

Seismic and Magnetotelluric signatures of melt/fluid flux through Australian crust

Tom Wise, Stephan Thiel

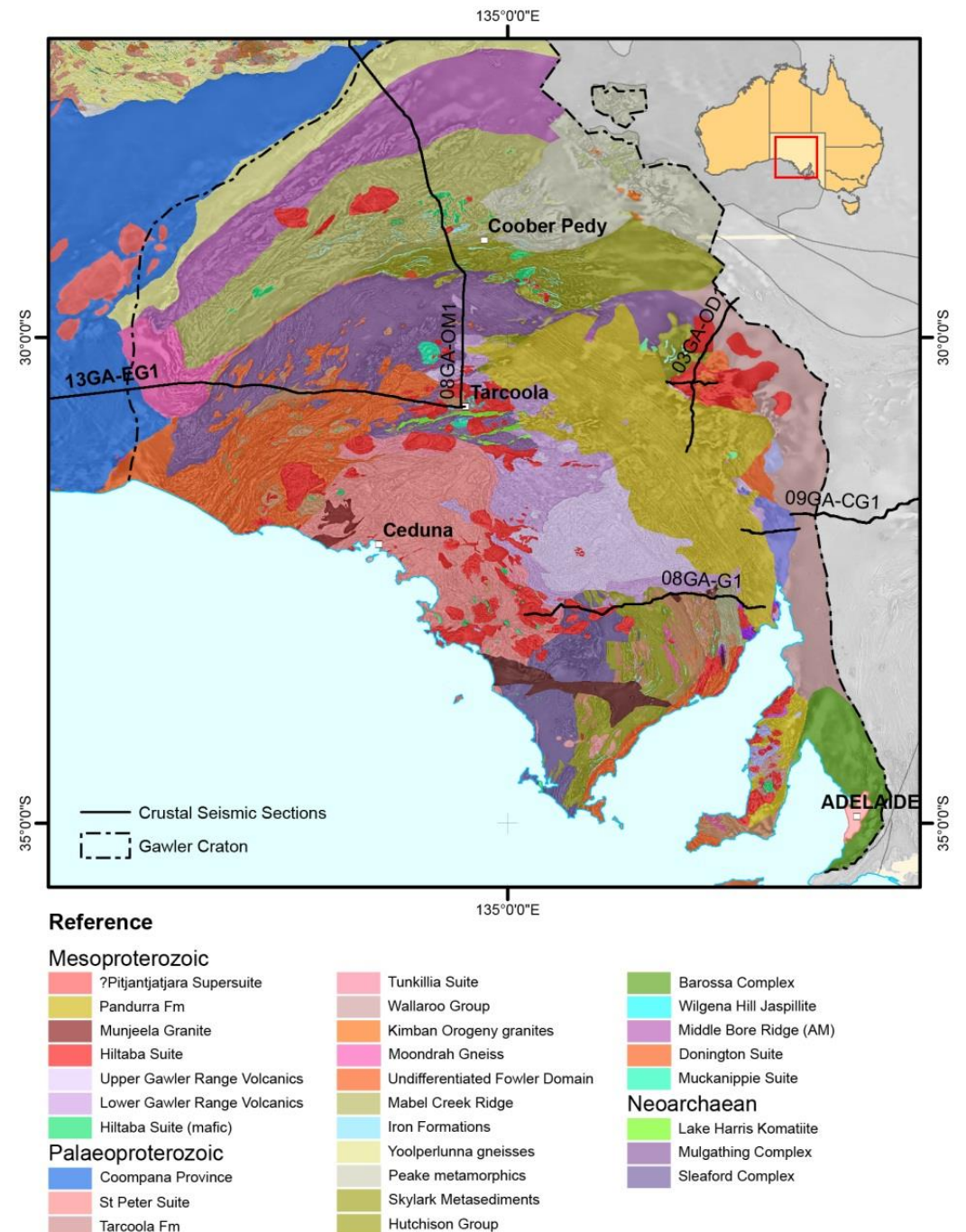
Geological Survey of South Australia

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A little on Proterozoic South Australia...

- Dominantly Paleo-Mesoproterozoic volcano-sedimentary successions built on an Archean basement
- Major thermal events in the Mesoproterozoic
- BUT 75% is covered, hence the need for geophysics



Deep Crustal Seismic Reflection Profiling: Australia 1978-2011

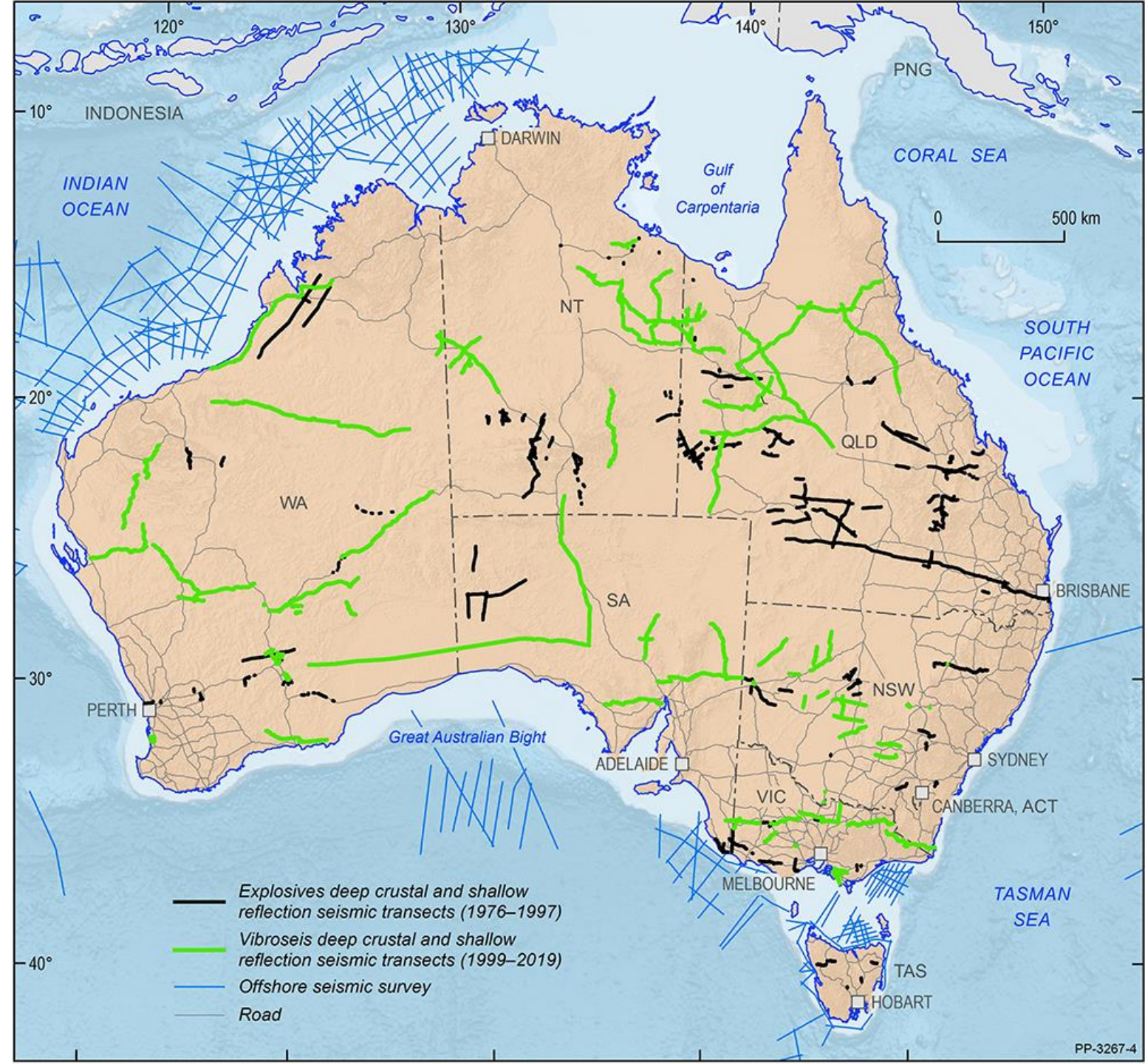
B.L.N. Kennett, E. Saygin (Research School of Earth Sciences, The Australian National University)
T. Fomin and R. Blewett (Geoscience Australia)



