Conceptual model of a lens in the upper crust determined from joint analysis of petrophysical models (Northern Tien Shan case study)

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A lens having a diameter of about 40 km and a thickness of 10 km was determined at depths 14-22 km in the junction of the Kyrgyz Range and the Chu Basin Depression Trough of the Northern Tien Shan area by 3D seismic tomography carried out earlier. The following questions are still unanswered:

- what are its petrophysical characteristics?
- what is the nature of the geophysical anomalies?
- what is the mechanism of its formation?
- how long does it exist within their present boundaries?

In order to address these key issues, it is insufficient to analyze the depth behavior of the P-waves velocities as it was done before. To this end we have built additionally the electrical resistivity, density, lithotypes, temperature, porosity, and fluid saturation models along the N-S collocated seismic and magnetotelluric profile intersecting the study area.

Their integrated analysis enabled to propose a conceptual model of a lens in the Earth's crust which answers the questions enumerated above. In particular, it was determined that the lens is characterized by low $V_p$ and $V_S$ velocities and their ratio $V_p / V_S$; low resistivity (3–30 $\Omega$.m); low density (at most 2.45 g/cm$^3$); high porosity (above 1.2%) and fluid saturation (above 0.1%); pressure range of 4–6 Kbar; temperature range from $T_{SCF} = 350$-400°C at the lens' top to $T_{BDT} = 600$–650°C at the bottom, characteristic for the emergence of supercritical fluids and for the solidus of granite, respectively; presence of a cap (a relatively dense, poorly permeable zone) that shields the forming fluid reservoir from above.

Joint analysis of these models made it possible to rule out the molten rocks as a responsible factor for high electrical conductivity and, with a high degree of confidence, assume supercritical fluid nature of the observed petrophysical anomalies. It was supposed that the lens is most likely to be a giant reservoir of supercritical fluids located at the depths between isotherms $T_{SCF}$ and $T_{BDT}$ corresponding to the PT-conditions of existence of supercritical fluids, on the one hand, and
granite solidus (brittle / ductile transition), on the other hand.

The mechanism of its formation could be explained by dehydration of amphibolites accompanied by dissolution of chlorides which, in turn, leads to the emergence of films with sufficiently high electrical conductivity typical of supercritical highly mineralized solutions. Although this formation scenario fairly well explains the observed anomalies, it does not exclude another mechanism associated with the partially melted material risen from the large depths.

The lens lifetime was determined from properties of the cap. Assuming that for the Cenozoic folding regions, the rock permeability is around $10^{-21} \text{ m}^2$ we could roughly estimate the rate of fluid migration through it. Accordingly the lens lifetime is around 33 million years which is consistent with the age of the Cenozoic activation zones.