

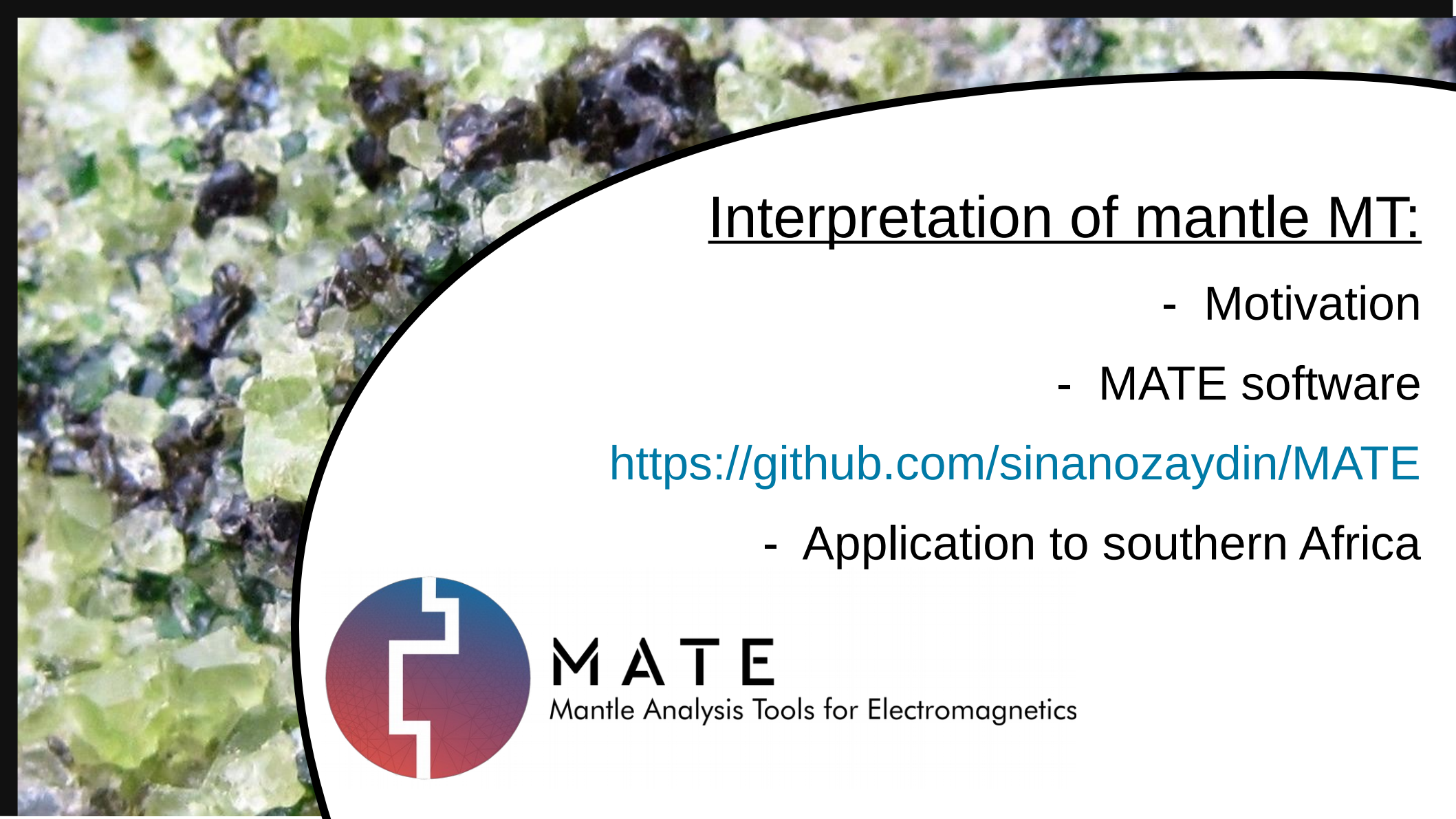


***Interpreting MT models:  
Laboratory results coded into MATE***

*Kate Selway  
Sinan Özaydin*



**Australian Government**  
**Australian Research Council**



## Interpretation of mantle MT:

- Motivation
- MATE software

<https://github.com/sinanozaydin/MATE>

- Application to southern Africa

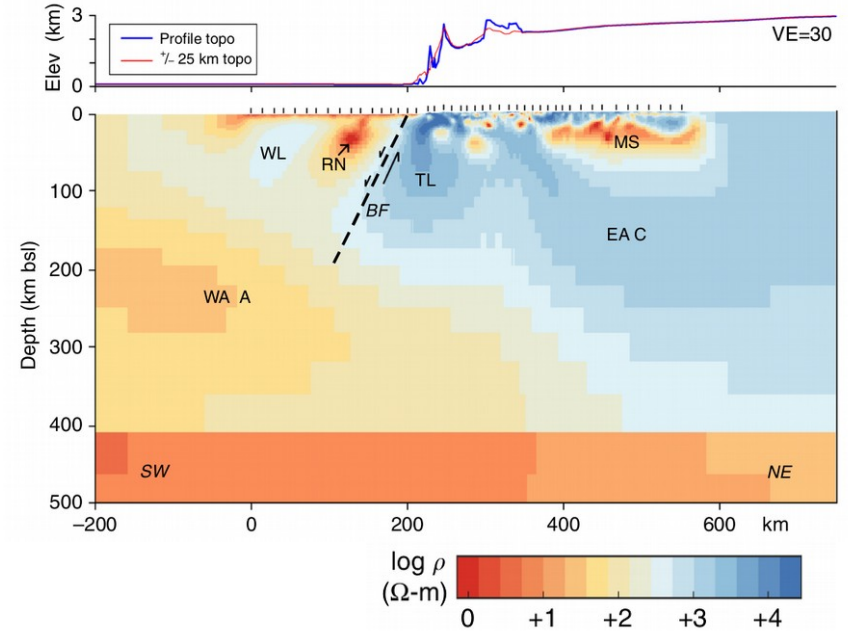
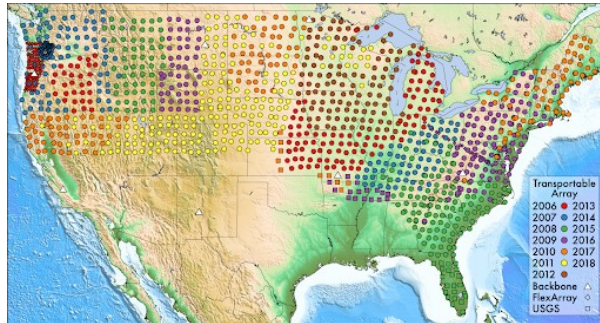
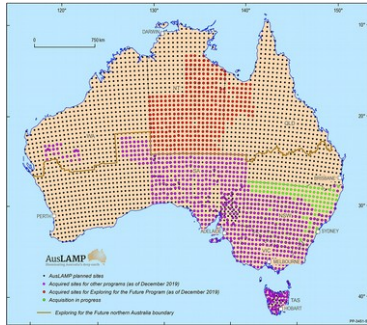


