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A possibility of a CM fault thermometer Part 1: Reflectances

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The chemical kinetics of thermal maturation (coalification) of carbonaceous matters (CMs) in the oil and gas windows was well investigated by Burnham and his coworkers (e.g., Braun and Burnham, 1987). Burnham and Sweeney (1989) and Sweeney and Burnham (1990) introduced an activation energy distribution model for their rate law of dehydration and degassing of CMs and presented the correlation between the reflectance of CM in oil (%Ro, in percent) and the extent of the reaction (F) calculated from the rate law. They also noted that the rate law can be applied for heating rates ranging from laboratory conditions (1C/week), igneous intrusions (1C/day), and geothermal systems (10C/100 yr) to burial diagenesis (1C/10 m.y.).

On the other hand, Huang (1996) demonstrated that %Ro increased after a few days heating experiments and estimated a power rate law with t (second) to the power of 0.078. Muirhead et al. (2012) also examined that R1 ratios of Raman spectra of CMs increased after a few tens-seconds pyrolysis and proposed a power rate law with the power depending on T (K). However, those power rate laws were obtained from the experiments with bare CM fragments extracted from rocks. The power rate laws may not be applied to CMs in rocks, since we confirmed that the R1 ratios of CMs on surfaces of heated rock samples are larger than those inside the samples (details will be shown in the following presentation, Part 2).

Chips of pelitic rocks collected from the Shimanto accretionary complex were heated in an Ar-purged capsule in an oven. Since the oven takes 18-21 minutes to achieve pre-set steady temperatures and a few minutes for cooling down after heating, the following heating durations are regarded as those of constant temperatures during heating runs. The chips were heated at temperatures, 300, 350, 450, 550, 600 and 750C for 2, 5, 13 and 34 minutes.

Reflectance measurements and Raman spectroscopic analyses were taken for CMs in the chips of which surfaces were scraped off before polishing. The reflectances in air (Ra, not in percent) of CMs of unheated and heated chips and standards (SiC, GGG, YAG, sapphire and spinel) were obtained by analyzing gradations of G color of 24 bit color microphotographs taken by a reflecting microscope.

Averages of Ra of CMs in two unheated chips are 0.093 and 0.106, while an average of measured %Ro of the former is 1.99 of which F (extent of reaction) calculated from the correlation of Sweeney and Burnham (1990) is 0.618. Ra values of CMs in chips heated below 450C show no significant difference with those in unheated ones. This is consistent with that F simulated along the T-t paths of the 300C, 350C and 450C for 34 minutes runs are 0.618, 0.618 and 0.622, respectively.

On the other hand, averages of Ra of CMs heated at 550C, 600C and 750C for 34 minutes are 0.121, 0.127 and 0.151, respectively, and their respective F values simulated are 0.742, 0.811 and 0.850. It is interesting that the averages of Ra for the runs at 750C for 2, 5 and 13 minutes are 1.47, 1.50 and 1.50, respectively. The all simulated F values for the last three runs are 0.850, the maximum extent of reaction of the rate law.

Although additional heating experiments of rocks with CMs of various initial maturities are needed, we may say from the above results that the CM fault thermometer is quite possible for high temperature faulting.

CM maturations due to heating indicated by Raman spectra will be shown in the following presentation (Part 2).

Keywords: carbonaceous matter, thermometer, fault, reflectance