH

what defines a carbonatite?

A carbonatite is a type of igneous rock that is primarily composed of carbonate minerals, typically calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$). Carbonatites are unique because they contain a much higher concentration of carbonate minerals compared to other types of igneous rocks, where silicate minerals predominate.

Here are some key characteristics that define carbonatites:

1. High Carbonate Content: Carbonatites contain at least 50% or more of carbonate minerals, which is significantly higher than other types of igneous rocks.
2. Rare Element Enrichment: Carbonatites often contain elevated concentrations of rare elements, such as niobium, tantalum, thorium, and rare earth elements (REEs). These elements are of economic interest and are sometimes extracted from carbonatite deposits.
3. Low Silica Content: Carbonatites typically have a low silica content, which distinguishes them from silicate-rich rocks like granite and basalt.
4. Intrusive or Extrusive: Carbonatites can occur as both intrusive (plutonic) and extrusive (volcanic) rocks. Intrusive carbonatites form when molten carbonatite magma cools and solidifies beneath the Earth's surface, while extrusive carbonatites result from eruptions of carbonatite magma at the surface.
5. Unique Mineralogy: In addition to carbonates, carbonatites may contain other minerals, such as apatite, magnetite, pyrochlore, and others. The presence of these minerals can make carbonatites valuable for mining and resource extraction.
6. Often Associated with Alkaline Igneous Rocks: Carbonatites are frequently associated with alkaline igneous rocks, like nepheline syenites and phonolites, which share a similar chemical and geological context.
7. Uncommon Occurrence: Carbonatites are relatively rare compared to other rock types and are found in specific geological settings, such as rift zones, hotspots, and continental margins.

Carbonatites are of interest to geologists and the mining industry due to their unique mineral composition and potential economic significance. They are also valuable for studying the Earth's mantle and the processes that lead to the formation of unusual igneous rocks.

Mineral Systems Model – Key Notes

- The Dolomite carbonatite contains higher REO% than the calcite carbonatite. This is a function of the carbonatite magma.
- The Calcite rich magma crystallises earlier and at a higher temperature than the dolomite rich magma.
- Rare Earth minerals are less compatible in clcite magma, hence, only a small proportion of REE minerals crystallise ini calcite rich carbonaite.
- TEE remain in magmatic melt until the magma cools further, where dolomite starts to crystallise along with the REE minerals at lower temps.
- Dolomite carbonatite started off with more REE content that the calcite carbonaite (before weathering).
- Fracture zones and breccia zones facilitate for deeper weathering zones due to groundwater circulation