Vibroseis-sourced since 1999

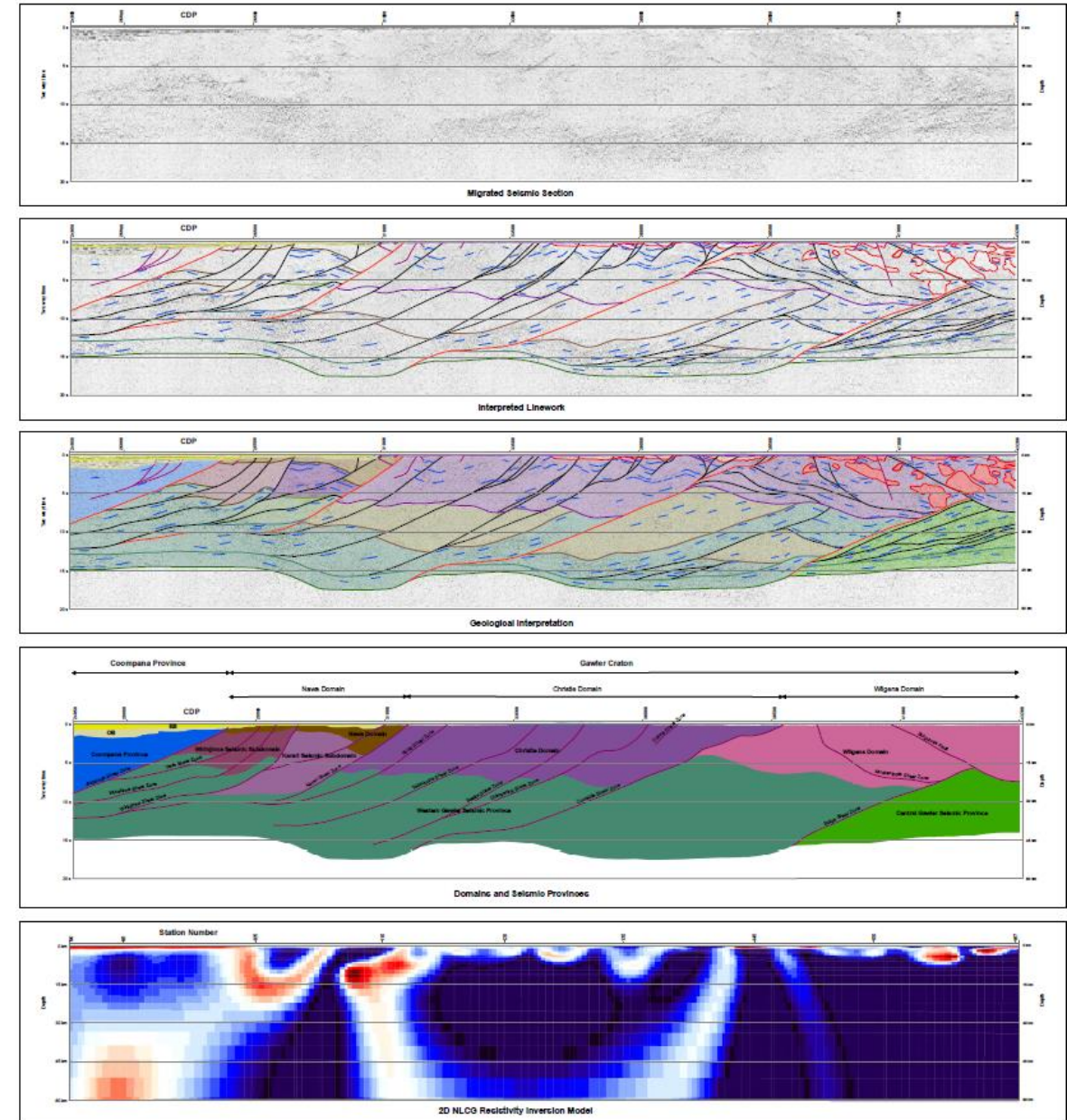
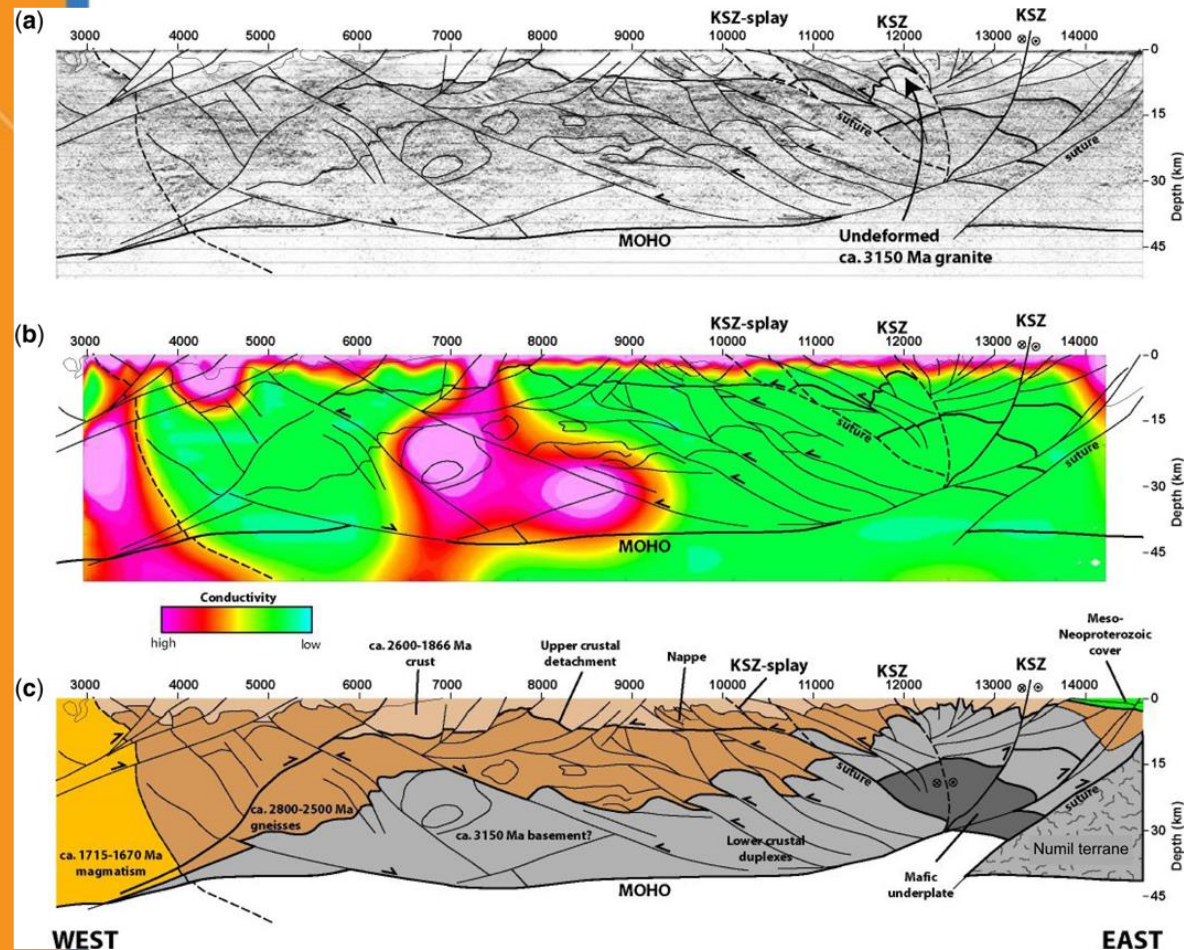
Accompanied by MT and gravity surveys in recent years

Collaborative programs with State and Federal geoscience agencies



- **over interpretation and telling the full story?**

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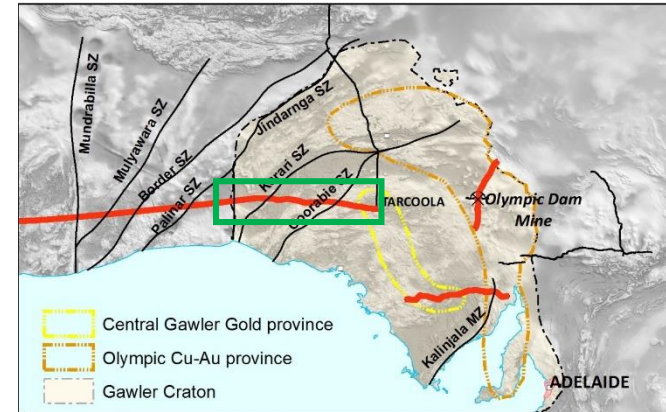


Conductors within the crust. What are they?

- Shear zones?
- Partial Melt?
 - Fossil melt pathways?
- Fluid?
 - Fossil fluid pathways?

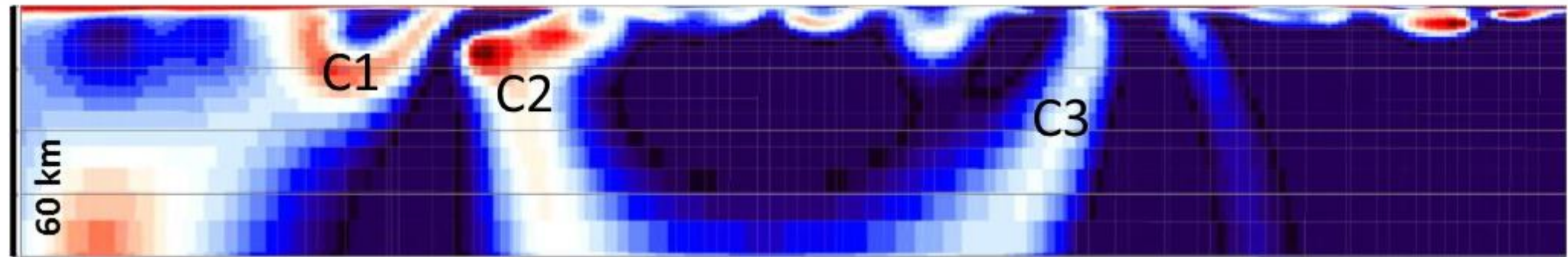
What can seismic imagery tell us about the nature of, and the controls on the location of conductors within the crust?