**MATE**

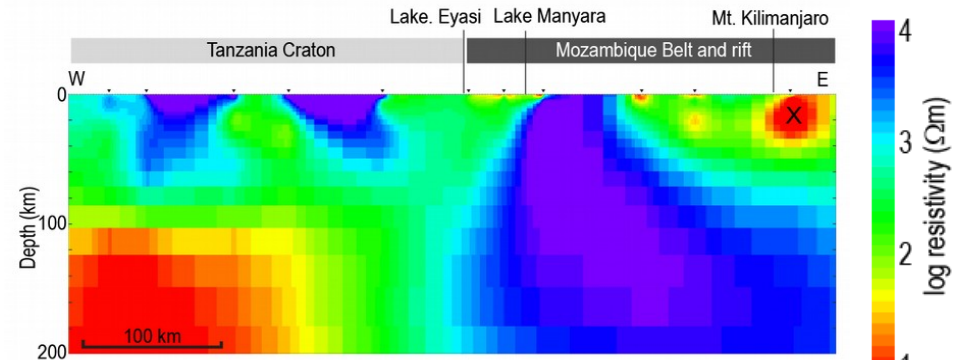
Mantle Analysis Tools for Electromagnetics

# Motivation

- MT provides unique views on the upper mantle
- Using MT data for tectonic, dynamic or mineral exploration interpretation requires quantitative interpretations



Wannamaker et al., 2017, Nat. Comms.



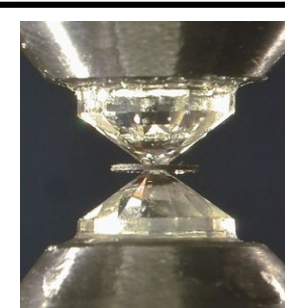
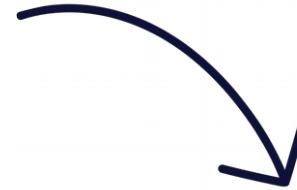
Selway, 2015, Nat. Gsc.



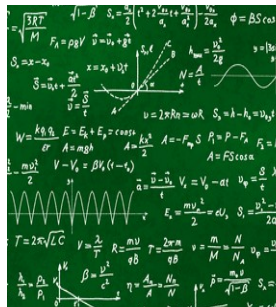
# Motivation: The steps to quantitative interpretation



Theoretical idea  
*What controls the physical property?*



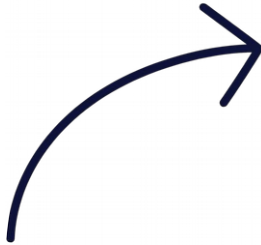
Experiments  
*Measuring the relationship*



Extrapolation  
*Experimental conditions to Earth conditions*



Calibration  
*Against the real Earth*



# Motivation: The steps to quantitative interpretation



Published: 20 September 1990

## The role of hydrogen in the electrical conductivity of the upper mantle

S. Karato

*Nature* 347, 272–273(1990) | [Cite this article](#)

365 Accesses | 442 Citations | 0 Altmetric | [Metrics](#)


**Olivine conductivity =**

**Proton conductivity (hydrogen) + Polaron conductivity (electrons) + Ionic conductivity (Fe, Mg)**



Published: 26 October 2006

## Hydrous olivine unable to account for conductivity anomaly at the top of the asthenosphere

Takashi Yoshino , Takuya Matsuzaki, Shigeru Yamashita & Tomoo Katsura

*Nature* 443, 973–976(2006) | [Cite this article](#)

340 Accesses | 205 Citations | 0 Altmetric | [Metrics](#)

Published: 26 October 2006

## The effect of water on the electrical conductivity of olivine

Duojun Wang, Mainak Mookherjee, Yousheng Xu & Shun-ichiro Karato 

*Nature* 443, 977–980(2006) | [Cite this article](#)

677 Accesses | 259 Citations | 0 Altmetric | [Metrics](#)



ELSEVIER

Earth and Planetary Science Letters

Volume 408, 15 December 2014, Pages 79–86

High and highly anisotropic electrical conductivity of the asthenosphere due to hydrogen diffusion in olivine

Lidong Dai <sup>a, b</sup>, Shun-ichiro Karato <sup>a, c</sup> 



ELSEVIER

Physics of the Earth and Planetary Interiors

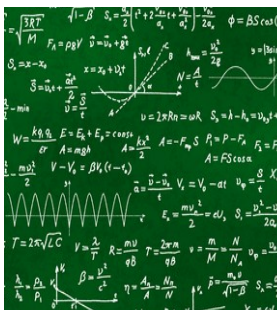
Volume 181, Issues 3–4, August 2010, Pages 103–111

Electrical conductivity anisotropy of dry and hydrous olivine at 8 GPa

Brent T. Poe <sup>a, b, c</sup> , Claudia Romano <sup>c, 1</sup> , Fabrizio Nestola <sup>d, 2</sup> , Joseph R. Smyth <sup>c, 3</sup> 



