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Geochemistry of mud volcano fluids in the Taiwan accretionary prism

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Abstract

Taiwan is located at the collision boundary between the Philippine Sea Plate and the Asian Continental Plate and is one of the most active orogenic belts in the world. Fluids sampled from 9 sub-aerial mud volcanoes distributed along two major geological structures in southwestern Taiwan, the Chishan fault and the Gutingkeng anticline, were analyzed to evaluate possible sources of water and the degree of fluid-sediment interaction at depth in an accretionary prism. Overall, the Taiwanese mud volcano fluids are characterized by high Cl contents, up to 347 mM, suggesting a marine origin from actively de-watering sedimentary pore waters along major structures on land. The fluids obtained from the Gutingkeng anticline, as well as from the Coastal Plain area, show high Cl, Na, K, Ca, Mg and NH_4, but low SO_4 and B concentrations. In contrast, the Chishan fault fluids are much less saline (1/4 seawater value), but show much heavier O isotope compositions ($\delta^{18}O = 5.1$–6.5 ‰). A simplified scenario of mixing between sedimentary pore fluids and waters affected by clay dehydration released at depth can explain several crucial observations including heavy O isotopes, radiogenic Sr contents ($^{87}Sr/^{86}Sr = 0.71136$–$0.71283$), and relatively low salinities in the Chishan fluids. Gases isolated from the mud volcanoes are predominantly CH_4 and CO_2, where the CH_4–C isotopic compositions show a thermogenic component of $\delta^{13}C = -38$ ‰. These results demonstrate that active mud volcano de-watering in Taiwan is a direct product of intense sediment accretion and plate collision in the region.

1. Introduction

Mud volcanoes are unique features in tectonically compressed areas, e.g., Taiwan, Trinidad, Indonesia, Russia, and Barbados (see Yassir, 1987; Milkov, 2000; Kopf et al., 2003; Fig. 1A). Studying the chemical characteristics of expelled fluids associated with mud volcanoes activity helps to delineate possible fluid origins and/or sediment–water interactions at depth within the accretionary prisms. Recent Ocean Drilling Program (ODP) drill holes in the Barbados ridge complex, the Peru Margin, and Nankai Trough have drawn further attention to possible impacts of the fluid expulsion fluxes on oceanic chemical budgets (Gieskes et al., 1989; Kastner et al., 1991). The first order estimated water fluxes range from 0.01 to 2 km^3/a globally based on calculations of porosity reductions or clay dehydration in worldwide convergent margins (Bray and Karig, 1985; Kastner et al., 1991). These fluids with their unique chemical compositions, are transported upward along faults, through permeable layers (Gieskes et al., 1993; Moore et al., 1988; Vrolijk et al., 1991) or through activity of mud volcanoes and, eventually, return to the ocean (Barber et al., 1986; Brown, 1990; Kopf et al.,

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