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Hydrothermal zeolites and related authigenic minerals in the Upper Oligocene to Lower Miocene Smrekovec Volcanic Complex

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Volcanic and volcaniclastic deposits hosting hydrothermal systems commonly undergo alteration characterised by the development of zeolites, clay minerals and related silicates. Replacing primary constituents and filling veins and voids, authigenic minerals affect primary porosity and permeability of the rock, and influence the system's hydrodynamic conditions.

Upper Oligocene to Lower Miocene Smrekovec Volcanic Complex is remain of a submarine stratovolcano composed of lavas, shallow intrusive bodies, and pyroclastic and volcaniclastic rocks of andesitic affinity (Kralj, 1996). In prograde temperature regime, zonation of authigenic mineral assemblages developed. The highest-temperature zone comprises chlorite, albite, quartz, prehnite and sphene; instead of prehnite, actinolite, pumpellyite or epidote may locally occur. Lower-temperature zone is characterised by widespread development of laumontite that replaces volcanic glass and pyrogenetic plagioclases, and fills vesicles, pore-space and fissures. Yugawaralite occurs locally as a vein mineral. In the lowest-temperature alteration zone analcime, clinoptilolite, heulandite, stilbite, mordenite and smectite occur.

Retrograde reactions are related to the system cooling and are overprinted to the prograde mineral zones. The most outstanding retrograde reactions are from prehnite to laumontite and from laumontite to heulandite. The reaction from laumontite to heulandite can be direct, or indirect from through a smectite precursor. The temperature drop itself seems insufficient for the reactions to occur, but is possibly aided by the change in chemical composition of reacting fluids – like the activity of silica, calcium or potassium ions, the change in pH or influx of the CO2-gas.

Superimposed reactions involve locally changed temperature regime and/or a change in chemical composition of reacting fluids. The reaction from laumontite to analcime and from albite to analcime is accompanied by extensive development of chlorite/smectite mixed layered filosilicate (Ch/S = 50/50) and potassium feldspar as paragenetic minerals. The cause of alteration is possibly a shallow intrusion and contemporaneous incursion of saline waters in the system.

Two other types of zeolitisation reactions were recognised in the Smrekovec Volcanic complex. The first occurred in lavas undergoing desintegration into hyaloclasts. The source of heat is the cooling lava flow and the reacting fluid external - marine water. Volcanic glass is extensively replaced by, and the pore-space and vesicles filled with, smectite, clinoptilolite and heulandite. The second type occurs in some intrusive hyaloclastite breccias. Shallow subsurface magma intrusions into water-saturated sediments and volcaniclastic deposits underwent autobrecciation along the contacts. The heat released from the cooling magma heated interstitial water in the enclosing sediment. Laumontite is the most common zeolite filling fissures, micro-fissures and vesicles.

Our study has shown that rather diverse and complex authigenic mineral assemblages of zeolites, clay minerals and related silicates can develop in a hydrothermal system hosted in a submarine stratovolcano. They form in prograde, retrograde and superimposed temperature regimes and in cooling and desintegrating lava flows and shallow intrusive bodies by local heating of external water. Geochemical gradients and changing chemical conditions in reacting fluids are very important in the reactions from higher- to lower-temperature zeolites. Zeolites reduce porosity and permeability of the reservoir rock and influence the reservoir hydrodynamic conditions. In modern hydrothermal systems under exploitation (Kralj et al., 2010) such changes in mineralogy should be monitored carefully in order to avoid the decrease in the fluid yield and ensure efficient and sustainable production.

Kralj, P., 1996: Lithofacies characteristics of the Smrekovec volcaniclastics, northern Slovenia. Geologija 39, 159-191.

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