Eucla-Gawler East (13GA-EG1E)

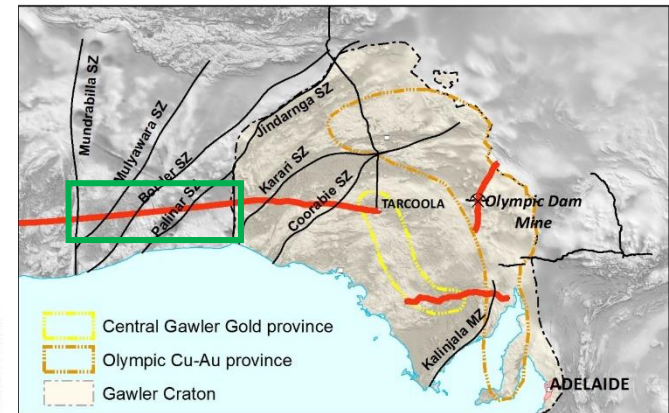
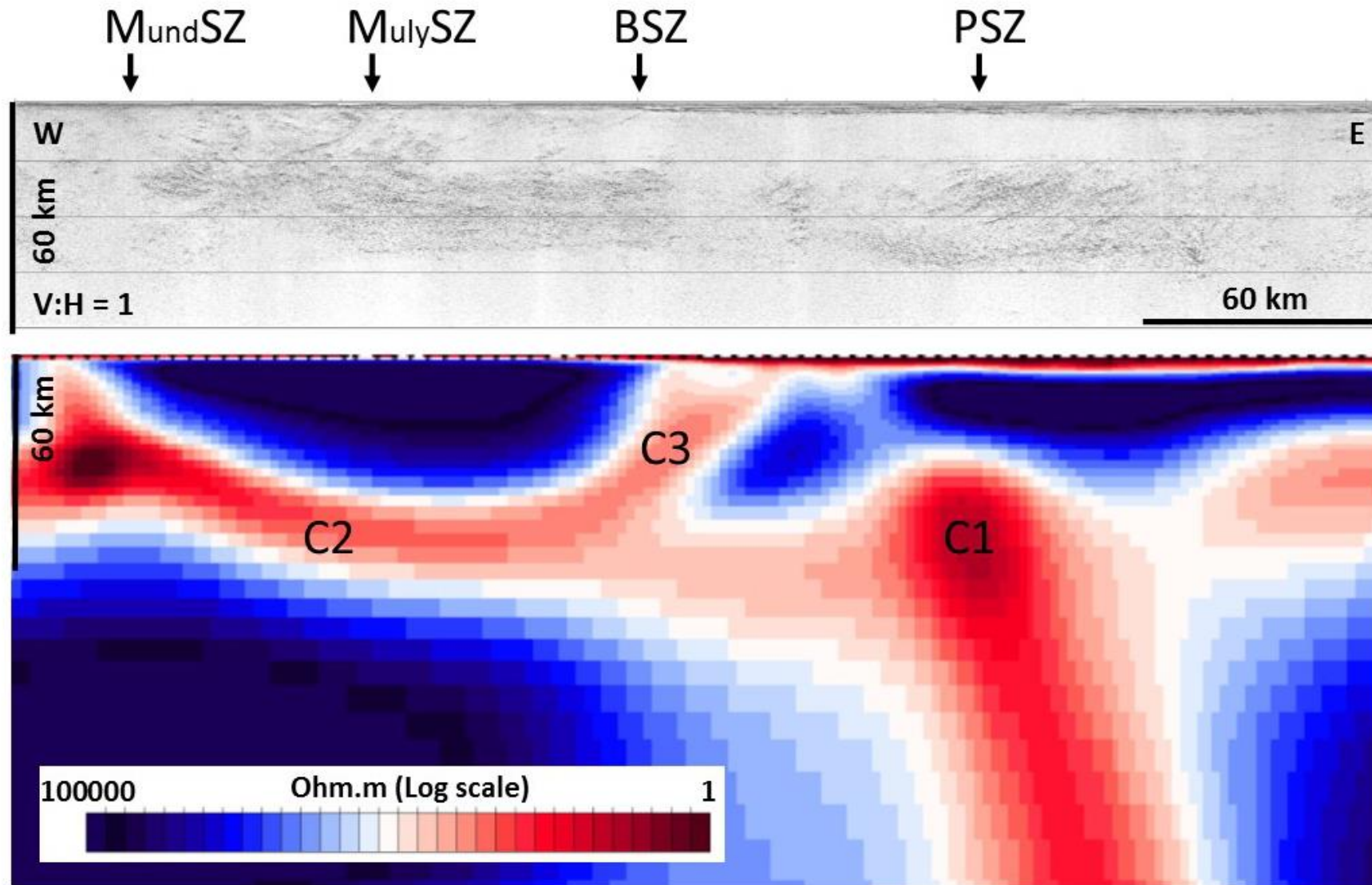


KSZ
↓

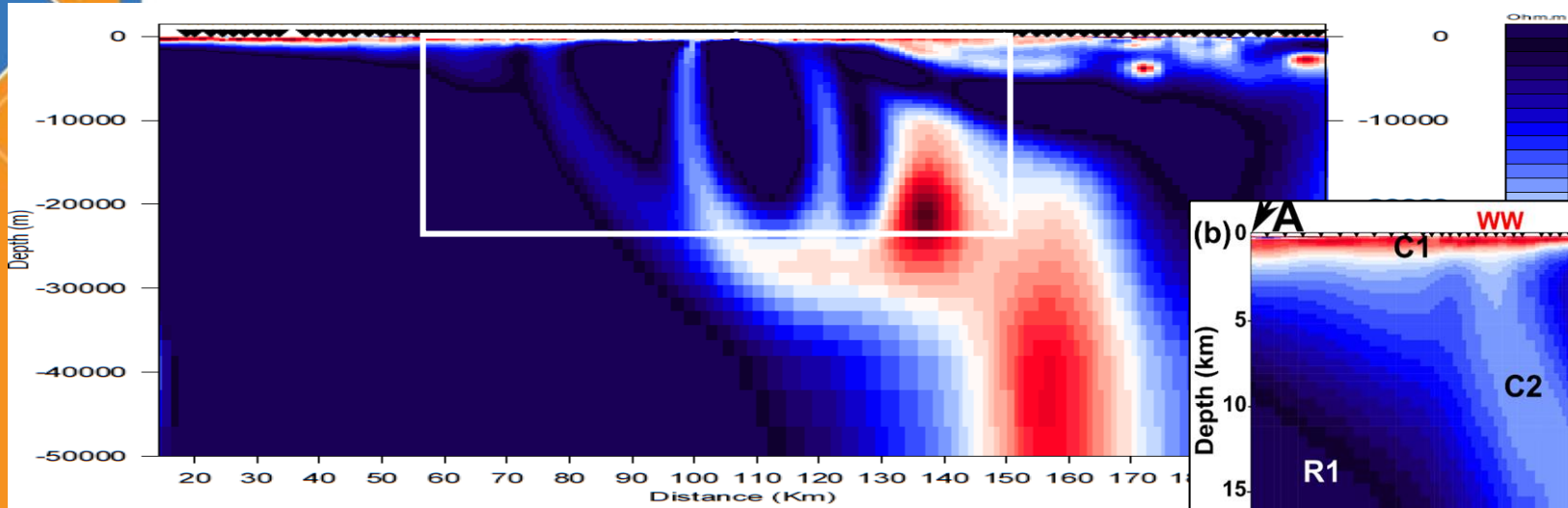
CSZ
↓



Eucla Gawler West (13GA-EG1W)

