Cation exchange capacity and water content of opal in sedimentary basins: Example from the Monterey Formation, California

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ABSTRACT

Surface characteristics of sedimentary opal-A and -CT were investigated for a large collection of samples from the Monterey Formation, California, based on the bulk rock mineral and chemical analysis, cation exchange capacity (CEC), and water content. Two approaches were used: (1) modeling bulk CEC and adsorbed water content for the entire data set using the contents of opal and clay minerals measured by XRD, and (2) correcting the chemical composition and CEC of the most pure opal samples for the mineral impurities quantified by XRD.

Modeling indicates that the bulk rock data can be best explained by mixing an illite-smectite (CEC = 59 meq/100 g, 7–8% H_2O), consistent with the XRD characteristics of the clay fraction, with opal-A (8 meq/100 g, 3.4% H_2O), and opal-CT (13 meq/100 g, 3.7% H_2O).

Correcting the chemical composition of the most pure opal samples leaves a large excess of cations (Al, Fe, Na, K, Ca, and Mg). Iron is suspect to form traces of separate (oxy-)hydroxide phases, not detected by XRD, while Al for Si substitution in the opal structure produced local negative charge, which was compensated by Na, K, Ca, and Mg exchange cations. A perfect balance of positive and negative charges is observed if the clay admixture in pure opals has the composition of montmorillonite. The concentration of heterogeneous impurities in silica network in opal leads to smectite formation on or within the diatom frustules. These dispersed smectite particles, perhaps monolayers, can be missed during the bulk rock mineral quantification.

The recalculated CEC of the opal, assuming the occurrence of dispersed smectite particles, varies from 3 to 11 meq/100 g, which is slightly less than that evaluated by modeling all the rock samples in the set, and corresponds to ~10–50% of the total opal charge quantified by the degree of Al for Si substitution. The remaining charge of the opal structure represents non-exchangeable cations. As opposed to smectite, opal CEC may depend on the size of cation used for the CEC measurement.

For opals in the Monterey Formation the content of water removable at 200 °C can be modeled as a sum of a constant value and a variable value dependent on CEC; the latter component is similar to the H_2O-CEC relationship that is typical for smectite. The combined system of a constant H_2O + variable H_2O in opal can potentially be applied for mineral modeling programs in wireline log formation evaluation in diatomaceous hydrocarbon reservoirs.

Keywords: Adsorbed water, cation exchange capacity, illite-smectite, Monterey Formation, opal, smectite