# Motivation: The steps to quantitative interpretation



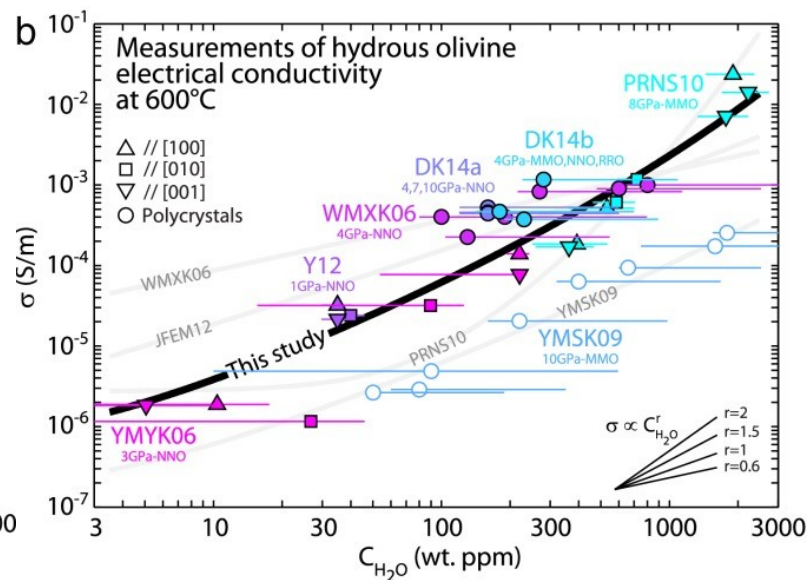
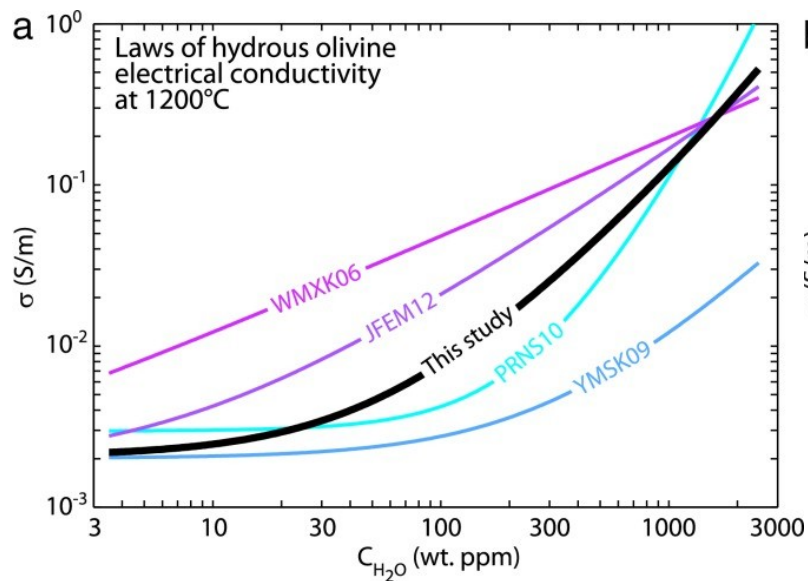
## Geochemistry, Geophysics, Geosystems

Research Article | [Free Access](#)

### Toward a unified hydrous olivine electrical conductivity law

Emmanuel Gardés , Fabrice Gaillard, Pascal Tarits

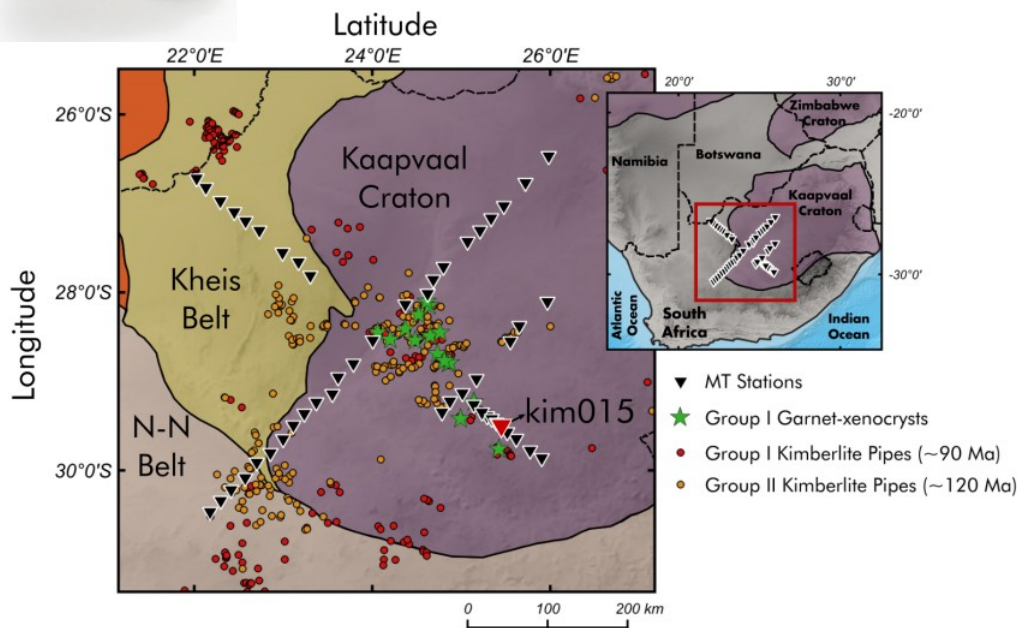
First published: 09 December 2014 | <https://doi.org/10.1002/2014GC005496> | Citations: 64



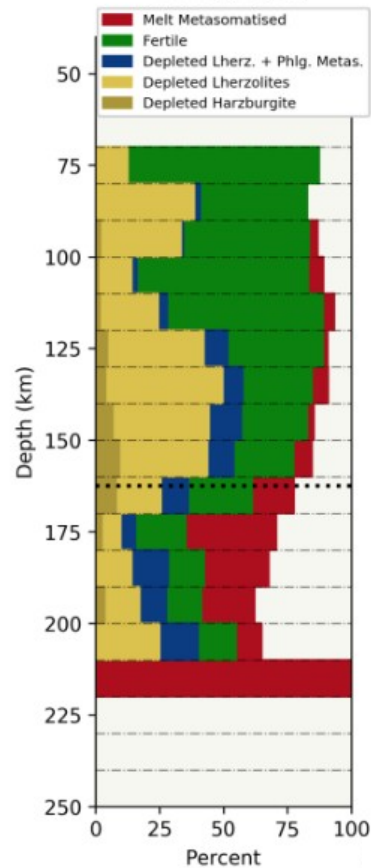
# Motivation: The steps to quantitative interpretation



