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Barite mineralization in the Deryugin Basin of the Okhotsk Sea: active processes and formation conditions

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Abstract

The paper reports on seafloor terrains mapped to a high resolution, the structure of shallow-water sediments, and the extent of barite mineralization in the Deryugin Basin, Okhotsk Sea. The data were collected by different methods of remote sounding of the bottom and a *Comanche* submersible in the area of the Barite Ridge deposit. The sedimentary cover, including Holocene sediments, is strongly deformed in this area and in some other areas of the basin. Several small mud volcanoes and new barite build-ups along the ridge axis are evidence of active fluid venting. Precipitated barite forms columns (chimneys) or grows over older layered barite build-ups. The research confirms the hypothesis of Ba supply by deep cold hydrotherms.

Keywords: barite; mud volcanoes; bacterial mats; defluidization; venting; sedimentary cover; Kashevarov rift zone; Deryugin Basin; Okhotsk Sea

Introduction

Back-arc rift basins have been extensively investigated in recent decades in many aspects, including release of lithospheric fluids at the continent–ocean transition and related formation of oil, gas, and mineral deposits (Sharapov et al., 2013). Active gas emission occurs in the Deryugin Basin in the Okhotsk Sea (Fig. 1), which thus attracts interest in terms of petroleum potential and gas hydrate formation, as well as the global budget of atmospheric greenhouse gases (Mazurenko et al., 2009; Obzhirov et al., 2004). Yet, sediments with very high contents of Mn and some trace elements in the central part of the basin have received less attention (Astakhov et al., 2000, 2007b, 2008; Bezrukov, 1960; Ostroumov, 1954). The trace-element chemistry of sediments deposited at high rates in the central Deryugin Basin, with high Ba, Zn, Ni, Pb, Cu, and Hg enrichment, resembles geochemical fields at sites of venting magmatic fluids and hydrotherms (Kalinchuk and Astakhov, 2014; Spiridonov et al., 2014). Research cruises in the 1980s, on RV *Kallisto* (1981, trip headed by B.I. Vasiliev) and RV *Pegas* (1986, trip headed by O.S. Kornev) revealed massive barite mineralization in the eastern Deryugin Basin (Astakhova, 1993; Astakhova et al., 1987, 1990), which was studied in later cruises (Derkachev et al., 2000; Dullo et al., 2004; Greinert et al., 2002; Salomatin and Yusupov, 2009). Barite precipitation has been universally attributed to originally hydrothermal Ba-rich fluids which generated at 60 ℃ at a depth of several kilometers (Derkachev and Nikolaeva, 2007). Precipitated barite forms <12 m high travertine-like tubular build-ups (chimneys) in the water, at the contact with dissolved sulfate, while percolation of the fluids into sediments produces diverse concretions, tubes, and burrow-fillings (Astakhova, 1993; Astakhova et al., 1987, 1990; Derkachev et al., 2000). The hydrothermal origin of the fluids is supported by decrepitation of gas–fluid inclusions in barite crystals from the chimneys (Obzhirov et al., 1999) and by isotope-geochemical evidence (Akhmanov et al., 2015). Some barite can precipitate at nearly bottom-water temperatures in the basin (Derkachev and Nikolaeva, 2007), presumably from cooling hydrothermal waters that percolate through sediments, while some is redeposited diagenetically.

The source of Ba in the fluids remains unclear: it may come from Ba-rich silicic diatomaceous mud (Derkachev et al., 2000; Greinert et al., 2002), volcanic-sedimentary rocks, or from magmatic reservoirs (Astakhova et al., 1987; Kulinich

