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GEOCHEMISTRY

First Data on Microelemental Composition of Benthic Organisms from the 9°50′ N Hydrothermal Field, East Pacific Rise

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Hydrothermal vents on the ocean bottom are surrounded by geochemical barriers related to extreme gradients of water temperature and concentrations of reduced compounds and heavy metals [1]. Such conditions promote the formation of unique bottom communities characterized by symbiothrophy, i.e., utilization of nutrients produced by bacterial symbionts in the process of chemosynthesis [2, 3]. It is evident that hydrothermal communities with a biomass of ~10 kg/m^2, which is anomalous for the pelagic zone, can participate in biodifferentiation, i.e., change the fate of the chemical elements delivered from hydrothermal vents. However, the available publications [4–8], in which only some tissues of particular organisms rather than the bottom community as a whole have been investigated, are insufficient to estimate the geochemical implications of the benthos.

This study is focused on the behavior of some microelements involved in bioaccumulation by the bottom community in the 9° N hydrothermal field, East Pacific Rise (EPR). The study area is interesting for several reasons. First, it is situated in the axial rift zone of the fast-spreading ridge, which stands out by the highest rate of the formation of oceanic basaltic crust (10 cm/yr). Second, lava flows covered all bottom communities in this area after a volcanic eruption in the spring of 1991 [9], resulting in evolutionary changes of the geochemical medium and recovery of the biotope [10].

More than 50 samples of organic tissues pertaining to the predominant groups of the bottom community and 7 samples of fluid from the 9°50′ N hydrothermal field were collected by *Mir-1* and *Mir-2* manned submersibles during Cruise 49 of the of R/V *Akademik Mstislav Keldysh.* Contents of Fe, Mn, Zn, Cu, Co, Ni, Cr, Pb, Cd, Ag, As, Se, Sb, and Hg were determined with INAA and AAS on KVANT-2A and KVANT-Z.ETA devices at the Shirshov Institute of Oceanology.

Two types of hydrothermal vents are recognized in the 9°50′ N hydrothermal field: low-temperature diffuse seeps and high-temperature vents with sulfide mounds and black smokers [11]. The Fe, Mn, Zn, Cu, and Ni concentrations in hot fluid from a black smoker (Station 4668) are 50–500 times higher than in the cool seep (moire) at Station 4631. The difference in concentrations of Cr, Sb, As, Pb, and Ag is not so significant, and the Co and Cd concentrations are equal at both stations (Fig. 1). Thus, the behavior of metals in fluids of different types is dissimilar. It is worth noting that the measured Fe, Mn, Zn, Cu, and Ag concentrations in the least diluted fluid from the black smoker (Station 4668) are comparable to the end-member concentrations (i.e., concentrations at the initial stage of mixing when the dilution of fluid with oceanic water is absent) in fluid from the 21° N EPR field [12]. Hence, the metal concentrations in fluid from the 9°50′ N hydrothermal field

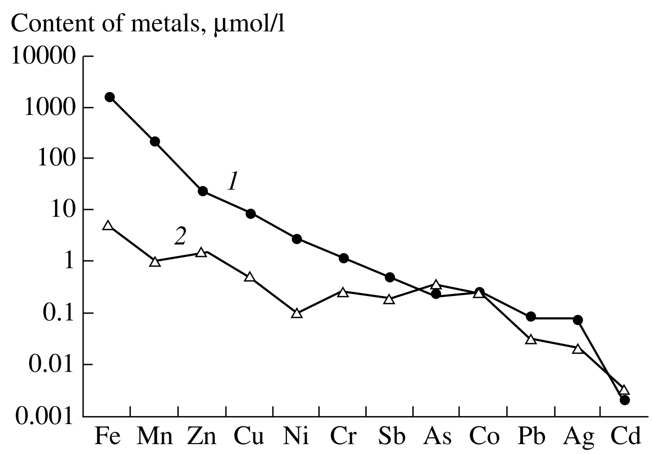

Fig. 1. Content of metals, μmol/l in two types of fluids from vents of the 9°50′ N EPR hydrothermal field. (*1*) High-temperature least diluted fluid from a black smoker (Station 4668); (*2*) low-temperature most diluted fluid from a moire (Station 4631).