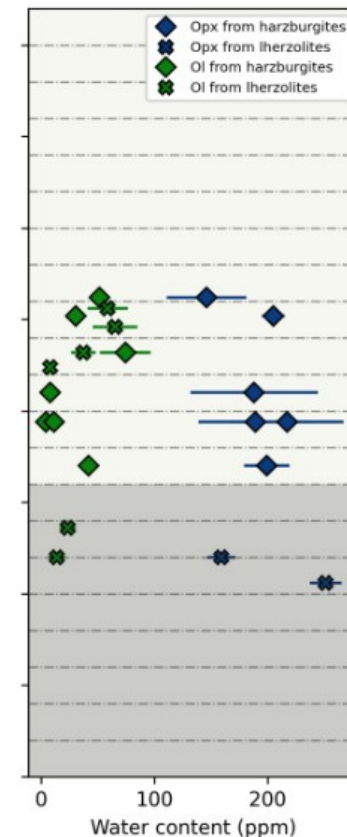
## Calibration: Kaapvaal Craton



## Garnet xenocryst Geochemical Tomography




## Water content measurements



# Motivation: The steps to quantitative interpretation



## JGR Solid Earth

Research Article | [Open Access](#) | 

### Electrical Conductivity of Ti-Bearing Hydrous Olivine Aggregates at High Temperature and High Pressure

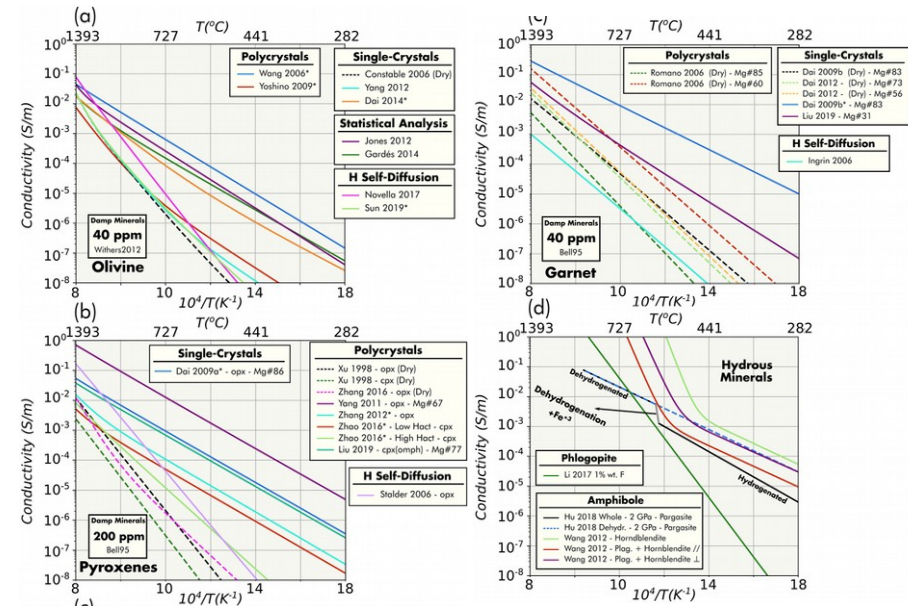
Lidong Dai  Shun-ichiro Karato

First published: 26 September 2020 | <https://doi.org/10.1029/2020JB020309> | Citations: 1



# Key factors in quantitative mantle MT interpretation:

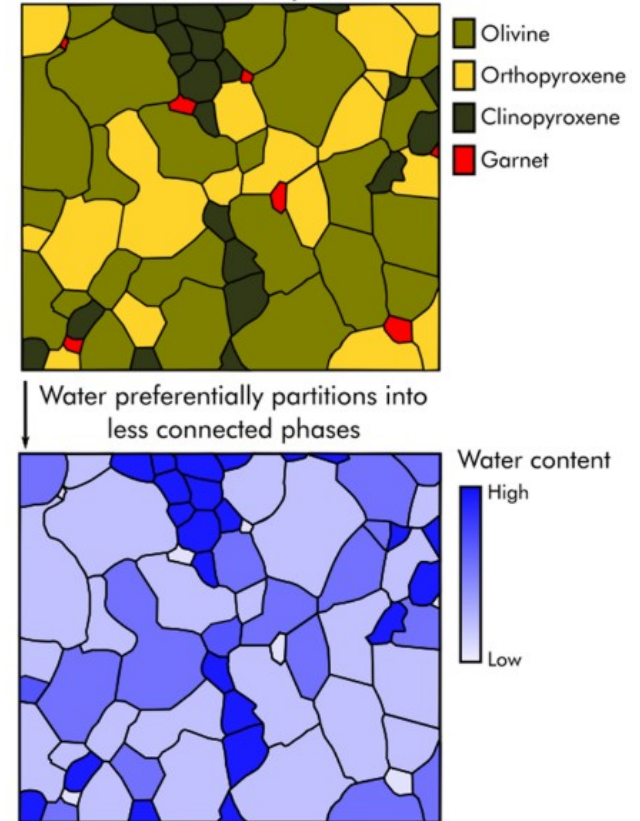
- Conductivities of individual mantle minerals (Temp,  $X_{Fe}$ ,  $C_{H_2O}$ , etc.)
- Hydrogen partitioning between mantle minerals
- Maximum hydrogen solubility in mantle minerals
- Geometries of mantle rocks
- The possibility of other, previously unconsidered, conductive phases



Özaydin and Selway 2020, *G Cubed*

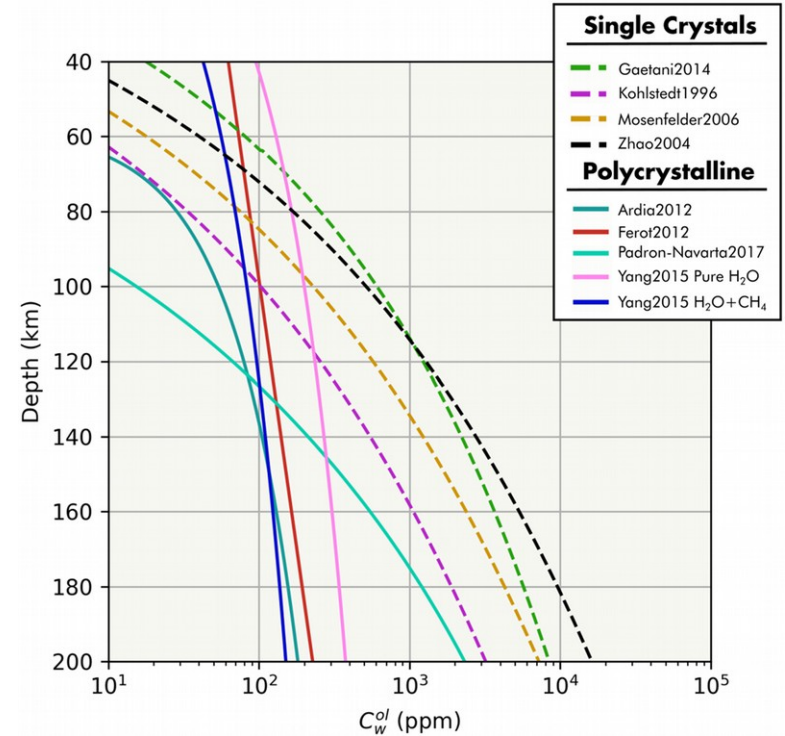
# Key factors in quantitative mantle MT interpretation:

- Conductivities of individual mantle minerals
- **Hydrogen partitioning between mantle minerals**
- Maximum hydrogen solubility in mantle minerals
- Geometries of mantle rocks
- The possibility of other, previously unconsidered, conductive phases



