Realizing 2D magnetotelluric inversion in the case of divergent geoelectric strike directions in the crust and mantle

Case study using synthetic models and real data from the Tajo Basin (Spain)

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Two-dimensional (2D) inversions of magnetotelluric (MT) data are presently far more commonly used than three-dimensional (3D) inversions as they still significantly outperform 3D inversions in terms of speed, thus allowing for much better resolution of the subsurface through a larger feasible number of grid cells. The suitability of 2D inversion needs thereby to be tested for cases where the electric resistivity structure of the subsurface is potentially 3D to some extent.

One particular case of a 3D subsurface structure consists of lateral interfaces with varying orientations at crustal and mantle depths. Such a case might emerge, for instance, where crustal faulting, originating from present day tectonics, is situated above a mantle where structures are dominated by earlier or current plate tectonic processes. Those plate tectonic processes could comprise continental collision from an oblique direction, or lattice preferred orientation in the lithosphere-asthenosphere transition zone due to an oblique relative motion between lithosphere and asthenosphere. Whereas recovery of crustal structures can usually be achieved in a straightforward manner by confining the modelled frequency range to the crustal depths, deriving mantle structures is more challenging. Different approaches for this case have been investigated here using synthetic model studies as well as inversion of a real MT dataset collected in southern Spain as part of the PICASSO fieldwork campaign.

The PICASSO project intends to enhance knowledge about the geological setting of the Alboran Domain beneath the western Mediterranean Sea and its surrounding regions and through that knowledge to understand processes related to continent-continent collision. The Iberian Peninsula is the focus of the first phase of DIAS's PICASSO efforts, and comprised a magnetotelluric profile crossing the Tajo Basin and Betics Cordillera.

Analyses of MT responses and seismic tomography data indicate varying geologic strike direction with depth and along the profile. Geoelectric strike direction in the Tajo Basin crust is approximately NW-SE, coinciding with the direction of the Iberian Range and Neogene faults, whereas at mantle depths a dominant NNE-SSW direction is determined; the Betics region on the contrary exhibits a highly 3D structure originating from its complex tectonic orogeny. This circumstance motivated separate inversions for crustal and mantle structures of the Tajo Basin, as well as for the Betics region. Inversion results of the Tajo Basin subsurface indicate a relatively conducting upper crust underlain by more resistive structures in the lower crust and mantle. The most noticeable features of the models are the apparent upward extension of an electrical resistive lower crustal layer beneath the centre of the basin and the presence of a resistive mantle region that coincides with an area of low seismic velocity. The later indicates an unusual geological situation since typical causes for decreased seismic velocity, e.g. higher temperature, fluids, and less depleted rock chemistry, are commonly thought to decrease electric resistivity.