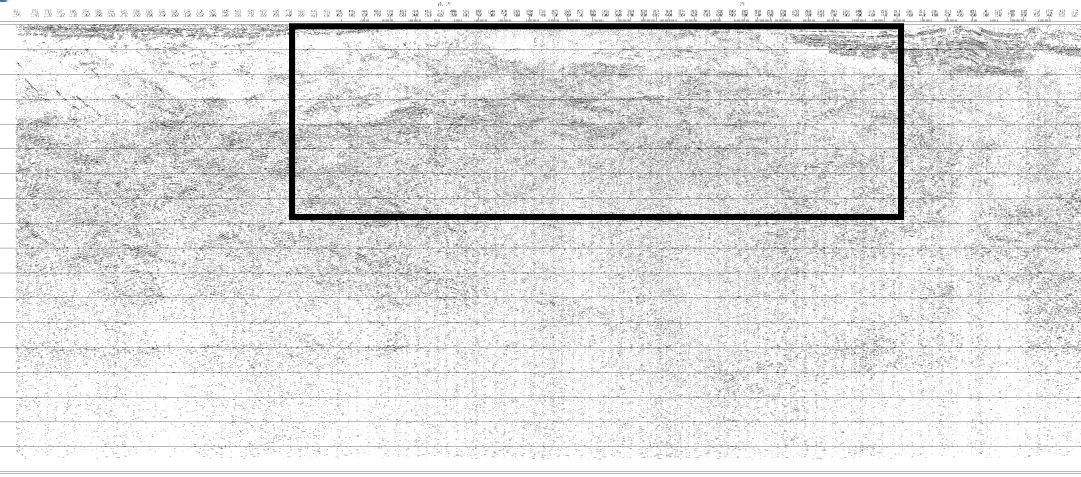
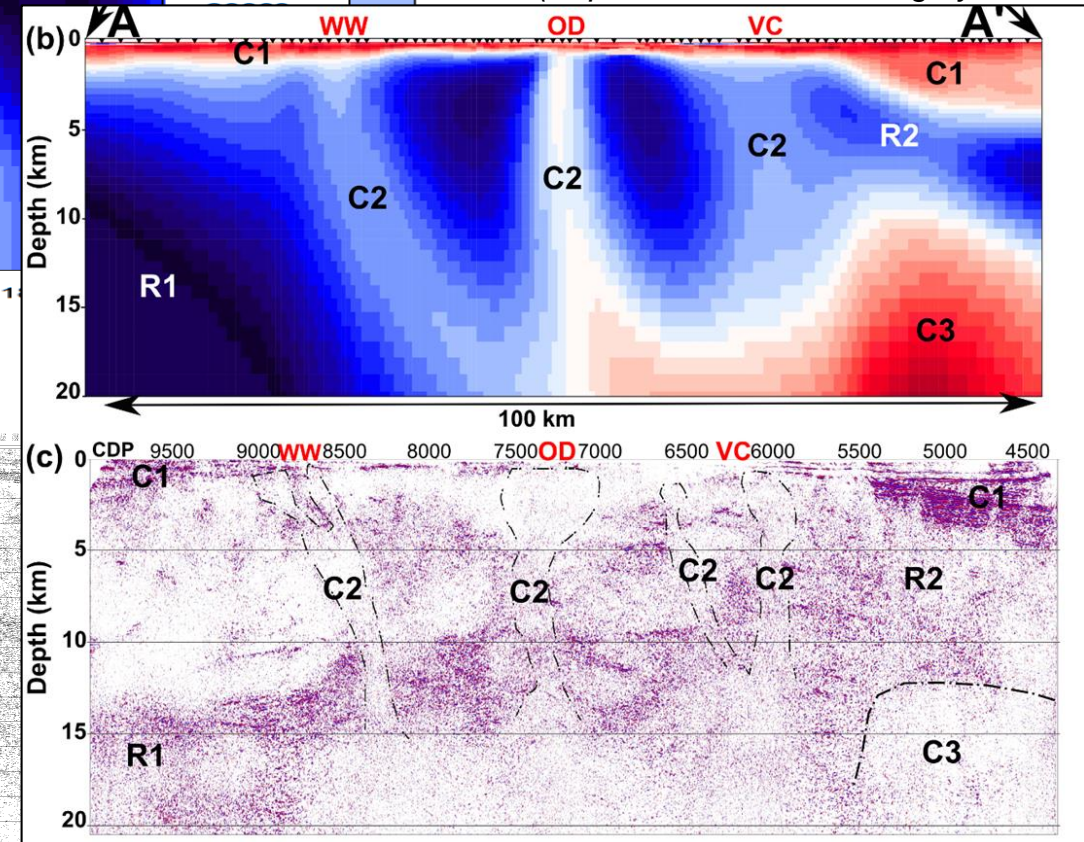
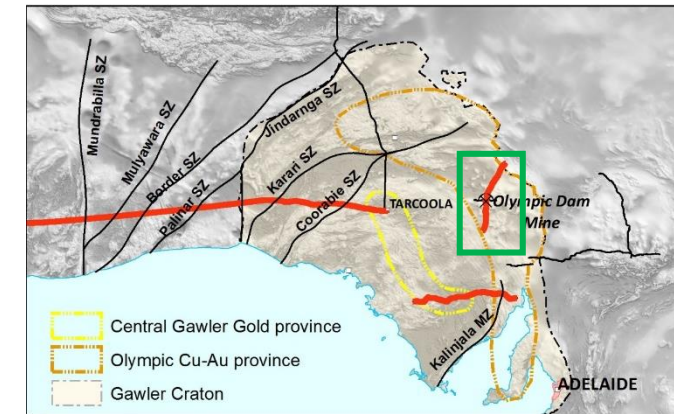


Olympic Dam (03GA-OD1)



Heinson et al., 2018.

(Reprocessed seismic imagery after Wise et al 2016)



Types of spatial association between conductivity and reflectivity

Stratabound

Coherent package of reflectors
with coincident conductivity anomaly

e.g. sedimentary/metasedimentary successions

Structure Related

Structural break in reflectors or inclined reflector
associated with a shear zone with coincident
conductivity anomaly

e.g. enhanced conductivity along shear zone,
precipitated sulphides/magnetite

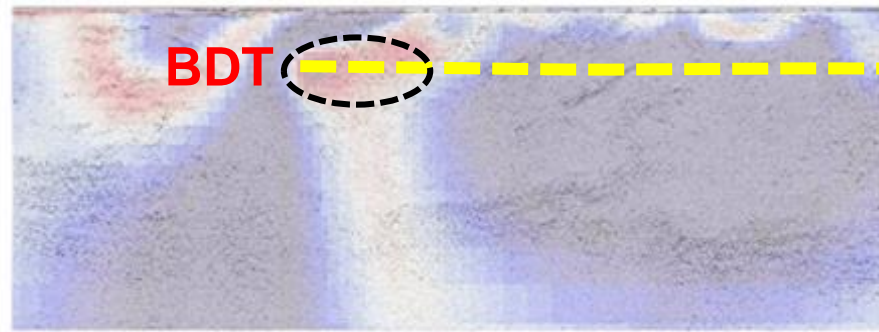
Discontinuity Related

Rheological contrast associated with distinct
reflective and conductive character

e.g. Moho, Brittle-Ductile Transition

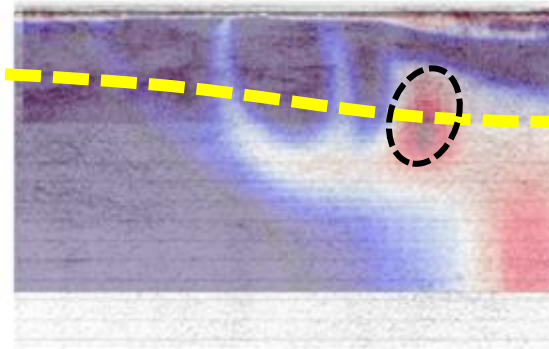
Not one of the above

Types of spatial association – Discontinuity Related

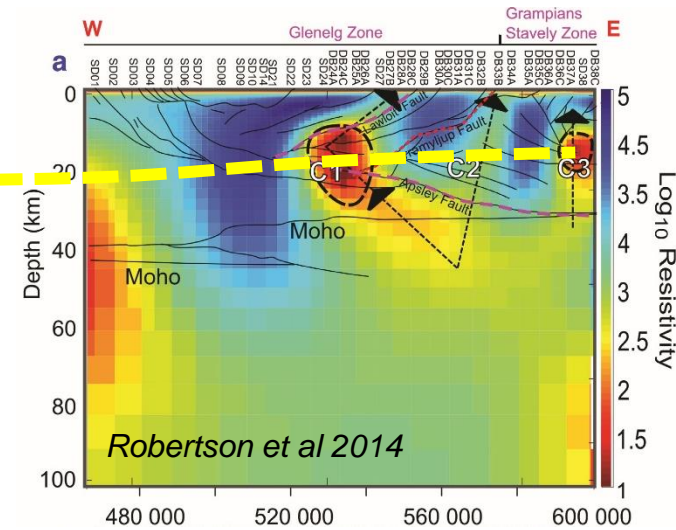


Eucla-Gawler East

60 km
V:H=1



Olympic Dam



Robertson et al 2014

Delamerian Orogen

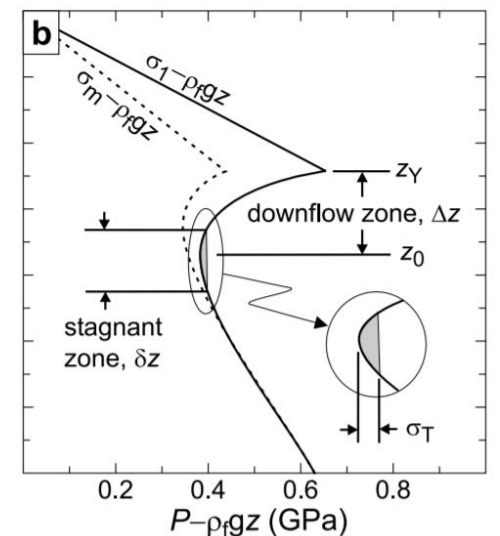
Discontinuity Related

Rheological contrast associated with distinct reflective and conductive character

e.g. Moho, Brittle-Ductile Transition

Brittle-Ductile Transition

- High-reflectivity
- High conductivity
- Often 'fed' from a deeper source in the lower crust/mantle
- **Fluid/melt stagnation and accumulation**