# Key factors in quantitative mantle MT interpretation:

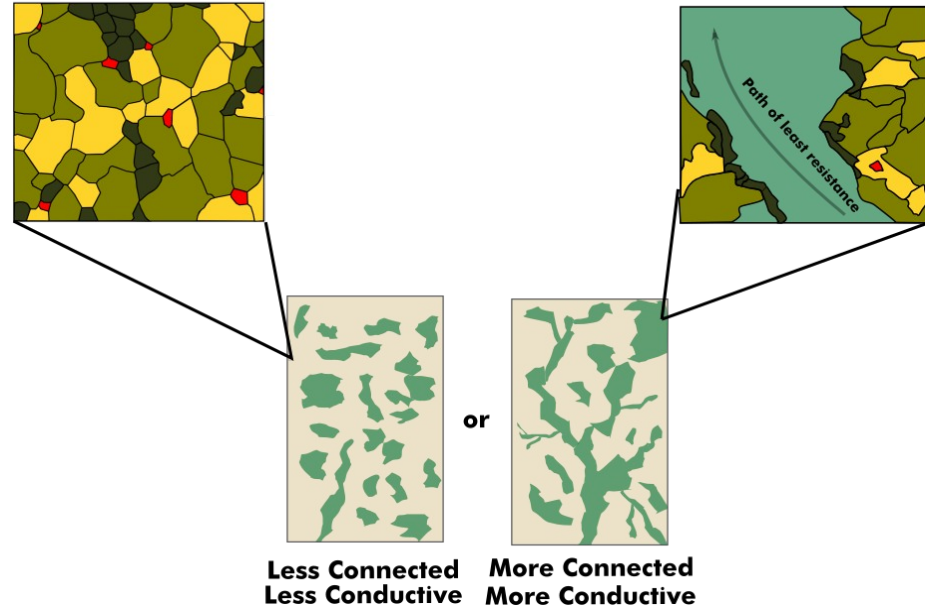
- Conductivities of individual mantle minerals
- Hydrogen partitioning between mantle minerals
- **Maximum hydrogen solubility in mantle minerals**
- Geometries of mantle rocks
- The possibility of other, previously unconsidered, conductive phases



Özaydin and Selway 2020, *G Cubed*

# Key factors in quantitative mantle MT interpretation:

- Conductivities of individual mantle minerals
- Hydrogen partitioning between mantle minerals
- Maximum hydrogen solubility in mantle minerals
- **Geometries of mantle rocks**
- The possibility of other, previously unconsidered, conductive phases





# Key factors in quantitative mantle MT interpretation:

- Conductivities of individual mantle minerals
- Hydrogen partitioning between mantle minerals
- Maximum hydrogen solubility in mantle minerals
- Geometries of mantle rocks



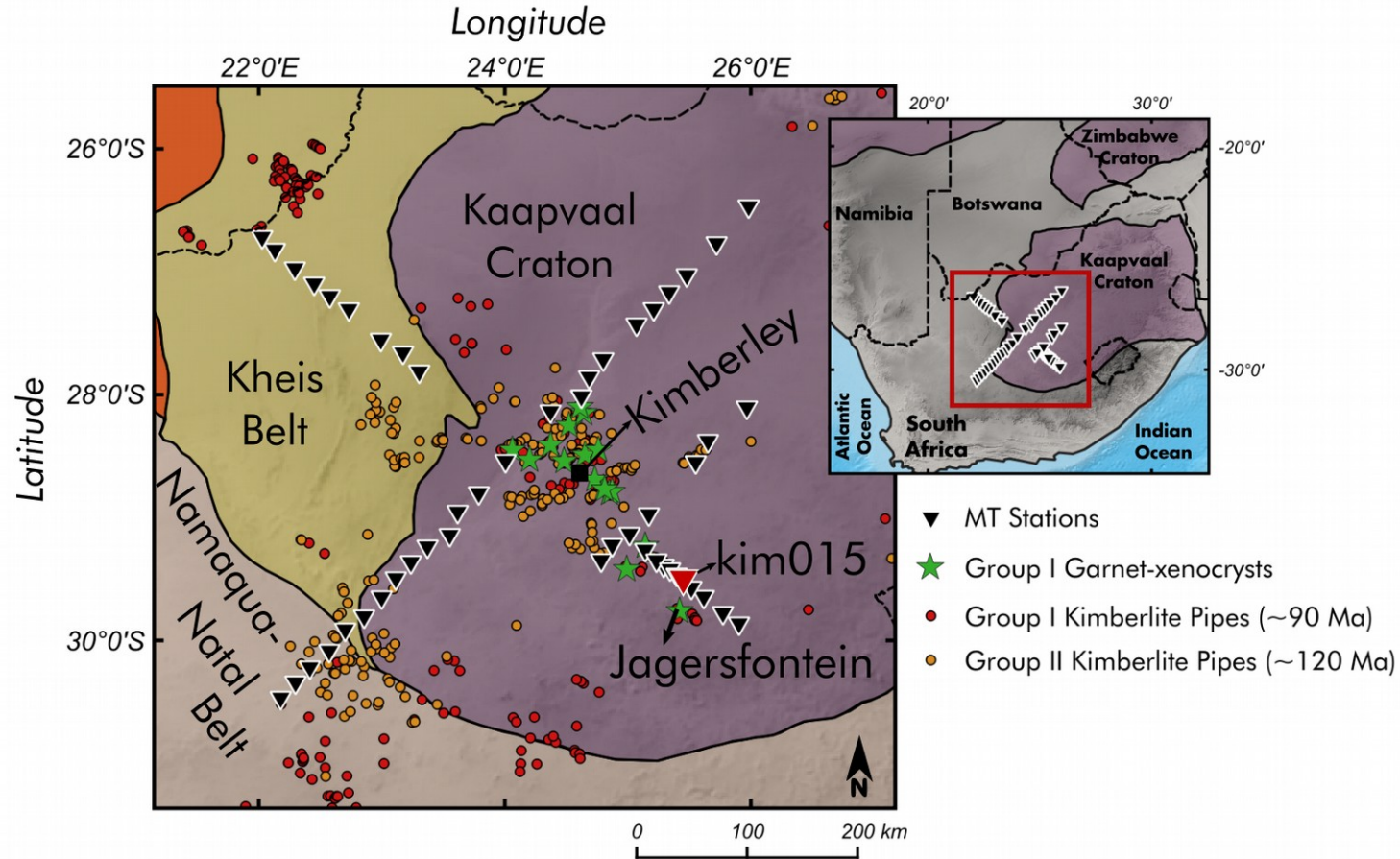
**MATE**

Mantle Analysis Tools for Electromagnetics

<https://github.com/sinanozaydin/MATE>

Summary / case study slides:

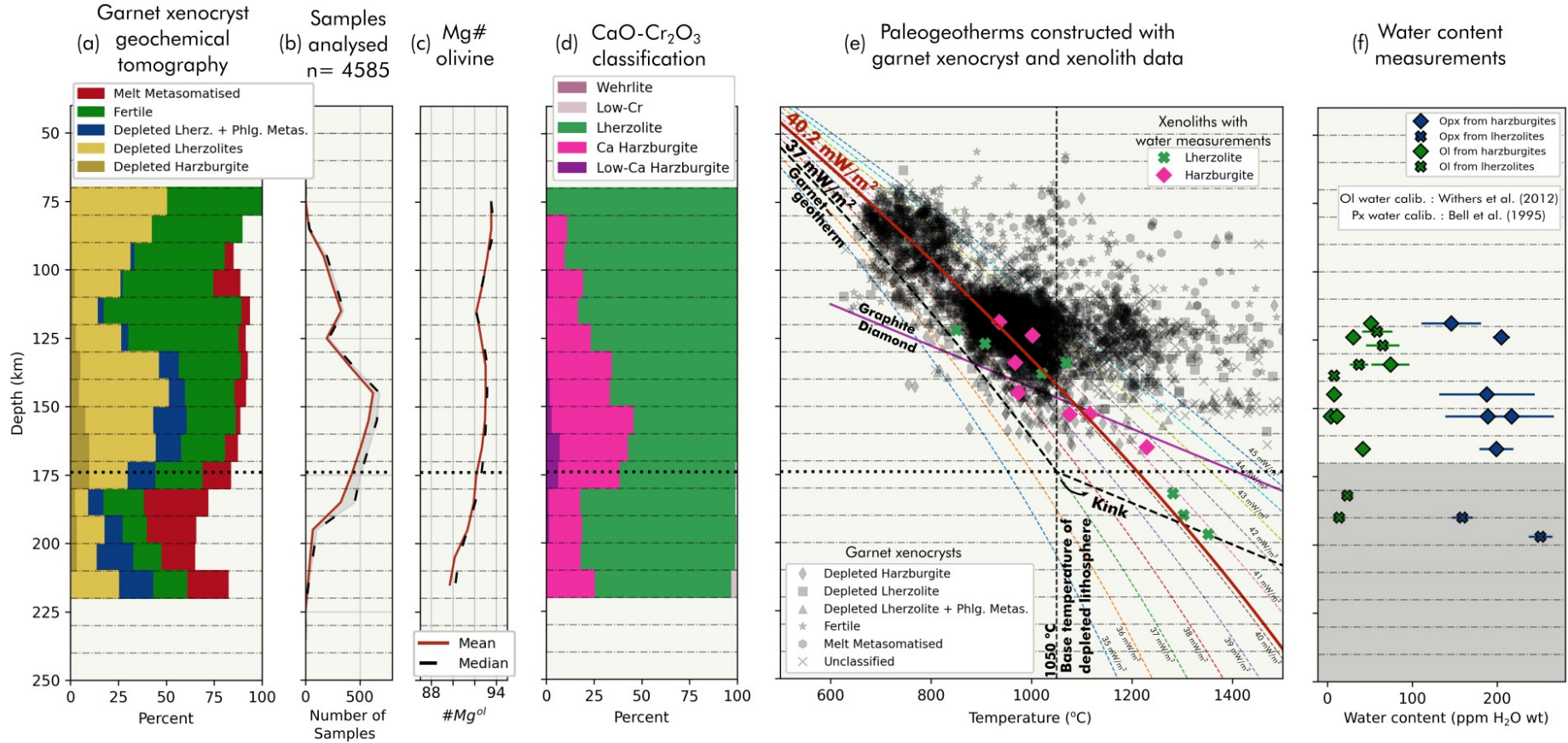
# Case Study - Southwestern Kaapvaal Craton



- Are xenoliths and xenocrysts representative of the mantle here? Water contents, metasomatic imprints?

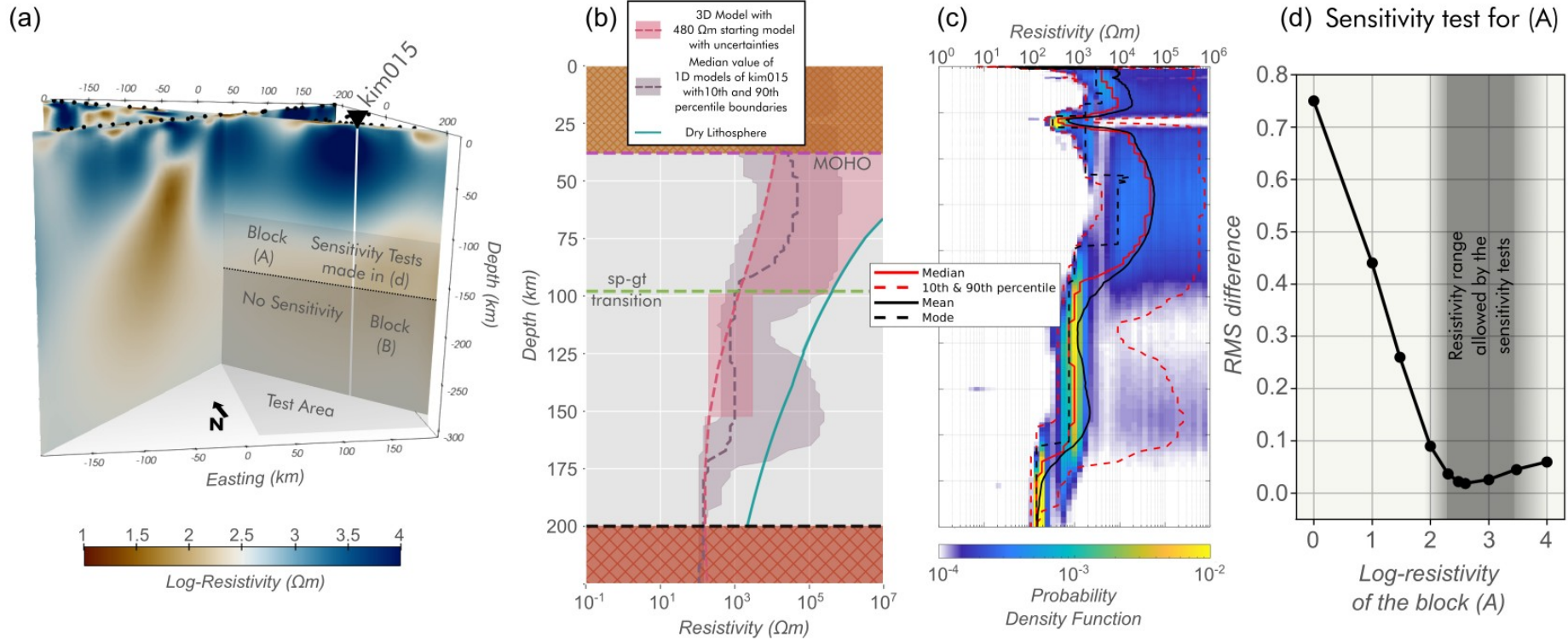
- To what ends they agree with the quantified interpretation made on magnetotelluric models.

