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Relation between resistivity variations and mineralogical composition of the lithological units in the Travale geothermal area (Southern Tuscany, Italy)

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A significant reduction in resistivity has been observed in the geothermal reservoirs in Tuscany. MT data recently acquired in the Travale area have confirmed this reduction. At Travale, as well as in the Larderello area, the geothermal fluid exploited is superheated steam, which should not contribute to a resistivity reduction. Thus the strong resistivity decreases pose new questions about the important role of lithological changes and the alterations of the reservoir rocks as well as issues regarding the nature of the fluid within the geothermal reservoir. Resistivity varies with lithology, both as matrix and alteration minerals, and with fluid distribution and state. In order to investigate the role of mineralogical compositions and minerals abundance on the such resistivity anomaly, X-ray powder diffraction (XRPD) mineralogical analysis on cuttings from the main lithological units found in two wells of the Travale area were compared with resistivity logs. In particular the following units were found in the examined wells, from top to bottom: Ligurian Units (mainly shales, siliceous limestones, marly limestones and calcareous arenites); "Scisti Policromi" formation of the Tuscan Nappe (shales and siliceous limestones); "Anidriti di Burano" formation of the Tuscan Nappe (anhydrites, dolomitic limestones); Phyllitic-quartzitic complex consisting of a Phyllite Member (mainly chloritic phyllites, graphitic phyllites and metabasites) and a Carbonate-anhydrite Member (limestone with quartz, recrystallised limestones and anhydrites); Micaschist Complex (almandine-bearing albite micaschist with minor amphibolite); Contact-metamorphic rocks (including skarn and hornfels) representing the metamorphic aureole of underlying granitic bodies, Granitic intrusive bodies. In addition, the occurrence of hydrothermal alteration, affecting particularly contact metamorphic rocks and granites, produced mineralogical changes in the examined rocks. The main mineralogical phases found in the different units are: quartz, feldspars, carbonates, phyllosillicates and anhydrite. Carbonates consist of calcite and dolomite contents, whereas phyllosilicates include chlorite, biotite, kaolinite and a “muscovite-type” phyllosilicate. The resistivity logs showed values generally higher than 1000 ohm.m. On the other hand, for thin fractured levels inside reservoir formations (contact metamorphic rocks and phyllitic units) resistivity showed values as low as few ohm.m. The phases constituting the analyzed rocks turned out to be characterised by relatively high-resistivity values. Among these phases, phyllosilicates (i.e chlorite, muscovite/illite, biotite, kaolinite) are comparatively less resistive than other minerals (i.e. quartz, carbonates). In particular, XRDP intensity of phyllosilicate showed a correlation with the average resistivity of the corresponding unit. Therefore, phyllosilicate abundances, occurring as primary mineralogical phases or as a secondary alteration minerals, may explain the resistivity reduction observed in the resistivity logs and related to limited and thin layers.