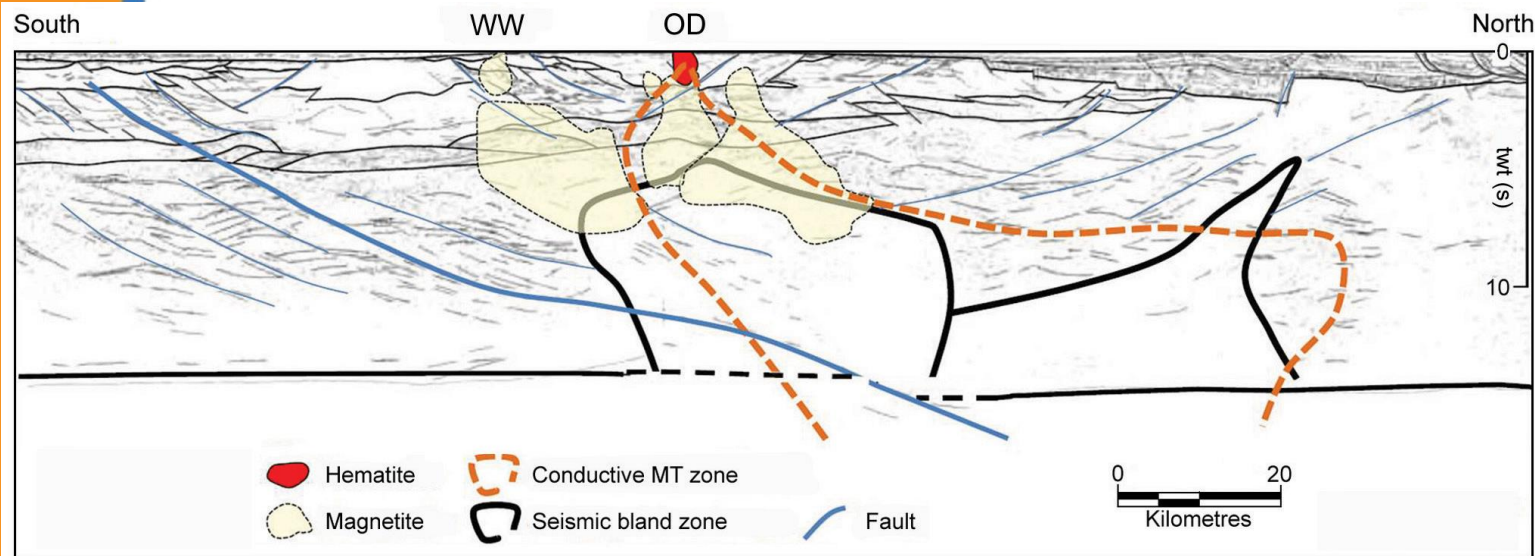


Connolly and Podladchikov, 2004

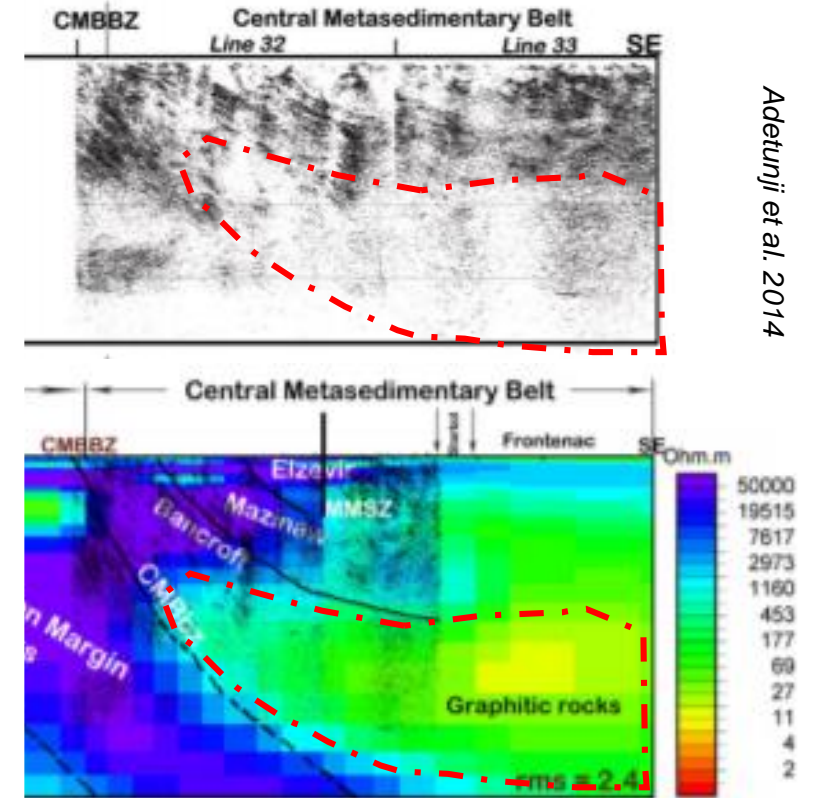
Types of spatial association

Not clearly related to major discontinuities, stratigraphic packages or structures – the “anomalous anomalies”.

Early long-period MT surveys give an indication that large, lower crustal regions may correlate with broad regions of low reflectivity.



Hayward and Skirrow. 2010



Adetunji et al. 2014

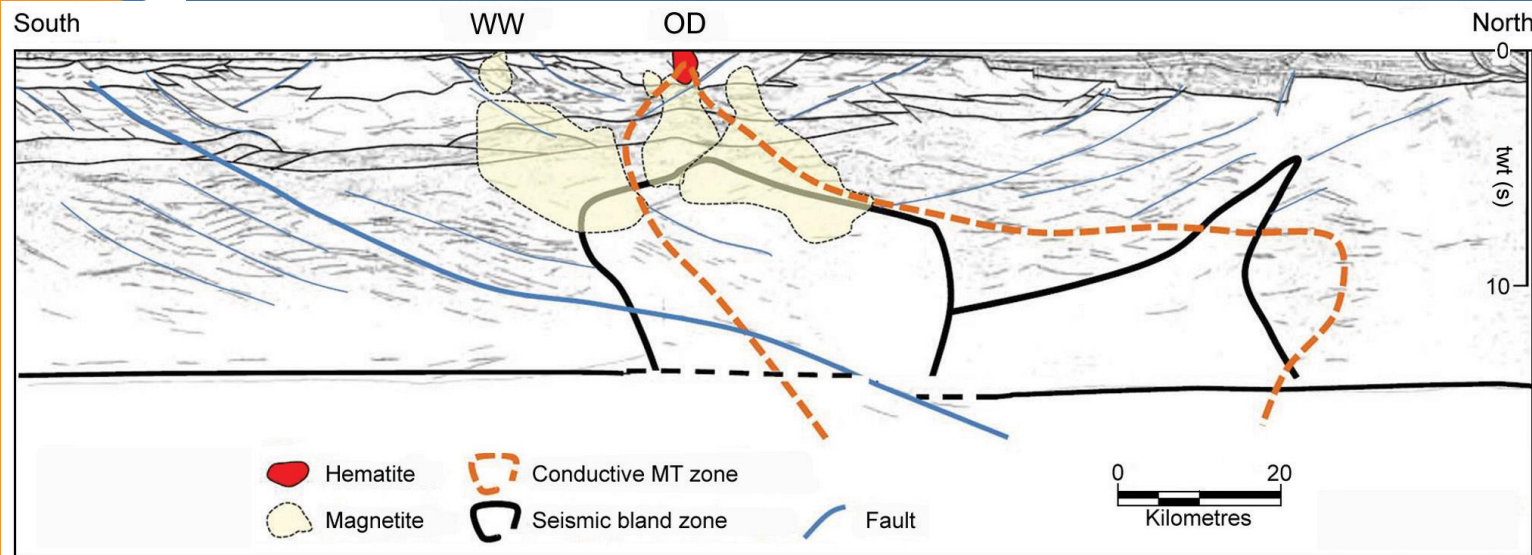
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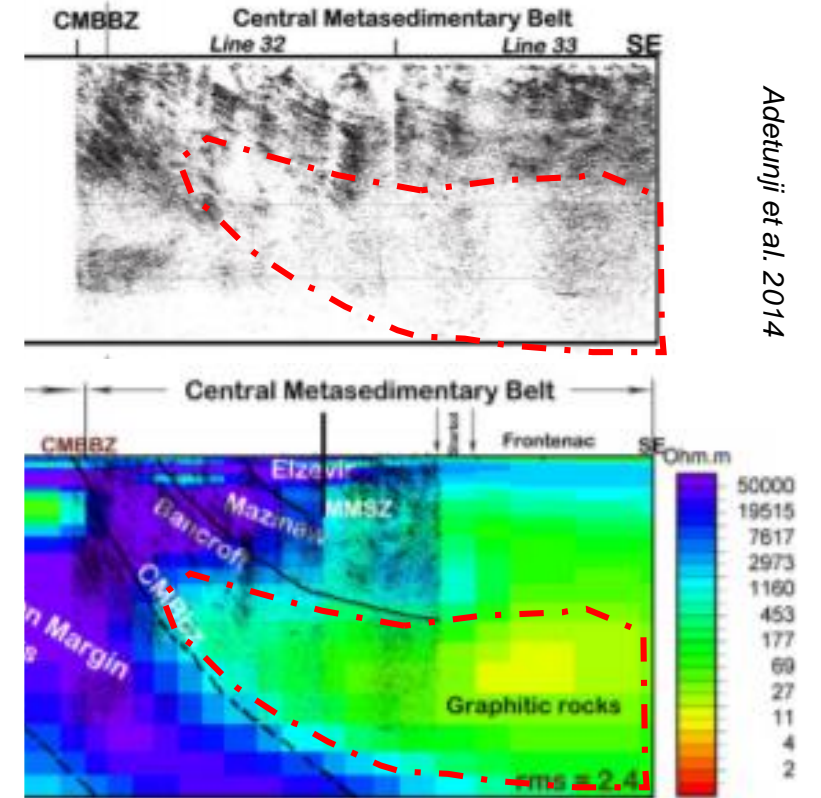
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Can a more discernible process be attributed?
Does this hold true when survey resolution is increased?
Can more discrete features be identified?



