

## A geochemical study on mud volcanoes along the southern margin of the Junggar Basin

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Although there are several mud volcanoes along the southern margin of the Junggar Basin, the geochemistry of mud volcanoes is not revealed in detail. In this study, we conducted a comprehensive study on the erupted mud, water and gas to understand the characteristics of mud volcanoes found in such an arid island area.

Major and trace element compositions of mud erupted from mud volcanoes are similar to those of the rocks collected from outcrop around the mud volcanoes, showing that the sedimentary rocks in the area studied here are almost uniform. Based on the chemical compositions of mud and reported values in Condie (1993), it was suggested that the source rock layer is the Mesozoic and/or Cenozoic sand stone.

Hydrogen and oxygen isotope ratios ( $\delta D$  and  $\delta^{18}O$ , respectively) of muddy water indicate that the water is originated from local meteoric water, showing the effect of intensive water-rock interaction. Europium anomaly of REE patterns of muddy water also supports that the water experienced the water-rock interaction.

Emitted gas are dominated by hydrocarbons, especially  $CH_4$ . Stable carbon isotope ratio ( $\delta^{13}C$ ) of the hydrocarbons indicates mixing of thermogenic and biogenic gas. Very high  $\delta^{13}C$  values ( $>20\%$  VPDB) were found from the emitted  $CO_2$  and dissolved carbonate in muddy water suggesting that the heavy carbon isotope ratios were originated from the bacterial activities. From the  $\delta^{13}C$  of  $CH_4$ , source rock layer can be Mesozoic sand stone.

In summary, it was revealed that the water which experienced water-rock interaction in deep underground was subject to high pressure by containing volatile components generated by the organic decomposition. As a result, muddy water erupted to surface to form mud volcanoes. The difference of the mud volcano from normal one around subduction zone will be discussed

## Quadruple sulfur isotope analysis of sulfur cycle in a stratified lake

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Quadruple sulfur isotope system ( $^{32}S/^{33}S/^{34}S/^{36}S$ ) is a potential new tracer for mass-dependent processes including biogeochemical reactions [1,2]. Sulfide oxidation by anaerobic photosynthesis is thought to have been important in ancient oceans where photic zone euxinia occurred. Some previous studies indicates that anaerobic photosynthesizers were present during important periods of earth history [3], and thus any consideration of the biogeochemical sulfur cycle or associated sulfur isotope signatures from these time periods should take them into account. Although microbial fractionations of quadruple sulfur isotopes have been studied by pure culture experiments [1, 2], actual isotope effect might be different in natural environment. We have studied quadruple sulfur isotopes of sulfate and sulfide in a small monomictic lake Fukami-ike, central Japan. The lake is eutrophic and is stratified from March to October, when green and purple sulfur bacteria (anaerobic photosynthesizer) are active at oxic-anoxic boundary layer, and sulfate reducing bacteria produces hydrogen sulfide in anoxic hypolimnion [4]. In August 2008, systematic changes of  $\delta^{34}S$  as well as  $\Delta^{33}S$  and  $\Delta^{36}S$  values were observed for sulfate and sulfide particularly just below the oxic-anoxic boundary layer, where maximum cell number of green sulfur bacteria was observed. We analyzed these isotopic profile and could estimate the fractionation factors of sulfide oxidation by anoxygenic photosynthesis (AP) and sulfate reduction (SR). The estimated fractionation factors of the SR were generally consistent with those of previous pure culture experiments [1]. The isotope effects by the AP, however, were larger than that of the previous estimate [2]. Moreover, our results suggest that symbiosis between the AP and SR shows a distinctive  $\Delta^{36}S/\Delta^{33}S$  relationship, which could be a useful new indicator for the past photic zone euxinia.

[1] Johnston *et al.* (2007) *GCA* **71**, 3929-3947. [2] Zerkle *et al.* (2009) *GCA* **73**, 291-306. [3] Brocks *et al.* (2005) *Nature* **437**, 866-870. [4] Yagi *et al.* (1986) *Jpn. J. Limnol.* **47**, 279-289.