

A new approach to quantification of metamorphism using Ultra-Small and Small Angle Neutron Scattering

L.M. ANOVITZ^{1,2}, G.W. LYNN², D.R. COLE²,
G. ROTHER², L.F. ALLARD², W.A. HAMILTON³,
L. PORCAR⁴ AND M.-H. KIM⁵

¹Department of Earth and Planetary Sciences, University of Tennessee, Knoxville, Tennessee 37996

²Oak Ridge National Laboratory, Oak Ridge, TN 37831

³Bragg Institute, Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW 2234 Australia

⁴NIST Center for Neutron Research, 100 Bureau Drive, Stop 8562, Gaithersburg, Maryland 20899-8562

⁵Mat. Sci. and Tech. Res. Div., Korean Inst. of Sci. and Tech. P.O. Box 131, Cheongryang, Seoul 130-650, Korea

Small- and Ultra-Small Angle Neutron Scattering (SANS and USANS) provide powerful tools for analysis of porous rocks because neutrons probe both the surface and the interior of the material providing bulk statistical information over a wide range of length scales. For monomineralic materials scattering contrast arises from the difference between the scattering length density of the rock and the pores (taken to be zero). Pore-grain interfaces are best described by self-similar fractals with non-universal dimensions ($2 < D < 3$). This leads to a non-integer power-law as a function of the scattering $I(Q) = I_1 Q^{-a} + B$ where B is the incoherent background. For a volume or mass fractal scatterer $a = D$; if only the surface is a fractal, then $a = 6 - D$. In this manner, surface fractals ($a > 3$) and mass fractals ($a < 3$) are easily distinguished. Non-fractal "fuzzy" interfaces ($a > 4$) may also be observed.

We have used SANS and USANS to characterize samples from two transects (contact out to ~1700 m) from the contact metamorphosed Hueco limestone at Marble Canyon, TX. Significant changes in a number of scattering parameters are observed as a function of distance, including regions of the aureole outside the range of classic reaction petrology. Our modeling suggests that changes in surface free energy, pore volume and hydrogen content, among other variables, can be quantified. Both the mass and surface fractals D_m and D_s can be fitted as a function of the surface fractal correlation length as:

$$\log_{10}(D/r) = -0.9648 * \log_{10}(r(\text{\AA})) + 0.30103$$

$$r^2 = 0.9999, s = 0.038$$

although metamorphism does not necessarily proceed linearly along this curve with increasing grade. Nonetheless, the ability to measure these variables shows that these techniques provide a novel approach to the analysis and study of metamorphism.

Natural analogue study on mineral formation and anion uptake at the hyperalkaline conditions

S. ANRAKU*, K. MORIMOTO, T. SATO AND T. YONEDA

Graduate School of Engineering, Hokkaido University, Japan

(*correspondence: sohtaro@gmail.com)

In Japanese transuranic (TRU) waste disposal facilities, ¹²⁹I is the most important key nuclide for the long-term safety assessment. Kd values of I⁻ ion to natural minerals are therefore important factor for the assessment. At the disposal facilities, however, degradation of the cement materials in the repositories can produce a high pH pore fluid and affect to anion sorption behavior. Therefore, an understanding for behavior of anions such as I⁻ at the hyperalkaline conditions should be necessary in the assessment.

Natural hyperalkaline spring water (pH > 11) has known to emanate from the partly serpentinized peridotite. Springs originated from Oman ophiolite is one of famous hyperalkaline springs. The spring water is characteristically hyperalkaline, reducing, low-Mg, Si and HCO₃⁻, and high-Ca, while the surface water is moderately alkaline, oxidizing, high-Mg and HCO₃⁻. Therefore, mineral formation and anion uptake at the springs are excellent analogue for interaction between cement pore fluid and natural Mg-HCO₃⁻ groundwater. In this context, mineral formation and anion uptake at the hyperalkaline springs in Oman were extensively investigated.

Water and precipitate samples were collected at the different distance from the spring vent to identify the effect of mixing ratios between spring and surface water on mineral composition. All samples including water and precipitates were analyzed iodine concentration by ICP-MS. The mineral composition of each precipitate was identified by XRD and XRF.

In all precipitates, aragonite was observed. In some samples, calcite, Mg-Al hydrotalcite-like compounds (HTlc) and brucite were also included. HTlc was observed at the springs with relatively high-Al concentration and brucite was the opposite. Calcite was observed only near the springs. At far from the springs, calcite formation was inhibited due to high-Mg fluid from surface water. During formation of the minerals at the mixing points, HCO₃⁻ in the surface water was fixed as carbonate minerals such as aragonite and calcite. H₃SiO₄⁻ in the surface water was dominantly fixed into interlayers and surface of HTlc. Iodine in the springs and surface water was mainly fixed in aragonite. This result was consistent with the results from laboratory experiments reported by Kitano and Okumura (1973) for F, Cl and Br.