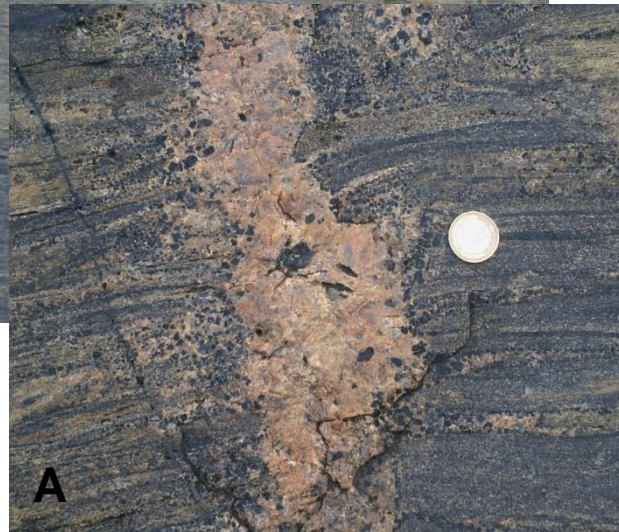
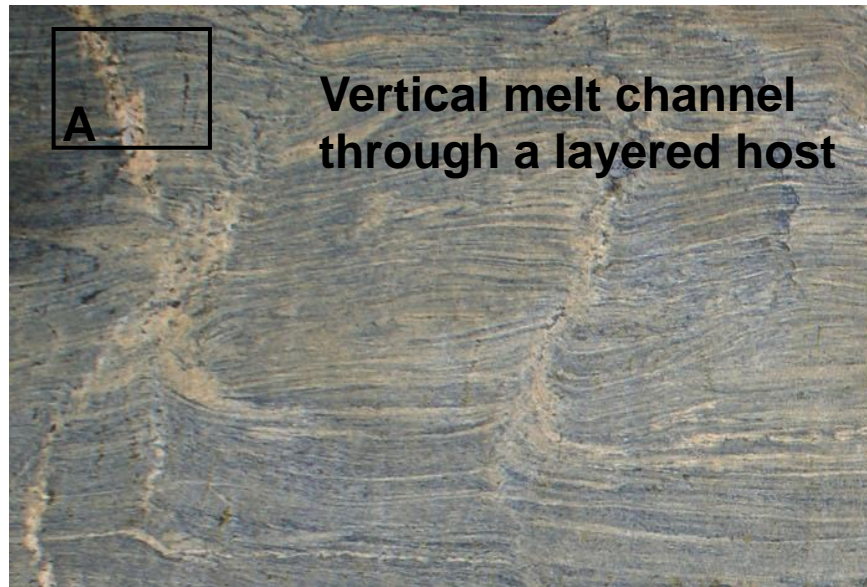
Hayward and Skirrow. 2010



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Not one of the above

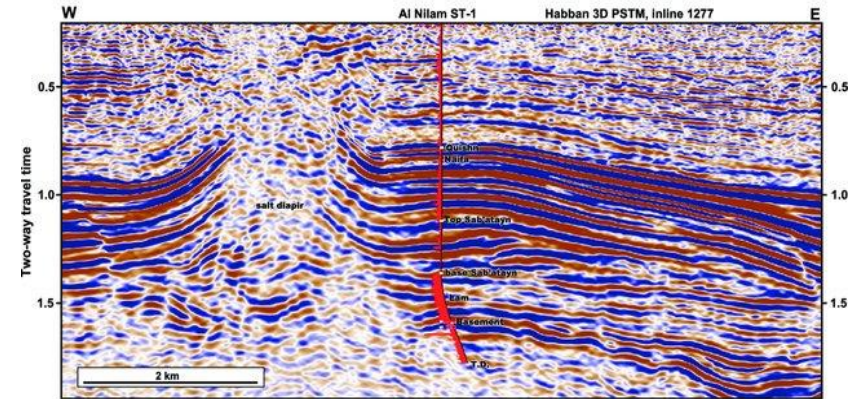
Melts?



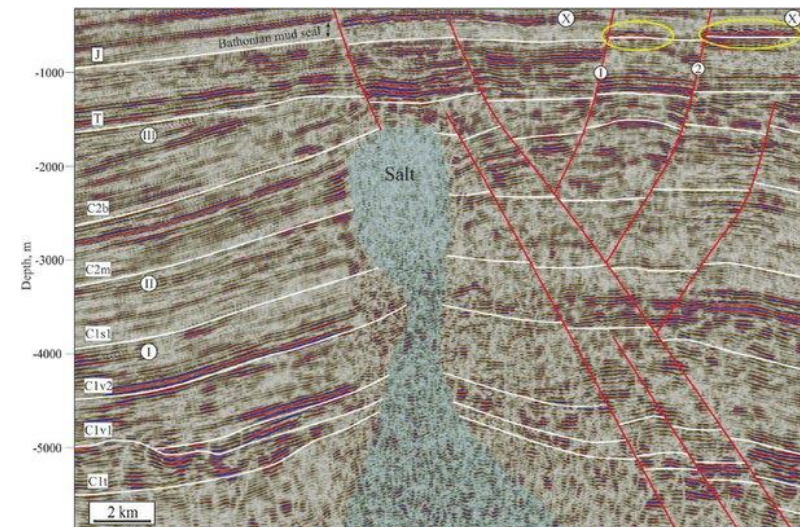
Photos courtesy of Roberto Weinberg

http://users.monash.edu.au/~weinberg/Pages/Finland_melt_features/Finland_melt_features.htm

Conductors are commonly sub-vertical. How would seismic cope?

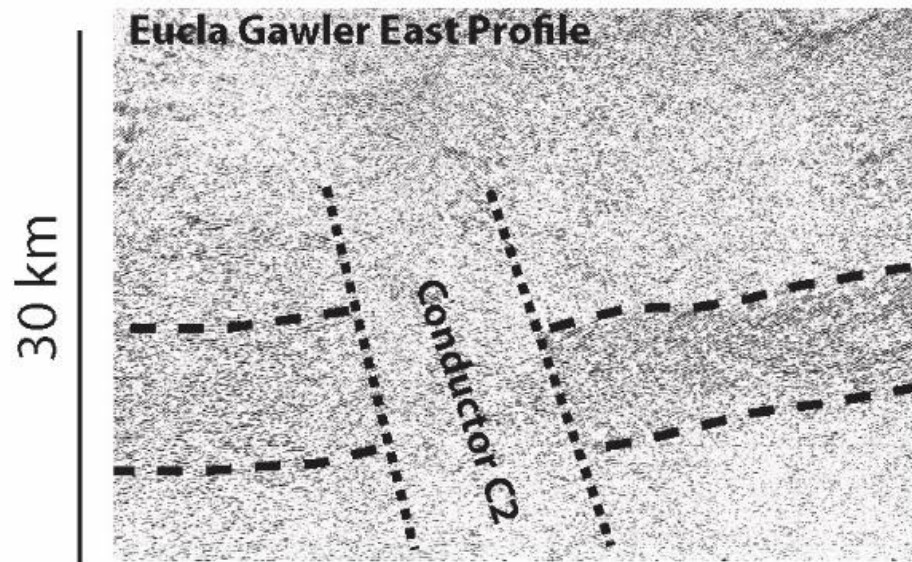
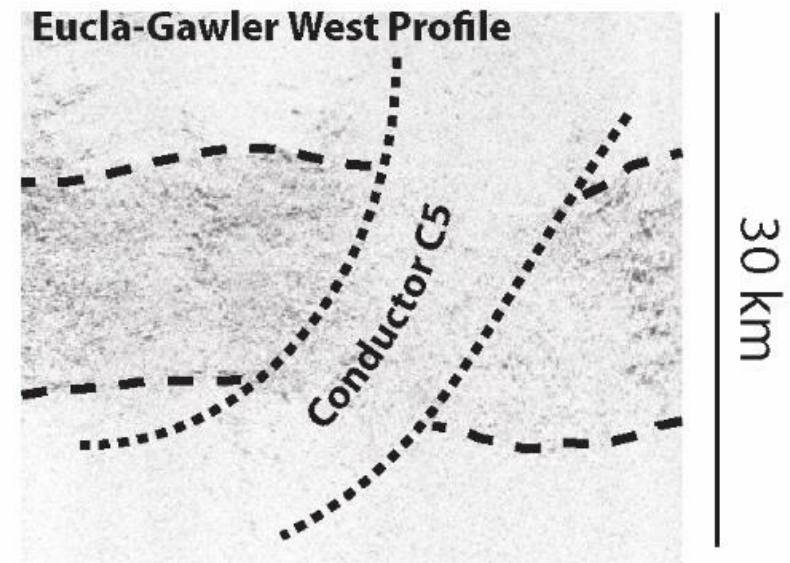
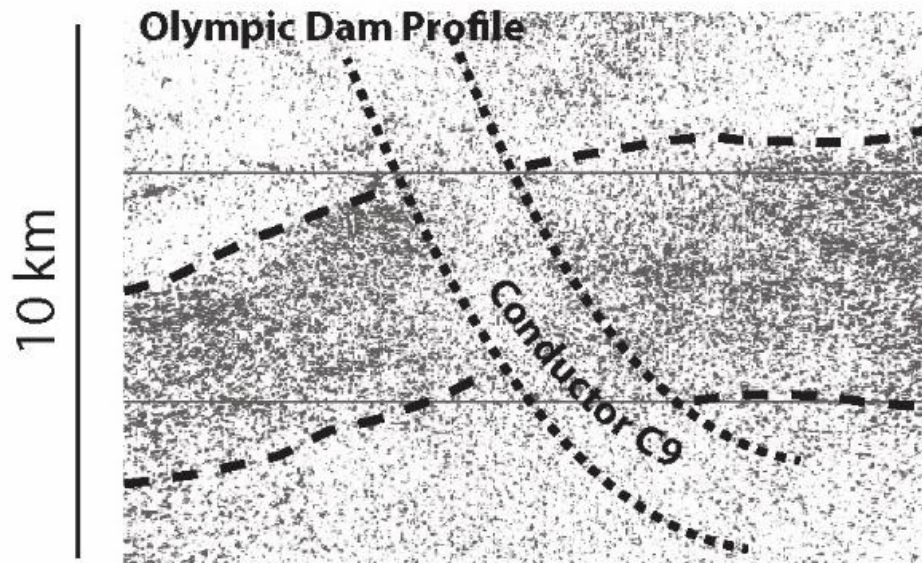