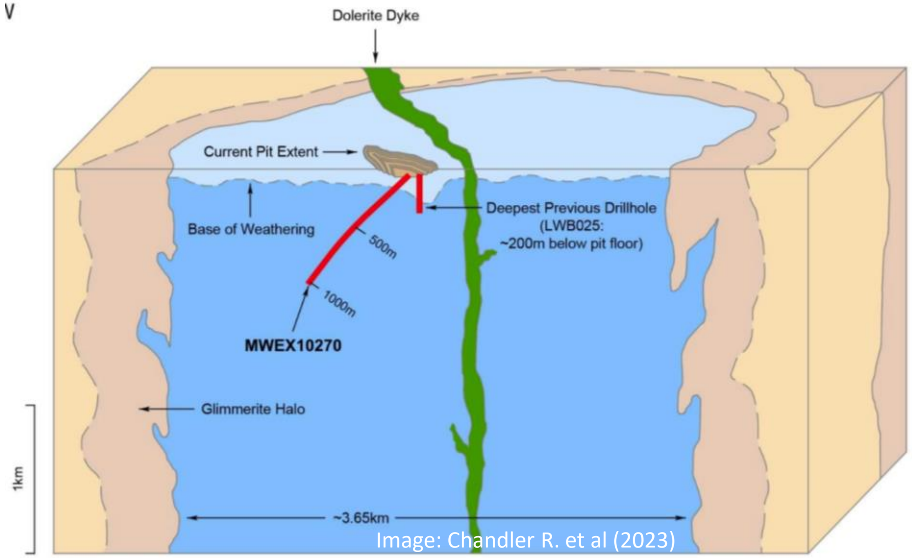
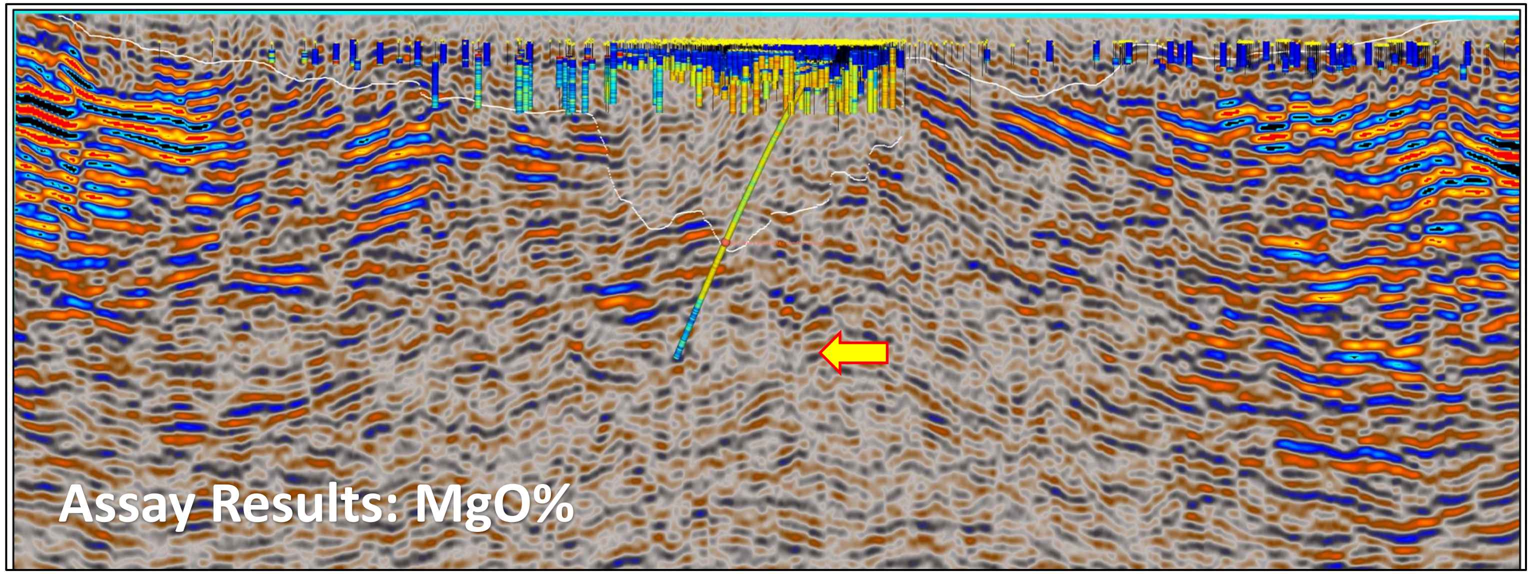
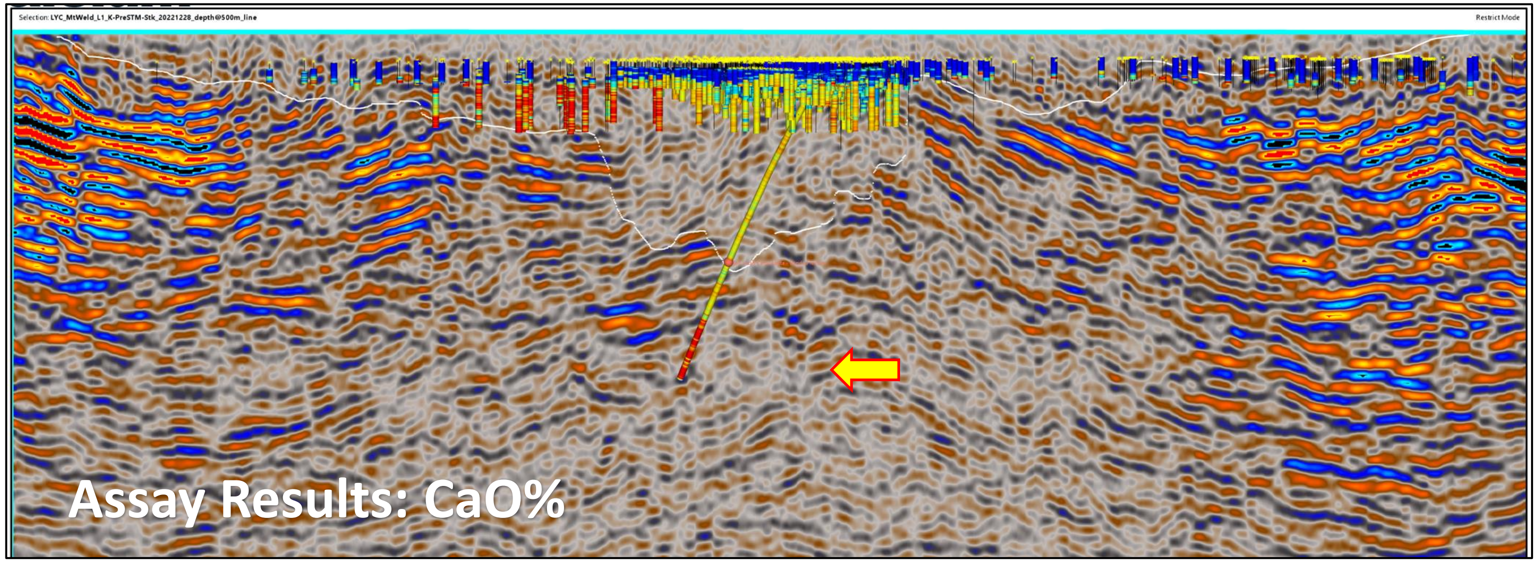


