CERAMAH TEKNIK TECHNICAL TALK

3D multiphysics technology for accurate geothermal resource exploration

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Date: 25 October 2023
Platform: Zoom and FB Live

1) Virtual presentation
The ZOOM and FB live talk on 25th October 2023 was presented by Dr Max A. Meju (founder and Managing Director of Geomaxo Ltd), on invitation from GSM and UKM. It was well attended with participants from Malaysia, Indonesia, USA and Africa. Assoc. Prof. Ts. P.Geol. Dr. Mohd Hariri Arifin (UKM), President of GSM, introduced the speaker and moderated the 2-hour (4-6 pm) session. The speaker began by explaining the reasons for the rapidly emerging interest in multiphysics investigation of geothermal energy resource. According to him, easy-to-find oil and gas accumulations no longer exist, and the deepening climatic emergency is driving a global transition to low-carbon energy sources, such as native hydrogen and geothermal reservoirs whose exploration pose very significant challenges. The technical challenges are made more difficult by the fact that individual geophysical methods on their own provide non-unique models of subsurface property and fluid-type present. However, integrating them together with geological models maximizes accuracy, minimizes uncertainty in a SHARED EARTH model, and leads to a consistent prognosis for the sought resource system. This is the basis of Multiphysics imaging. Multiphysics imaging technology combines different data types to improve subsurface exploration and monitoring and is emerging as the central tool for unlocking **geothermal resources**. He stressed that the methodological advancements in 3D/4D Multiphysics imaging and novel integrated investigative workflows (e.g. Meju, M.A. & Saleh, A.S., 2023. *Minerals* 2023, 13, 745. https://doi.org/10.3390/min13060745) provide a way for improved resource mapping and monitoring and, hence, a technology that could play a critical role in helping the world reach **net-zero CO_2 emissions by 2050**.

The 2-hour lecture introduced the attendees to the state-of-the art practice of multiphysics integration in geothermal energy industry and equipped them with the basic tools to drive applications in other fields of geoscience. The lecture consisted of two parts. **Part 1: Introduction to Multiphysics subsurface imaging technologies** focusing on the effective combination of seismic, electromagnetic, gravity, magnetic and geological measurements to improve accuracy, reduce interpretational uncertainty and create value (Figure 1). Part 2: **Crossgradient Multiphysics imaging for accurate geothermal (and geologic hydrogen) exploration and development**. He explained how to solve Multiphysics imaging problems using the crossgradient multiphysics data fusion technology that he co-invented (Figure 2) and practical applications in geothermal fields in Indonesia (Figure 3), Kenya, China and Brazil.

It was a highly interactive lecture, and the attendees were excited and continued to discuss with the presenter long after the official 6 pm stop and the recording was stopped at 6.30 pm. It was quite clear from the lively discussions that the attendees benefitted from the talk in terms of understanding what is meant by Multiphysics imaging or integration, the physico-chemical linkages used for resolving imaging challenges faced in subsurface investigations for geothermal resources, how/why geophysical models can be integrated to reduce uncertainty, why/how Multiphysics methods are used for geothermal reservoir exploration and production monitoring, and importantly the energy transition challenges on the road to **Net-Zero emissions by 2050**.

The video of the talk and discussions can be assessed at GSM Facebook page.
Link: https://us02web.zoom.us/j/86972943537?pwd=QXdoTEFmM0lCRk9aUlJZWGFIVWljdz09
Meeting ID: 869 7294 3537
Passcode: 907532