Tari et al., 2014



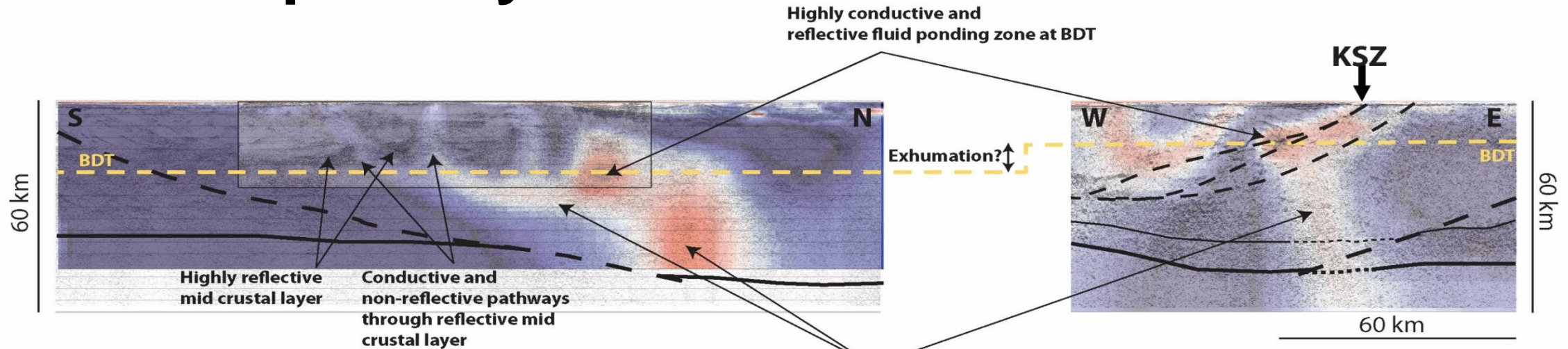
Okrepkyi & Tiapkina, 2016

– Examples from salt diapirs



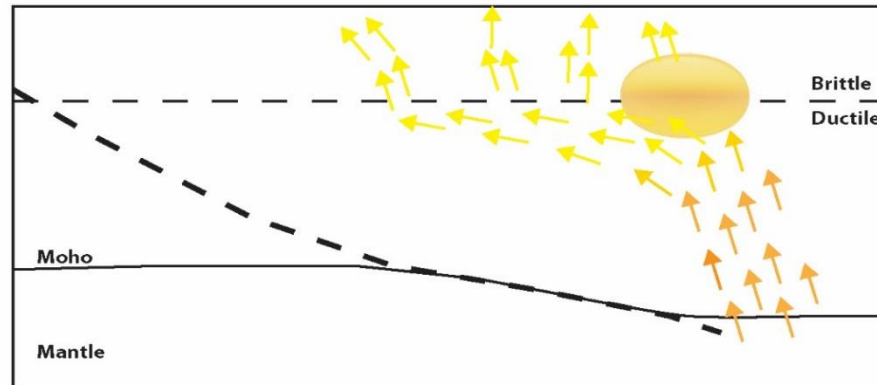
Conductors associated with zones of low reflectivity 3-10 km wide. Interconnected melt/fluid transfer zones?

Melt/fluid pathways?



Conductive and weakly reflective fluid migration zones

No shear zone control on fluid flow in the upper crust



Fluid migration pathway - enhanced conductivity and low reflectivity

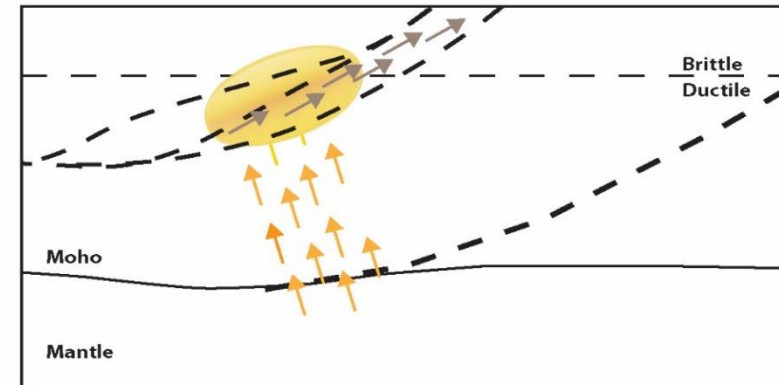


Fluid Migration Pathway along shear zones - enhanced conductivity and high reflectivity

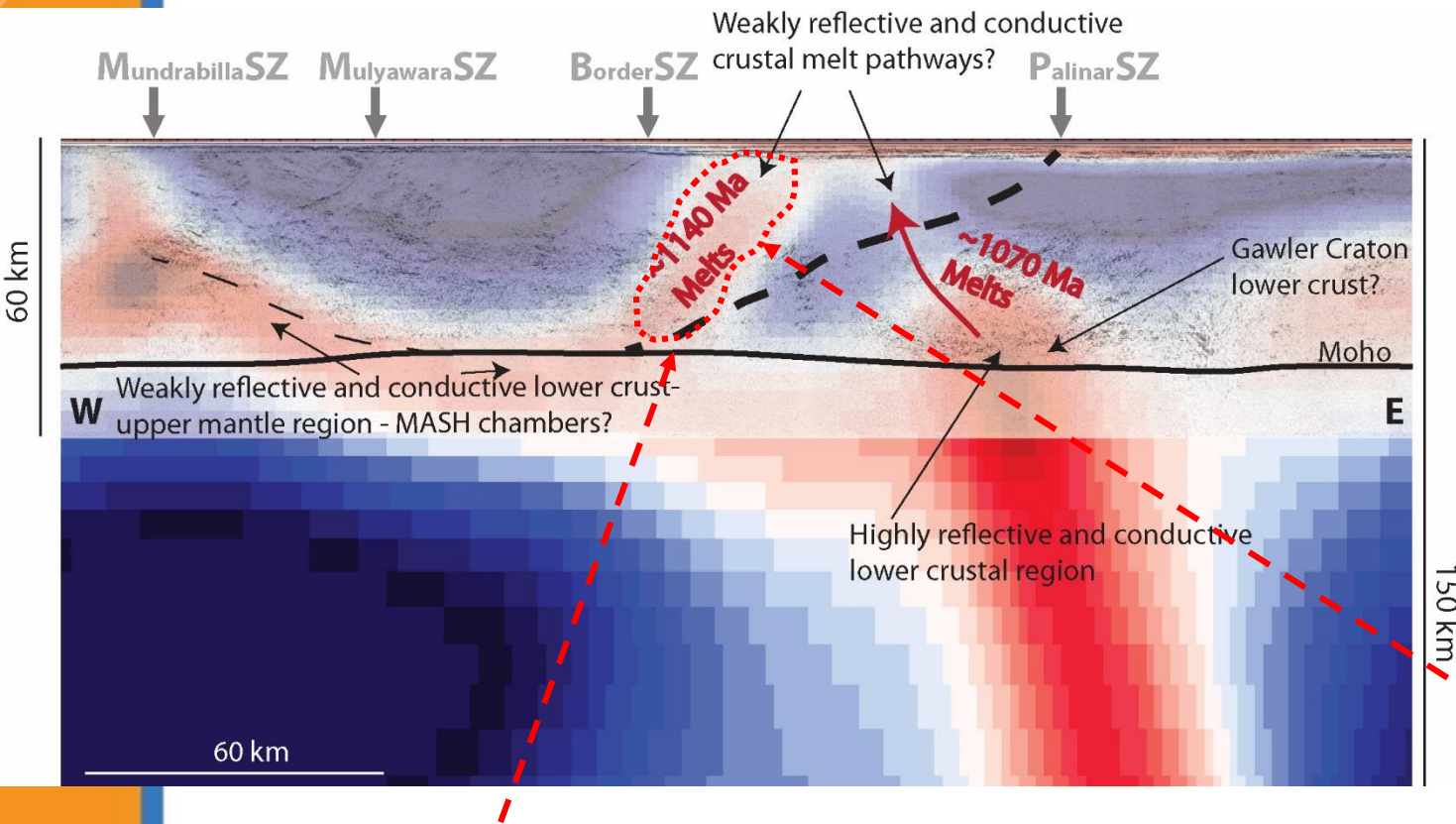


Fluid accumulation zone

Shear zone control on fluid flow in the upper crust



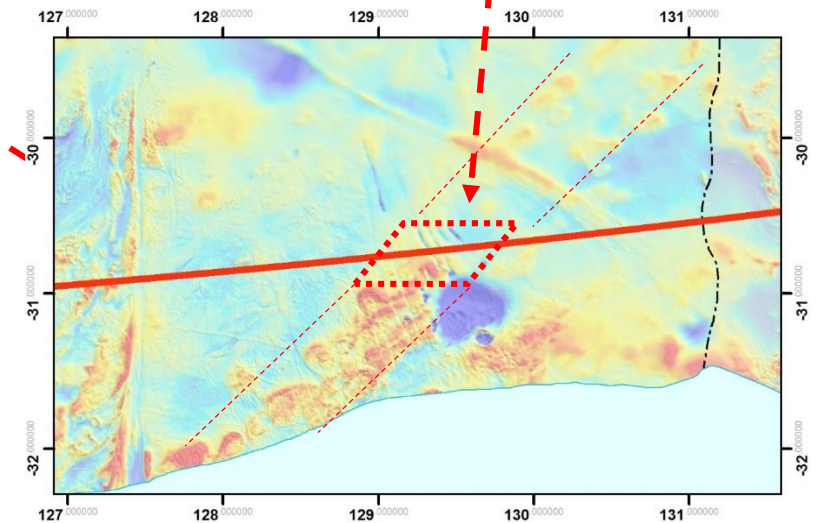
Melt/fluid pathways?



Trans-lithospheric structure intersecting the Moho providing the focal point for ascending melts?