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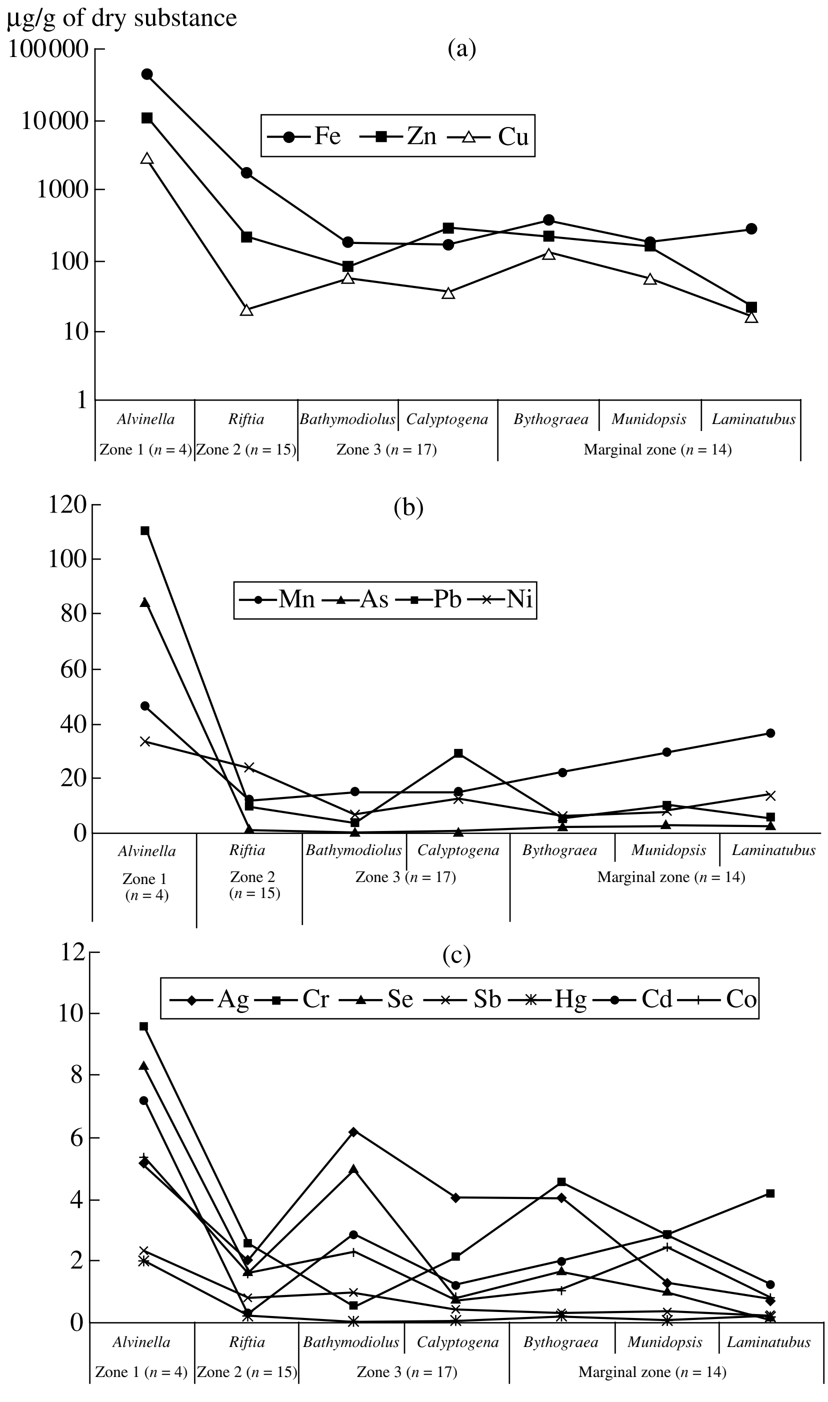

Fig. 2. Distribution of microelements (average values, μg/g of dry substance) in organisms of the bottom community in the 9°50′ N EPR hydrothermal field in zone 1 of anomalously high temperatures related to the influence of fluids, lower temperature zones 2 and 3 weakly affected by fluids, and marginal zone of background temperature. (a) Fe, Zn, and Cu; (b) Mn, As, Pb, and Ni; (c) Ag, Cr, Se, Sb, Hg, Cd, and Co.

are suggested to be higher than in fluid from the 21° N field; in both fields, the fluids mixed with seawater are enriched by a factor of 10^3–10^5 relative to the bottom water.