# Information from xenoliths and xenocrysts



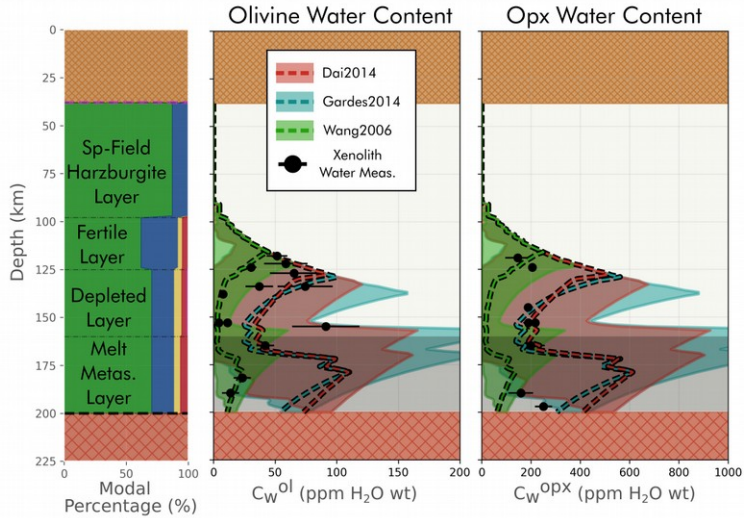


# MT Inversion and Bounds

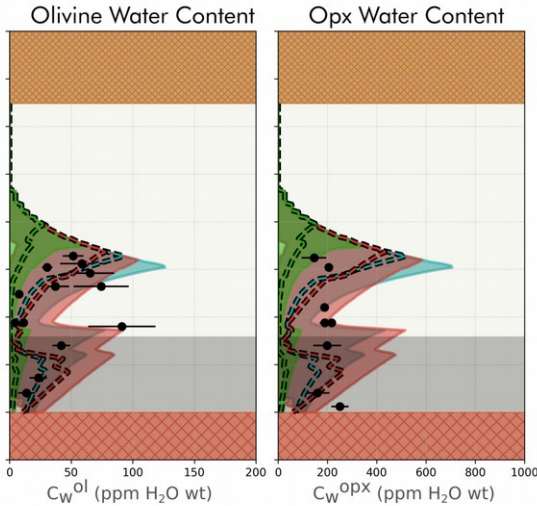


# Comparison of MT model and xenoliths.

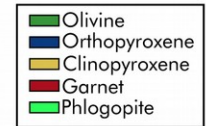
(a) 37 mW/m<sup>2</sup> Garnet-Xenocryst Geotherm



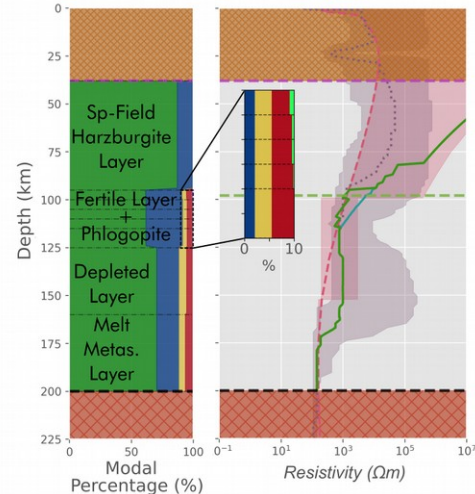
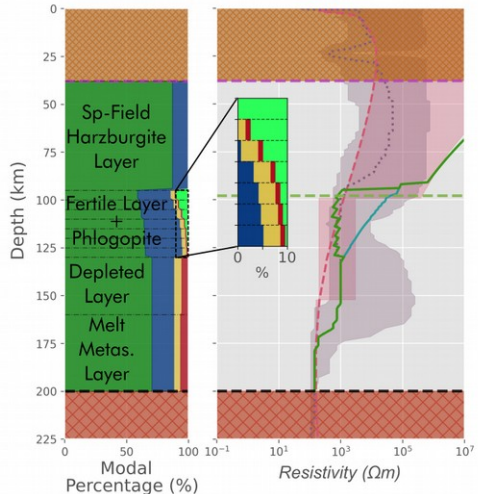
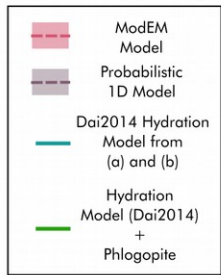
(b) 40.2 mW/m<sup>2</sup> Xenolith Geotherm



(c) Hydrated 37 mW/m<sup>2</sup> + Phlogopite (d) Hydrated 40.2 mW/m<sup>2</sup> + Phlogopite



Legend for (c) and (d)



-Calculated amount of water contents from MT decreases with depth, matching the fertility-depletion trend of xenocrysts.

- Water contents broadly falls into uncertainties derived from MT.

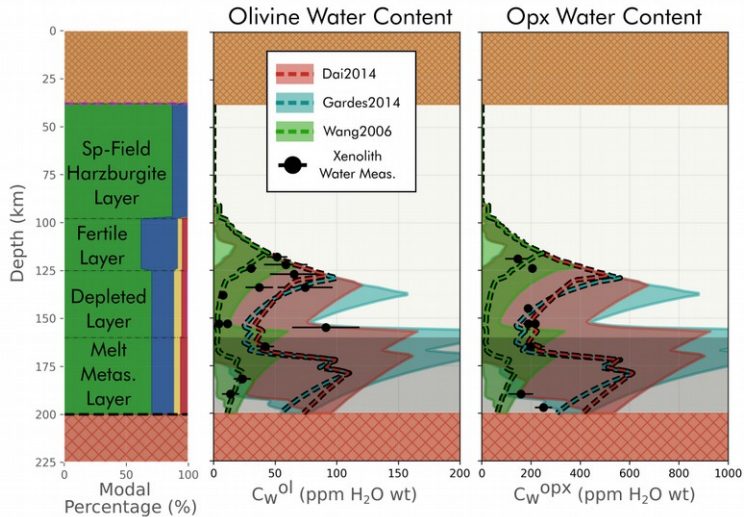
-Inconsistencies in fitting the water content suggests local metasomatic control.