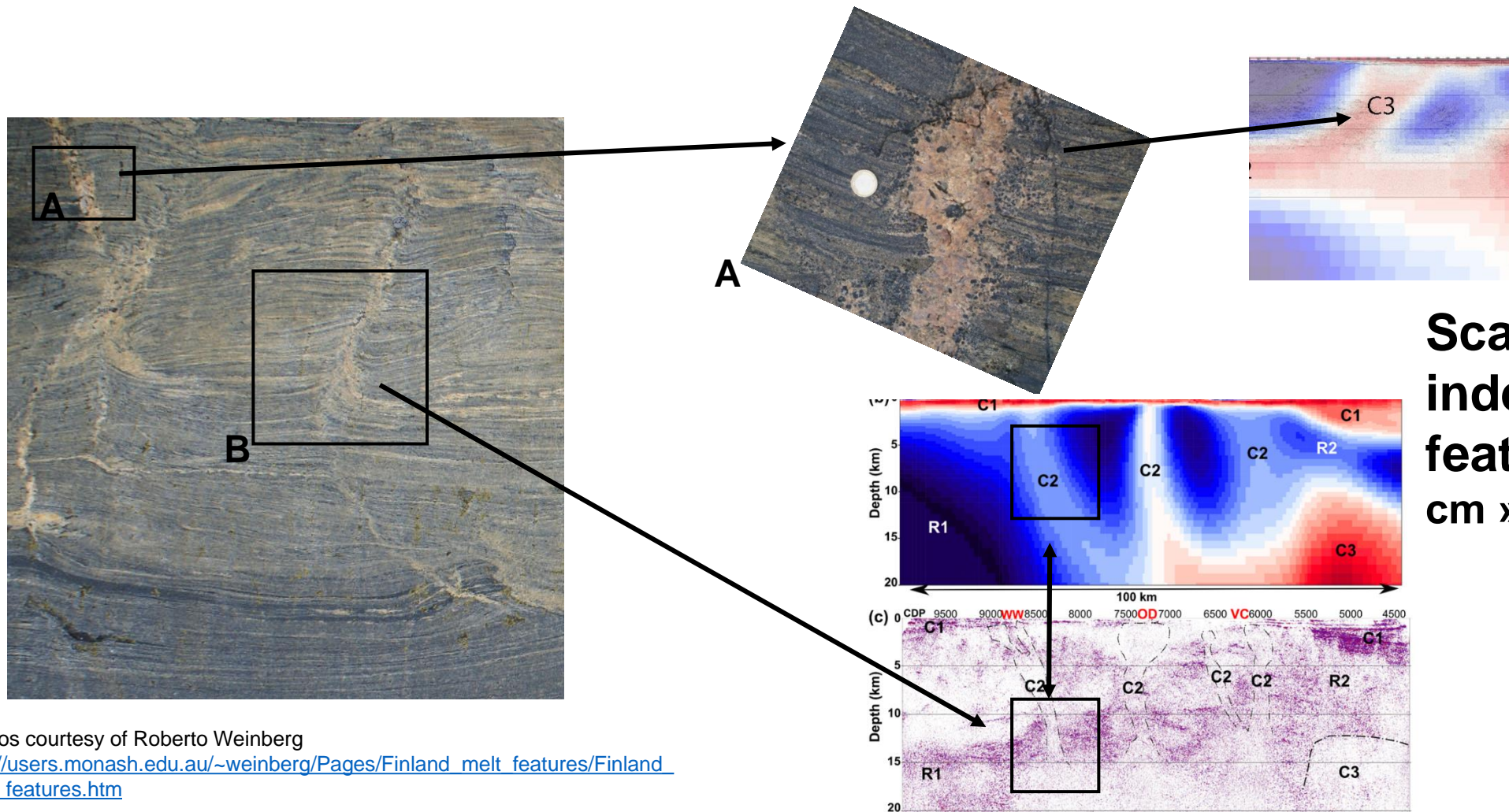
No obvious structural control within the lower-middle-upper crust

Conductor coincides with vertical zone of low reflectivity, and with the surface location of voluminous plutonism



Common themes

1. **Spatial coincidence between sub-vertical zones of low reflectivity and high conductivity** – plutonism/alteration/mineralization at surface



Photos courtesy of Roberto Weinberg

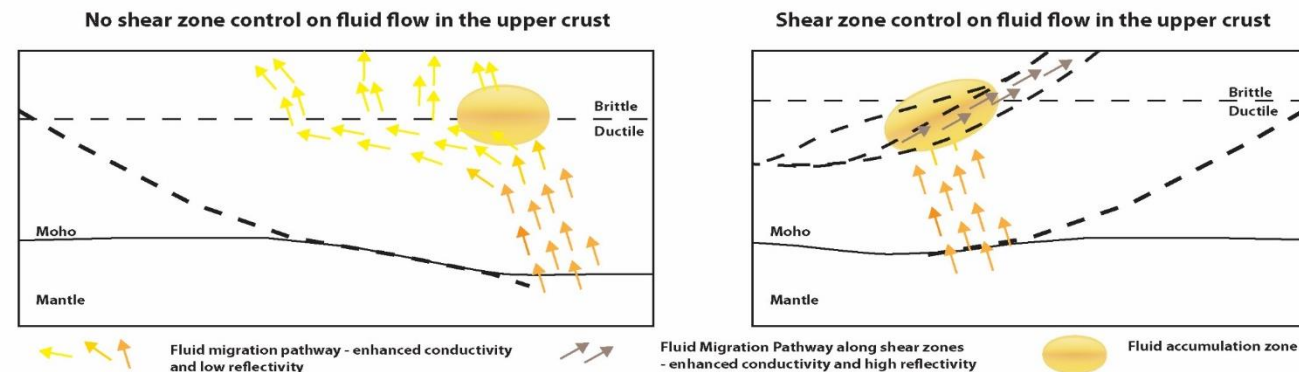
http://users.monash.edu.au/~weinberg/Pages/Finland_melt_features/Finland_melt_features.htm

Common themes

1. Spatial coincidence between sub-vertical zones of low reflectivity and high conductivity – plutonism/alteration/mineralization at surface

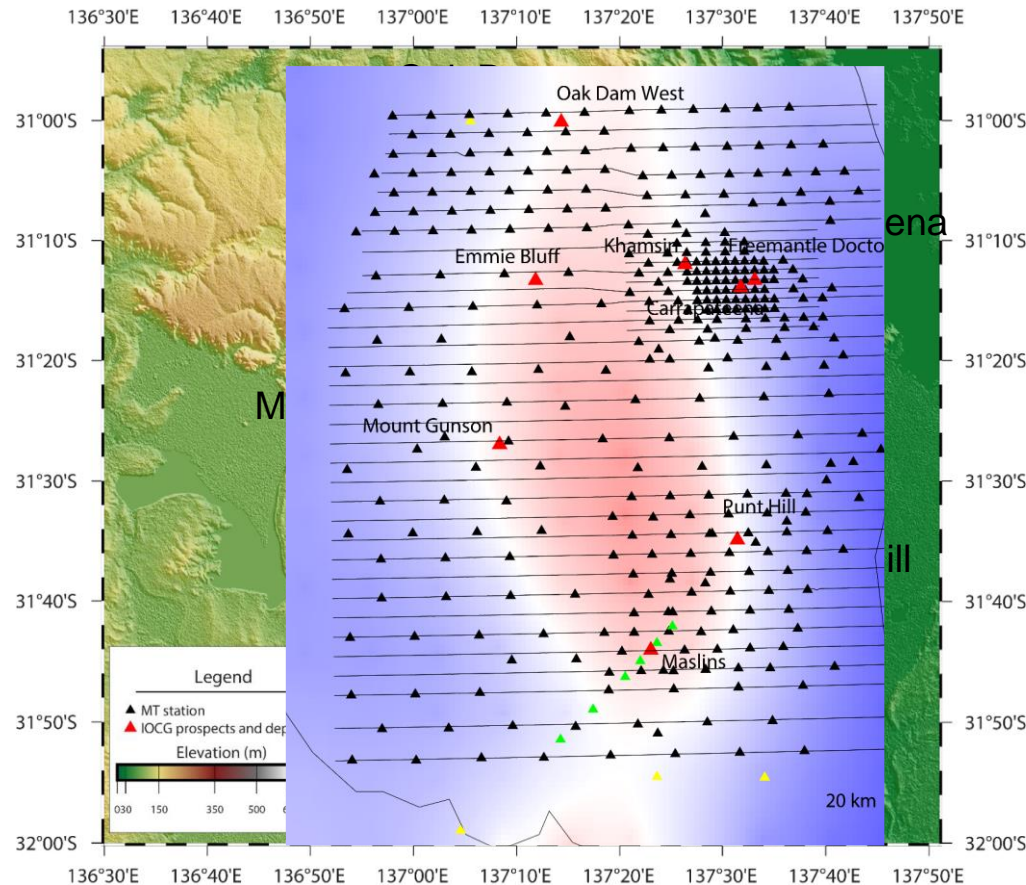
2. Importance of big structures

- Lithospheric structures intersecting the Moho localizes magmatic flux through the mechanical boundary
- Fluid pathways do not appear to be controlled by pre-existing shear structures in the lower-mid crust
- Fluid pathways may be shear controlled or not in the upper crust – dependent on tectonic regime?



Next step:

Olympic Domain in-fill survey



- Funded by PaceCopper, South Australia government initiative funding
- Tender process with Geoscience Australia
- Total of 334 BBMT and AMT stations (10^{-4} s - ~2000 s)
- Collected by Zonge in mid 2018, reprocessing by CGG in Q2 2019
- Variable site spacing between 1.5 km and 5 km
- Grid dependent on road access, geographical features (dry lake beds)
- Co-located airborne EM survey for cover characterisation

Courtesy S.Thiel

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**GEOLOGICAL
SURVEY OF**
South Australia



**Government
of South Australia**
Department for
Energy and Mining

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