Image: Chandler R. et al (2023)

Geochemical changes in Carbonatite





Lynas Annual Report 2023
https://wcsecure.weblink.com.au/pdf/LYC/02724575.pdf

Ore Reserves

as at 30 June 2023

1. MT WELD RARE EARTH DEPOSIT ORE RESERVES 2023

The Ore Reserve estimation for the Mt Weld Rare Earth Deposit is shown in Table 1, reported above a cut-off grade of 4.0% Total Rare Earth Oxides (TREO).

TABLE 1: MT WELD RARE EARTH DEPOSIT ORE RESERVES 2023

JORC CLASSIFICATION	MILLION TONNES	TREO %	CONTAINED REO '000 TONNES
Ore Reserves within Pit boundary			
Proved	12.0	7.9	951
Probable	4.5	6.9	312
Designed Pit Total	**16.5**	**7.7**	**1,263**
On Stockpiles			
Proved	1.2	12.5	148
Probable	0.0	0.0	0
Stockpiles Total	**1.2**	**12.5**	**148**
Total Ore Reserves			
Proved	13.2	8.3	1,099
Probable	4.5	6.9	312
Total	**17.7**	**8.0**	**1,411**

* TREO = Total Rare Earth Oxides (La_2O_3, CeO_2, Pr_6O_{11}, Nd_2O_3, Sm_2O_3, Eu_2O_3, Gd_2O_3, Tb_4O_7, Dy_2O_3, Ho_2O_3, Er_2O_3, Tm_2O_3, Yb_2O_3, Lu_2O_3) + Yttrium (Y_2O_3). Totals may not balance due to rounding of figures.

Note:

The Ore Reserves for the Mt Weld Rare Earth Deposit is as of June 30, 2023. The 2023 Ore Reserve update is based upon depletion of the in-situ ore reserves by mining activities between 1 July 2022 and 30 June 2023. Minor changes to the stockpiles occurred as a result of processing. The stockpiles were estimated using survey volumes of the stockpiles and grades assigned to the stockpiles by the grade control process. The grade control process is carried out by Mr Thomas Leggo, an employee of Lynas Rare Earths. The surveys have been carried out by Mr Bradley Hughes, an employee of Lynas Rare Earths. Mr Steve Lampron, (Ragnarok Mining Pty Ltd) has carried out a review and audit of these figures and found them to fall within expected error deviations. The company confirms that all material assumptions and technical parameters underpinning the estimated Ore Reserves set out in the ASX announcement dated August 6, 2018 continue to apply and have not materially changed.

2. MT WELD RARE EARTH DEPOSIT MINERAL RESOURCES 2023

The Mineral Resource estimation for the Mt Weld Rare Earth Deposit is shown in Table 2, reported above a cut-off of 2.5% Total Rare Earth Oxides (TREO).

TABLE 2: MT WELD RARE EARTH DEPOSIT MINERAL RESOURCES 2023

JORC CLASSIFICATION	MILLION TONNES	TREO %	CONTAINED REO '000 TONNES
Insitu			
Measured	15.4	7.1	1,097
Indicated	11.4	5.1	574
Inferred	25.9	3.6	937
Subtotal	**52.6**	**5.0**	**2,608**
On Stockpiles			
Measured	1.7	11.5	194
Subtotal	**1.7**	**11.5**	**194**
Total Mineral Resources			
Measured	17.1	7.6	1,291
Indicated	11.4	5.1	574
Inferred	25.9	3.6	937
Total	**54.3**	**5.2**	**2,802**

* TREO = Total Rare Earth Oxides (La_2O_3, CeO_2, Pr_6O_{11}, Nd_2O_3, Sm_2O_3, Eu_2O_3, Gd_2O_3, Tb_4O_7, Dy_2O_3, Ho_2O_3, Er_2O_3, Tm_2O_3, Yb_2O_3, Lu_2O_3) + Yttrium (Y_2O_3). Totals may not balance due to rounding of figures.

Mineral Resources have been reported above a cut-off of 2.5% TREO. The Mineral Resources are inclusive of Ore Reserves.

Note:

The Mineral Resource estimation for the Mt Weld Rare Earth Deposit is as of June 30, 2023. The company confirms that all material assumptions and technical parameters underpinning the estimated Mineral Resources set out in the ASX announcement dated August 6, 2018 continue to apply and have not materially changed. The exceptions are the inclusion of stockpiled material as a Measured Resource.

