Geophysical Research Abstracts,
Vol. 11, EGU2009-10353-1, 2009
EGU General Assembly 2009

The main factors controlling petrophysical alteration in hydrothermal systems of the Kuril-Kamchatka island arch

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This report is based on the results of petrophysical studies obtained on a number of hydrothermal systems in the Kuril-Kamchatka island arc (Pauzhetsky, Mutnovsky, Koshelevsky, Essovsky, a volcano of Ebeko, Oceansky). Mineral composition and pore-space structure of primary rocks change intensively during hydrothermal process, results in alteration of petrophysical properties – porosity, density, permeability, hygroscopy, sonic velocity, elastic modulus, mechanical properties, thermal and magnetic characteristics. Petrophysical alterations gradually lead to the change of the structure of hydrothermal system, and its hydrodynamic and temperature regime. The tendency of petrophysical alteration can be different. In some cases rocks “improvement” is observed i.e. consolidation, hardening, decrease of porosity and permeability, removal of hygroscopy. In other cases rocks “deterioration” occurs, i.e. formation of secondary porosity and permeability, a decrease of density, strength, and elastic modulus, and occurrence of hygroscopic moisture. The classical example of cardinal petrophysical alteration is the transformation of hard basalts to plastic clays. The opposite example is the transformation of only slightly consolidates porous tuffs to hard and dense secondary quartzite. The character of petrophysical alteration depends on a number of factors including peculiarities of primary rocks, temperature, pressure and composition of thermal fluids, duration of fluid-rock interaction, and condition of fluid (steam, water, boiling water). The contribution of each factor to change of volcanic rocks properties is considered and analyzed in details.

In particular, primary rocks controls speed, intensity and character of petrophysical alterations. Factors favorable for alteration are high porosity and permeability, micro crakes, weak cementation, glassy structure, basaltic composition. Kuril-Kamchatka region represents the volcanic island arch so host rocks in hydrothermal systems are mainly volcanic or volcaniclastic types of Neogene-Quaternary age. Volcanic rocks (lava rocks) are dense with high strength and elastic modulus and low porosity and permeability. The speed of their alteration is low. Basically volcanic rocks form impermeable horizons in the structure of hydrothermal system. But sometimes they form fracture-type reservoir. The origin of fracturing can be various. Volcanoclastic rocks are characterized by lower physical and mechanical properties, higher porosity and permeability. Due to high porosity and permeability they are greatly exposed to thermal fluids so they are altered intensively. Volcaniclastic rocks are the most common host rocks of geothermal reservoirs. Typically they form porous or fracture-porous aquifers. But in some cases they form water confining layers. The well-studied example is Pauzhetskaya hydrothermal system. The main reservoir is composed of highly porous (30-40%) and permeable medium-grained tuffs. The caprock is composed of fine-grained argillized tuffs. They are highly porous but due to small pore size porosity is un-effective for fluid and permeability is low.

The temperature and pressure in a hydrothermal system cardinally influence on rocks properties. High-temperature deep fluids (>200C) cause the perfect tendency of petrophysical alteration – consolidation, hardening, a decrease of porosity and permeability, and removal of a hygroscopic moisture. This petrophysical tendency is observed independently of composition of fluids. This is the result of the development of high-temperature secondary minerals, which fill pores and cracks, and substitute matrix and phenocrystals. The contacts between grains become strong and dense, intergranular porosity is disappeared that reinforces cementation of rock. The petrophysical alteration caused by low-temperature subsurface fluids (<150C) are more difficult and diverse. Depending on what process prevails – rocks leaching, sedimentation of secondary minerals in pores and cracks or replacement of primary minerals by secondary minerals, it can lead to both: an increase or a decrease in petrophysical properties.

Financial support from RFBR (project 05-07-00118-a)