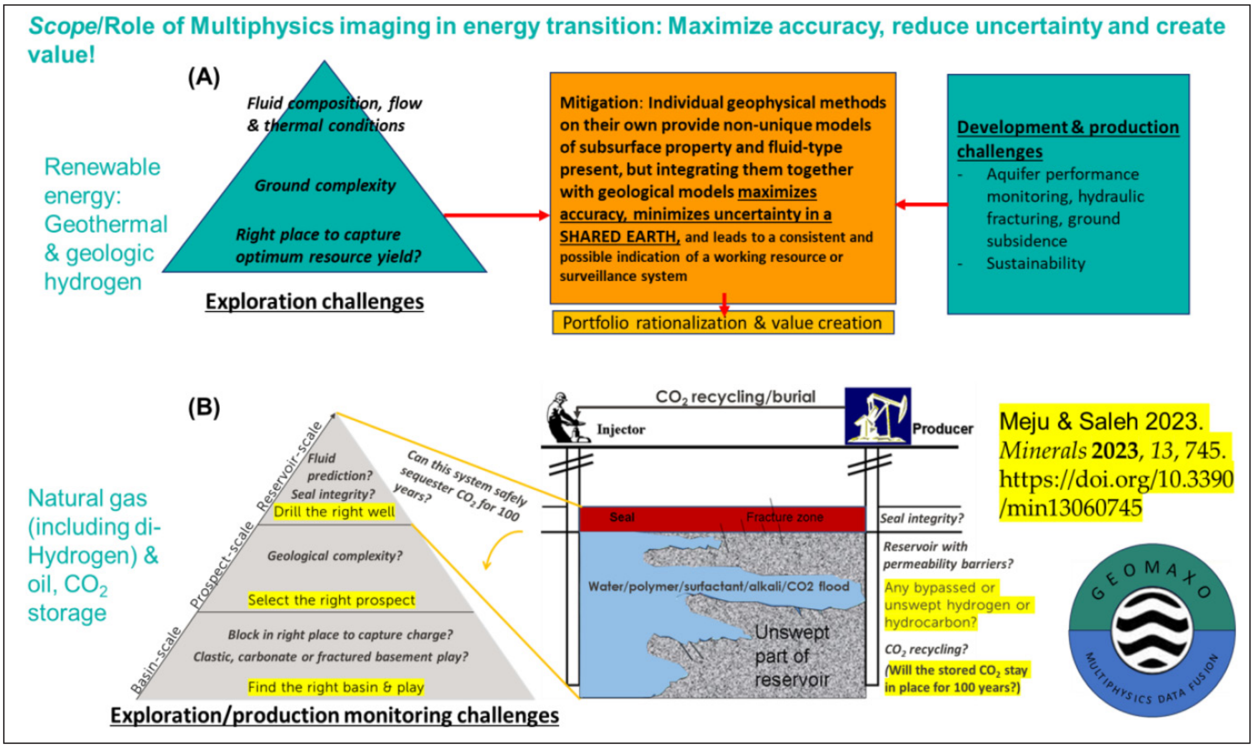

Figure 1: Scope of Multiphysics imaging in energy transition: Maximize accuracy, reduce uncertainty and create value! (A) Challenges in geothermal and geologic hydrogen exploration. (B) Challenges in natural gas (including di-Hydrogen) and oil reservoir surveillance, and CO_2 recycling and storage to reduce carbon footprint (after Meju & Saleh, 2023).

2) Crossgradient Joint Inversion technology for accurate resource evaluation

The deepening climatic emergency is driving a global transition to low-carbon energy sources, such as geologic hydrogen and geothermal reservoirs whose exploration pose very significant challenges. It is now necessary to quantitatively integrate various geophysical, geological and environmental modelling tools to increase accuracy and hence reduce uncertainty in subsurface predictions. In realistic practical operations, such a quantitative integration is best achieved using the crossgradient method invented by Gallardo & Meju (2003) and demonstrated in Figures 2 and 3.