3. NIOBIUM RICH RARE METALS MINERAL RESOURCES

The Mineral Resource estimation for the niobium rich rare metals prospect referred to as the Niobium Rich Rare Metals Project is shown in Table 3. The Rare Metals Project is located at Mt Weld.

TABLE 3: CLASSIFICATION OF MINERAL RESOURCES FOR THE NIOBIUM RICH RARE METALS PROJECT

CATEGORY	MILLION TONNES	Ta_2O_5 %	Nb_2O_5 %	TLnO %	ZrO %	P_2O_5 %	Y_2O_3 %	TiO_2 %
Measured	0	0	0	0	0	0	0	0
Indicated	1.5	0.037	1.4	1.65	0.32	8.9	0.1	5.8
Inferred	36.2	0.024	1.06	1.14	0.3	7.96	0.09	3.94
Total	**37.7**	**0.024**	**1.07**	**1.16**	**0.3**	**7.99**	**0.09**	**4.01**

Mt Weld – Global Standing

Table 4
RE resources and their global distribution (Source: Vonckens, 2016).

Deposit	Location	Type	Main REEs	REE-mineral(s)
Bayan Obo	China	Carbonatite/hydrothermal	La, Ce, Nd	bastnasite, parasite, monazite
Mountain Pass	USA	Carbonatite	LREE	bastnasite
Mount Weld	Australia	Laterite/Carbonatite	LREE	apatite, monazite, synchysite, churchite
Ilimaussaq	Denmark	Peralkaline igneous	La, Ce, Nd, HREE	eudialyte, steenstrupine
Pilanesberg	South Africa	Peralkaline igneous	Ce, La	eudialyte
Steenkampskraal	South Africa	Vein	La, Ce, Nd	monazite, apatite
Hoidas Lake	Canada	Vein	La, Ce, Pr, Nd	apatite, allanite
Thor Lake	Canada	Alkaline igneous	La, Ce, Pr, Nd, HREE	bastnasite
Strange Lake and Misery Lake	Canada	Alkaline igneous/hydrothermal	La, Ce, Nd, HREE	gadolinite, bastnasite
Nolans Bore	Australia	Vein	La, Ce, Nd	apatite, allanite
Norra Kärr	Sweden	Peralkaline igneous	La, Ce, Nd, HREE	eudialyte
Khibina and Lovenzero	Russia	Peralkaline igneous	LREE + Y, minor HREE	eudialyte, Apatite
Nkwombwa Hill	Zambia	Carbonatite	LREE	monazite, bastnasite
Kagankunde	Malawi	Carbonatite	LREE	monazite-Ce, bastnaesite-Ce
Tundulu	Malawi	Carbonatite	LREE	synchesite, parasite, bastnasite
Songwe	Malawi	Carbonatite	LREE, Nd	synchesite, apatite
Chinese ion adsorption deposits	China	Soils	La, Nd, HREE	clay minerals
Maoniuping	China	Carbonatite	LREE	bastnasite
Dong Pao	Vietnam	Carbonatite	LREE	bastnasite, parisite

Introduction: The Mt Weld paleoregolith

- Prolonged Permian to Eocene near-surface weathering resulted in development of critical metal enriched paleoregolith

- Three dominant styles of mineralisation occur within paleoregolith
    1. **LREE dominant**, high LREE/HREE, and low Nb+Ta typified by the Central Lanthanide Deposit (**CLD** – currently mined)
    2. **Nb+Ta dominant**, low LREE, low LREE/HREE typified by the Niobium-Tantalum-Lanthanide Deposit (**NTLD** – old name Crown Deposit)
    3. **P_2O_5 dominant** with minor REE – e.g. the Phosphate-Lanthanide Deposit (**PLD** – old name Swan Deposit)

- Diversity of mineralisation styles poorly understood but suggested to result from differential transport of metals horizontally and vertically during weathering process (e.g. Lottermoser, 1990)

- Recent (2021) deep exploration drilling returned 1020m @ 2.22% TREO and provided samples of fresh carbonatite to (downhole) depths of 1000m below the current surface

Discussion and conclusions: Geological evolution and architecture of Mt Weld

- Early evolutionary history simplified as the ~2.06 Ga intrusion of a large volume of calciocarbonatite that evolved to/was intruded by a central stock of magnesio- to ferrocarbonatite (with associated dyking), followed by a late hydrothermal overprint

- Magnetic signature results from unmineralised outer calciocarbonatite with primary REE mineralisation associated with low mag. zone in centre of complex

- Similar architecture to many global complexes, particularly those carbonatites in East Africa e.g. Ngualla, Chilwa Island, Mirima Hill – similar genetic stories? Similar mantle sources?

- Prolonged Permian to Eocene near surface weathering resulted in development of highly REE enriched paleoregolith