As is known, marine organisms accumulate chemical elements from water and food. The external organs and tissues have contact with dissolved metal species, whereas visceral cells accumulate metals from food. The hydrothermal biota has the following property: in addition to contact with metal-rich water, bacterial symbionts are located in external organs, such as the gills of bivalve mollusks, while the tubes of polychaetas and vestimentiferas have a thick bacterial coating. Furthermore, the gills and tubes contain organic compounds (largely chitin and collagen), which form stable organometallic complexes. According to our data, the peak concentrations of most metals are detected precisely in tubes of *Alvinella* polychaetas (μg/g of dry substance): 161000 Fe, 37305 Zn, 10808 Cu, 347 Pb, 118.7 Mn, 68 Ni, 30.5 Cr, 22.91 Cd, 17.9 Se, 12.13 Ag, 9.5 As, 6.43 Co, 5.8 Hg, and 0.77 Sb. This decreasing concentration series of metals in a tube of polychaeta *Alvinella* does not fit the concentration series in fluid (Fig. 1). Hence, bioaccumulation of heavy metals in hydrothermal fields has a selective nature.

The metal contents in carbonate shells of mollusks are commonly 1–3 orders of magnitude lower than the peak concentrations.

According to our data, the microelement contents in taxons from the 9°50′ N EPR region are much higher than in similar organisms from the fields of the Mid-Atlantic Ridge [8, 13]. This fact is consistent with higher contents of microelements in fluids from the EPR rift zones in comparison with the MAR.

The bottom community in the 9°50′ N EPR region is represented by dominant faunal groups that inhabit three high-temperature zones, which are affected by fluids, and in the marginal zone of background conditions [14]. The first zone is characterized by the most thermophilic fauna of episymbiont-bearing polychaetas and alvinellides (*Alvinella pompejana* and *Alvinella caudate*) that inhabit the walls of black smokers at an anomalous temperature of 40–25°C and high contents of metals. The second zone is characterized by vestimentiferas *Riftia pachyptila* that inhabit cool (25–6°C) seeps (moires). The third zone is marked by bivalve mollusks *Bathymodiolus thermophilis* and *Calyptogena magnifica* that commonly reside on basalts in a zone insignificantly affected by fluid (6–2°C), where moire is not observed. The carnivorous crabs *Munidopsis* and *Bythograea*, as well as polychaetas *Laminatubus* (Serpulidae) (specialized sestonophaguses), dominate in the marginal zone. In the throphic structure, organisms of the first three zones are the primary consuments (symbiothrophs), whereas the marginal taxons are the secondary consuments (carnivores and necrophaguses).

The highest concentrations of all studied metals are noted in polychaetas and alvinellides from the first zone affected by fluids to the greatest extent (Fig. 2). The elevated contents of metals are also characteristic of the vestimentiferas and mollusks residing in the second zone. On moving away from the hydrothermal vent, the average heavy metal contents in soft tissues decreases with various rates for specific groups of elements. Fe, Zn, and Cu, distinguished by much higher average contents ($n \cdot 10$–$n \cdot 10^4$ μg/g of dry substance) than other elements, are characterized by the most significant regular depletion from the first zone to the margin (Fig. 2a). Mn, As, Pb, and Ni, which have a lower range of contents in biota (2–120 μg/g of dry substance), reveal a depletion only at the transition from the first to the second zone (Fig. 2b). Concentrations of Ag, Cr, Se, Sb, Hg, and Cd (in general, <10 μg/g of dry substance) are slightly higher only in biota of the first zone (Fig. 2c). Some increase in contents of most metals in carnivorous crabs Bythograea dwelling in the marginal zone may be explained by their active quest for food in the hydrothermal field.

Thus, the bottom community in the 9°50′ N EPR hydrothermal field after the recovery of the biotope is characterized by a high ability to selective accumulation of Fe, Zn, Cu, Mn, As, Pb, Ni, Ag, Cr, Se, Sb, Hg, Cd, and Co. The elevated contents of the above microelements is detected in the tissues of primary consumers that inhabit the zone affected by fluids and precisely in the organs occupied by bacteria, e.g., in tubes of alvinellides and gills of bivalves. In organs and tissues of carnivorous taxons, i.e., the secondary consumers that live at a distance from the vent, the concentrations of microelements appreciably diminish.

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