-Fertile layer could be laterally pervasive feature to be sensed by the MT method.

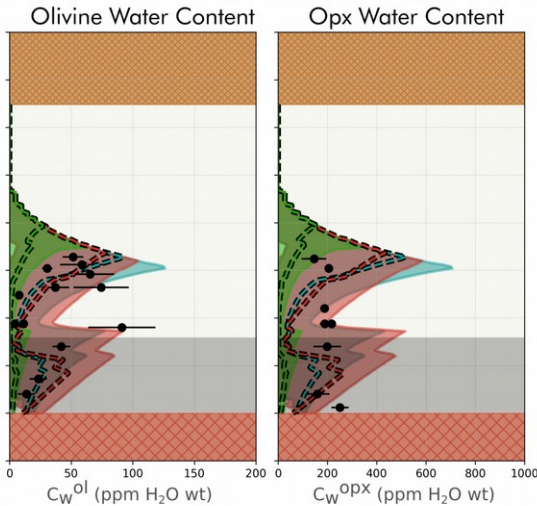


# Comparison of MT model and xenoliths.

(a) 37 mW/m<sup>2</sup> Garnet-Xenocryst Geotherm

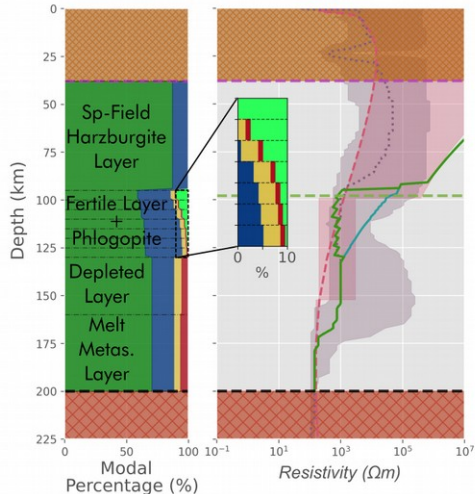


(b) 40.2 mW/m<sup>2</sup> Xenolith Geotherm

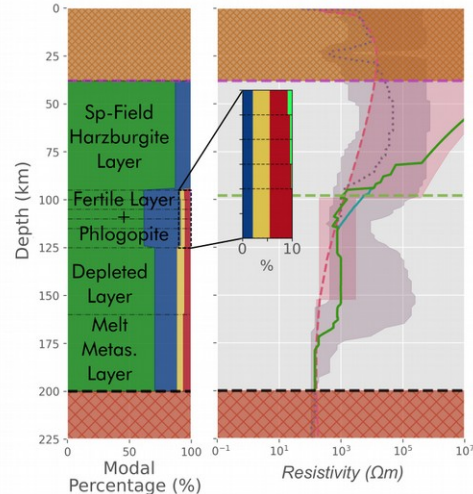


-For 37 mW/m<sup>2</sup> geotherm a 10 percent phlogopite layer around can be used.

(c) Hydrated 37 mW/m<sup>2</sup> + Phlogopite

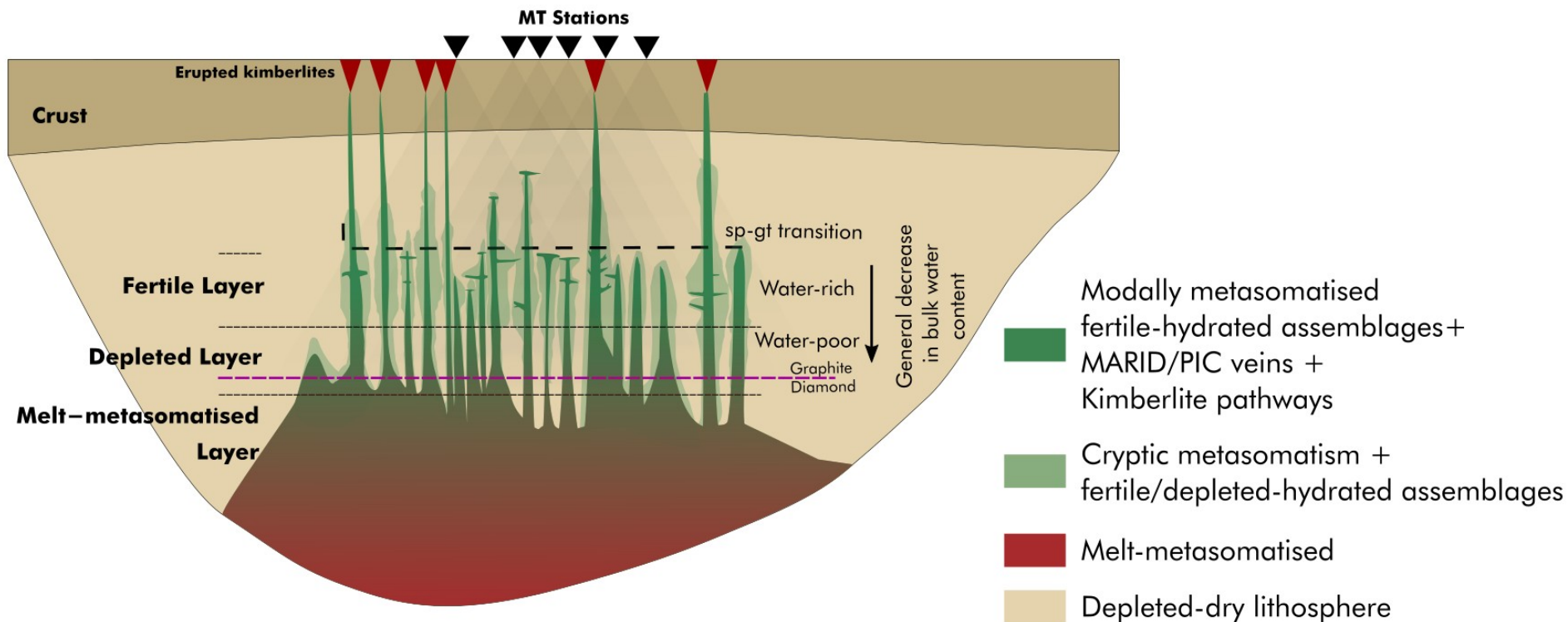


(d) Hydrated 40.2 mW/m<sup>2</sup> + Phlogopite



-For preferred 40.2 mW/m<sup>2</sup> geotherm, the effect of connected phlogopite can be negligible.

# Conceptual Sketch





**Thank you for listening.**

**MATE link to repository:**

**<https://github.com/sinanozaydin/MATE>**