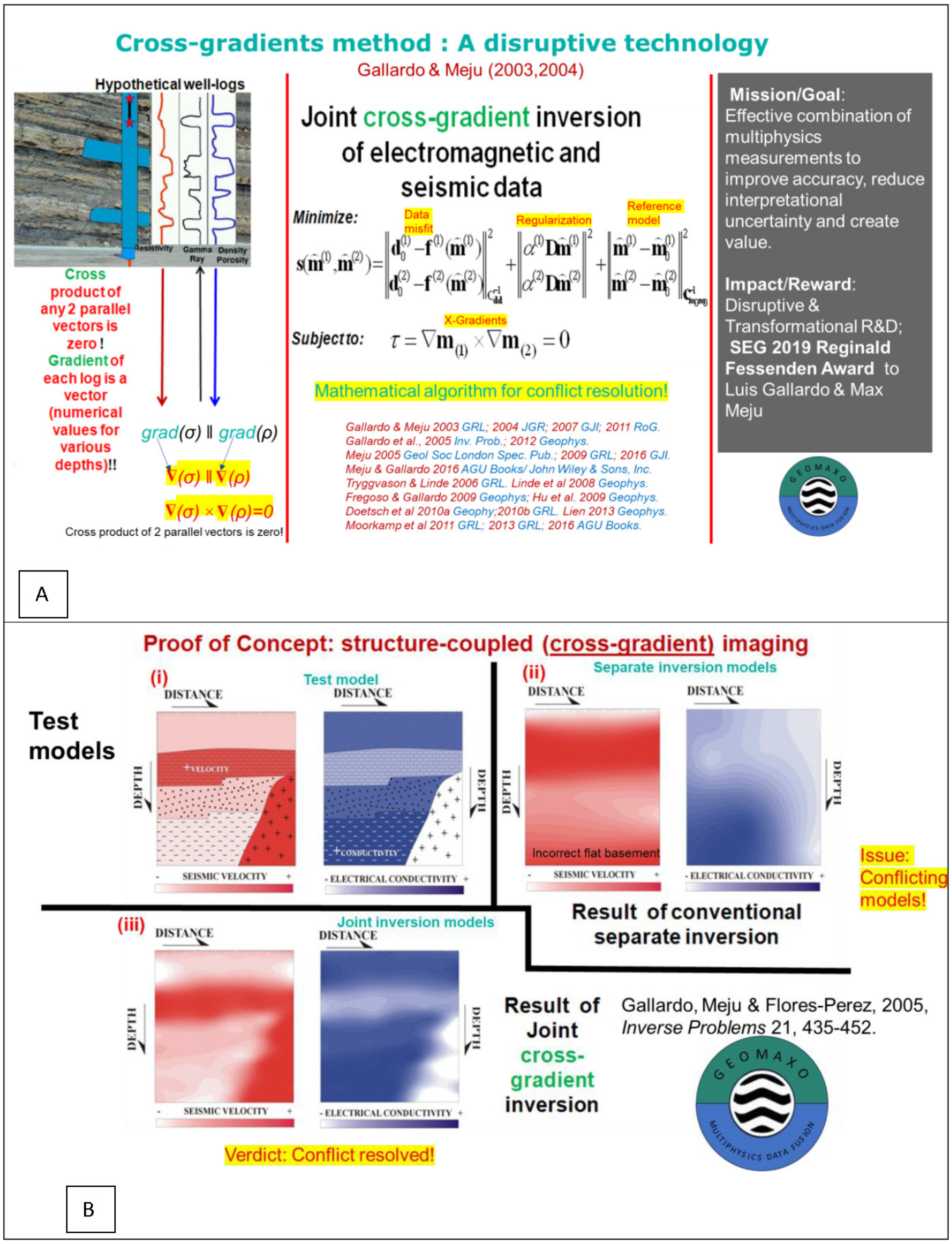

Figure 2: Crossgradient Multiphysics imaging technology to maximize accuracy and reduce uncertainty in decision-making with subsurface models. (A) Concept and mathematical algorithm. (B) Proof-of-concept using synthetic data. (i) Adopted geological test model; (ii) results of separate seismic refraction inversion and dc resistivity inversion; (iii) result of crossgradient joint inversion of seismic refraction and dc resistivity data.