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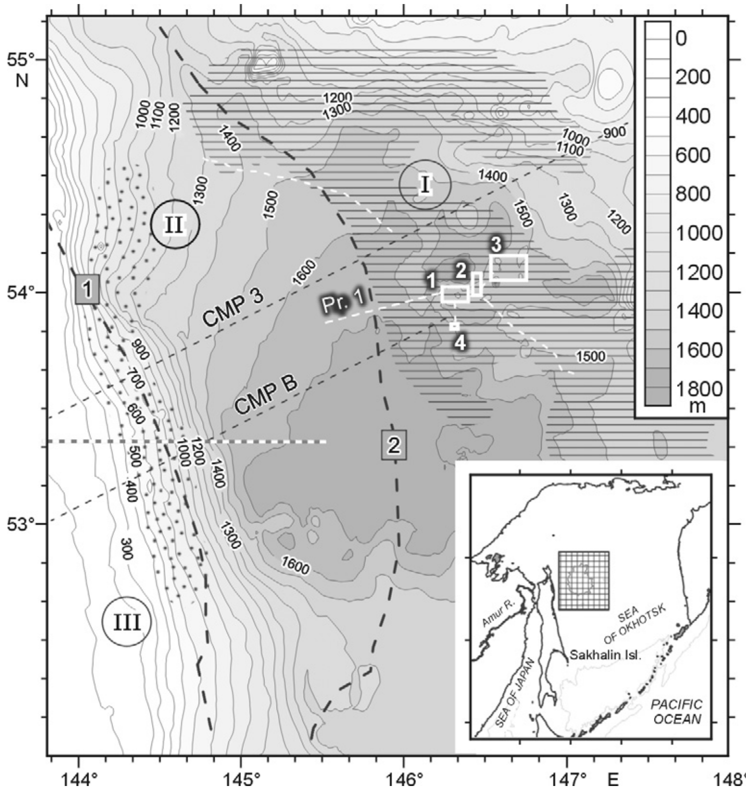

Fig. 1. Study area, bathymetry, and some structural units in the Deryugin Basin. White boxes are sites (1–4) of detailed studies (1, Barite Ridge); white dash lines are geophysical profiles; horizontal hatching marks areas of magnetic highs corresponding to the Kashevarov Trough, after (Kulinich and Obzhirov, 2003); dotted field is zone of methane seeps in the slope of Sakhalin Island; heavy dash lines are the West Deryugin (1) and East Deryugin (2) sutures between tectonic zones (Varnavsky et al., 2002): Central Okhotsk system (I); Deryugin rift zone (II), Hokkaido–Sakhalin Cenozoic fold system (III). Thin dash lines show CMP seismic reflection profiles (Lomtev and Litvinova, 2013; Volgin et al., 2009). Inset is location map of Deryugin Basin; thin line is 1500 m isobath.

and Obzhirov, 2003). Release of Ba is confirmed by Ba enrichment (130–680 ppm) of Oligocene and Late Miocene calc-alkaline volcanics in the acoustic basement found in the northern and northwestern parts of the study area (Emelyanova, 2004; Lelikov and Emelyanova, 2007).

Barite mineralization is especially abundant in the area of the so-called Barite Ridge, including Barite Mound. Video observations of the seafloor with a towed Ocean Floor Observation System (OFOS) revealed small barite build-ups grown over higher chimneys (Dullo et al., 2004), but it remains unknown whether they result from expulsion of deep fluids or redistribution of Ba accumulated previously during early diagenetic alteration of Ba-rich sediments. These problems can be solved by studying active geological processes and defluidization of sediments in the Barite Ridge area, as well as in the Deryugin Basin as a whole. Therefore, special studies in the Deryugin Basin were performed during cruise 54 by RV *Akademik M.A. Lavrentiev* in the May–June of 2011, as well as detailed geophysical surveys in the Barite Ridge along with TV-guided observations by a *Comanche* submersible (Adrianov et al., 2014), in order to study neotectonic deformation and active fluid venting.

Methods

The research included investigation of the seafloor, water, and uppermost sediments with geophysical (echo-sounding, acoustic, and geopulse acoustic) methods and *Comanche* submersible video observations.

A ship-mounted ELAC LAZ-72 E-V echo sounder was used for measurements of *water depths* to the seafloor and *bathymetric mapping*. Normalized and filtered echo data were converted by an ELAC STG-721 digitizer. The sound velocity was assumed to be 1500 m/s. The signals were positioned with two satellite 12-channel GARMIN GPSMap 420s and GARMIN GPS-128 sounders supported by a wide area augmentation system (WAAS). The terrain features in the area (Fig. 1) are named herebelow as in the reports on the KOMEX (Kurile–Okhotsk Sea Marine EXperiment) Project (Dullo et al., 2004).