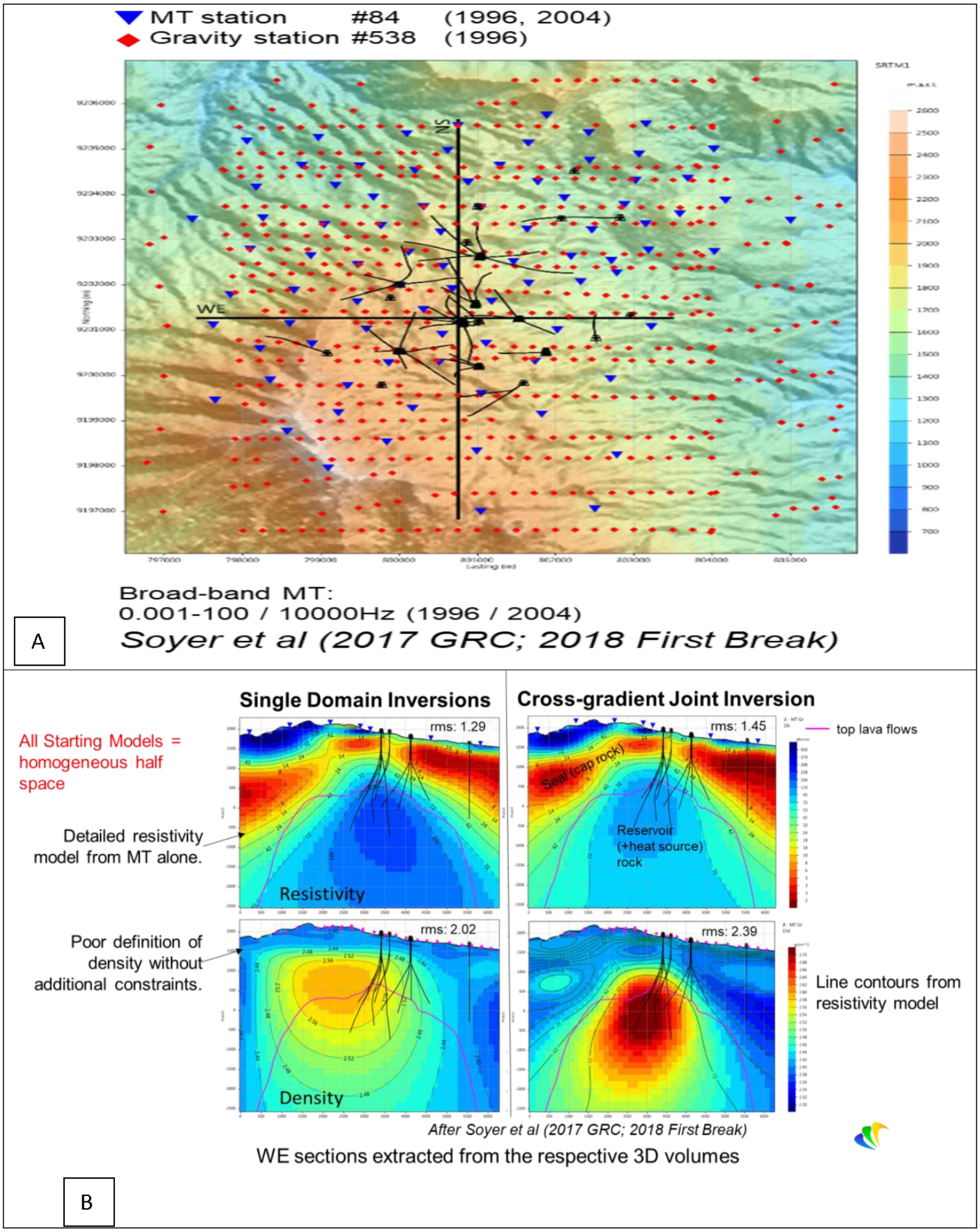

Figure 3: Application of crossgradient Multiphysics imaging technology to maximize accuracy and reduce uncertainty in subsurface models at the **Darajat geothermal field, West Java, Indonesia** (Soyer *et al*., 2018, First Break). (A) Geophysical survey layout. MT and gravity stations are shown. (B) Results from separate (single-domain) 3D inversions of MT and gravity data (left panels) compared to the result of crossgradient joint 3D inversion of MT and gravity data (right panels). The individual (single domain) MT and gravity models show different structure; there is poor definition of density without additional constraints. Crossgradient joint inversion forces them to be geologically consistent and more reliable.

Prepared by,
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28^{th} November 2023