Lithology and Mineral Resources, Vol. 33, No. 4, 1998, pp. 391–394. Translated from Litologiya i Poleznye Iskopaemye, No. 4, 1998, pp. 436–439.

SHORT COMMUNICATIONS

The Tectonic Position of Hydrothermal Fields on the Mid-Atlantic Ridge

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Received February 11, 1998

Abstract—The position of hydrothermal fields on the Mid-Atlantic Ridge has been compared to the satellite altimetry data and the position of earthquake epicenters (1937–1997). It has been established that the hydrothermal fields gravitate to the relatively stable (aseismic) parts of rift zones, which are most favorable for the stable circulation of solutions under the conditions of spreading at low velocities. Such regions are situated in the discontinuity areas. It is presumed that the solutions migrated not across the rift, as it has been believed, but in the directions with the best conditions of permeability, i.e., along the rift strike, in accordance with the orientation of cracks. In this case, the discharge areas must lie within the boundaries of most stable sites where the conditions for long-term (up to tens of thousands of years) stable circulation of hydrothermal solutions exist. The discontinuities seem to represent the regions with an increased amount of breccias or, in other words, with the increased open porosity and permeability. Thus, in the scheme proposed, the major circulation of oceanic water and its transformation into ore-forming fluids proceeds along the strike of rift zones.

The work at compiling a digital tectonic map of the Central Atlantic is carried out in the Laboratory of geomorphology and tectonics of the oceanic floor, Institute of Geology, RAS. This work is accompanied by creating the database and analyzing widely diverse materials. In the course of these investigations, the authors have accumulated observations that might be of interest to the specialists in the field of oceanic hydrothermal systems.

High-temperature hydrothermal sources were discovered in the late 1970s. At present, more than 100 hydrothermal active and relic fields of the World Ocean have been studied to a variable extent of detail (Rona and Scott, 1993).

Regional investigations (Rona, 1986; Rona and Scott, 1993; etc.) have shown that the majority of hydrothermal ore occurrences are situated within the boundaries of neovolcanic rift zones on the Mid-Atlantic Ridge (TAG, Snake Pit, and Broken Spur) and gravitate to the volcanic arches of these zones. It has been noticed that active hydrothermal sources are most frequently confined to the tectonic disturbance zones. The situation is known when the active hydrothermal field (e.g., Logachev field) is located on the surface of marginal bench of the rift valley, this bench being composed of serpentinized ultrbasic rocks (Bogdanov *et al.*, 1995). This situation does not fit well into the existing scheme of hydrothermal system circulation on spreading ridges.

When the map of magmatism of the Central Atlantic was compiled, the idea arose to reflect on it the position of hydrothermal fields as well. Upon their plotting on the map of gravitational anomalies compiled from satellite data (Sandwell and Smith, 1997), we compared the picture obtained with the position of earthquake epicenters (1937–1997). Information on the earthquakes was obtained via the Internet from the catalog of the National Earthquake Information Center (USA). This comparison has revealed the following.

The Logachev Field, recently discovered in the 14°15′N region (Bogdanov, 1995), is situated in the segment of the Mid-Atlantic Ridge between the Cape Verde and Marathon fractures. Analysis of the altimetric map (Fig. 1), combined with the earthquake epicenters, has showed that the aseismic region is located precisely in this area. The zone of extensive gravitational anomalies registered as a trench in relief is also located in this area. The anomalies are traced to many hundreds of km east and west of the ridge axis. Note that the three among five well-known deep-focus earthquakes in the axial part of the Atlantic Ocean with the epicenter depths of 60, 60, and 51 km and magnitudes 6, 7.3, and 4.7, respectively, are connected with the same lineament.

The TAG, Snake Pit, and Broken Spur hydrothermal fields (Fig. 2) are also situated either in aseismic zones or near them. The extensive bottom depressions (fractures) are also located near them. Deep-focus earthquakes have not been established in the Kane Fracture Zone. Within the TAG field, hydrothermal edifices were formed either on the surface of intensely crushed basement or within the talus composed of volcanite fragments (Lisitsyn *et al.*, 1990). The well-known hydrothermal plumes (Lukashin *et al.*, 1997) fall into the aseismic zone as well.

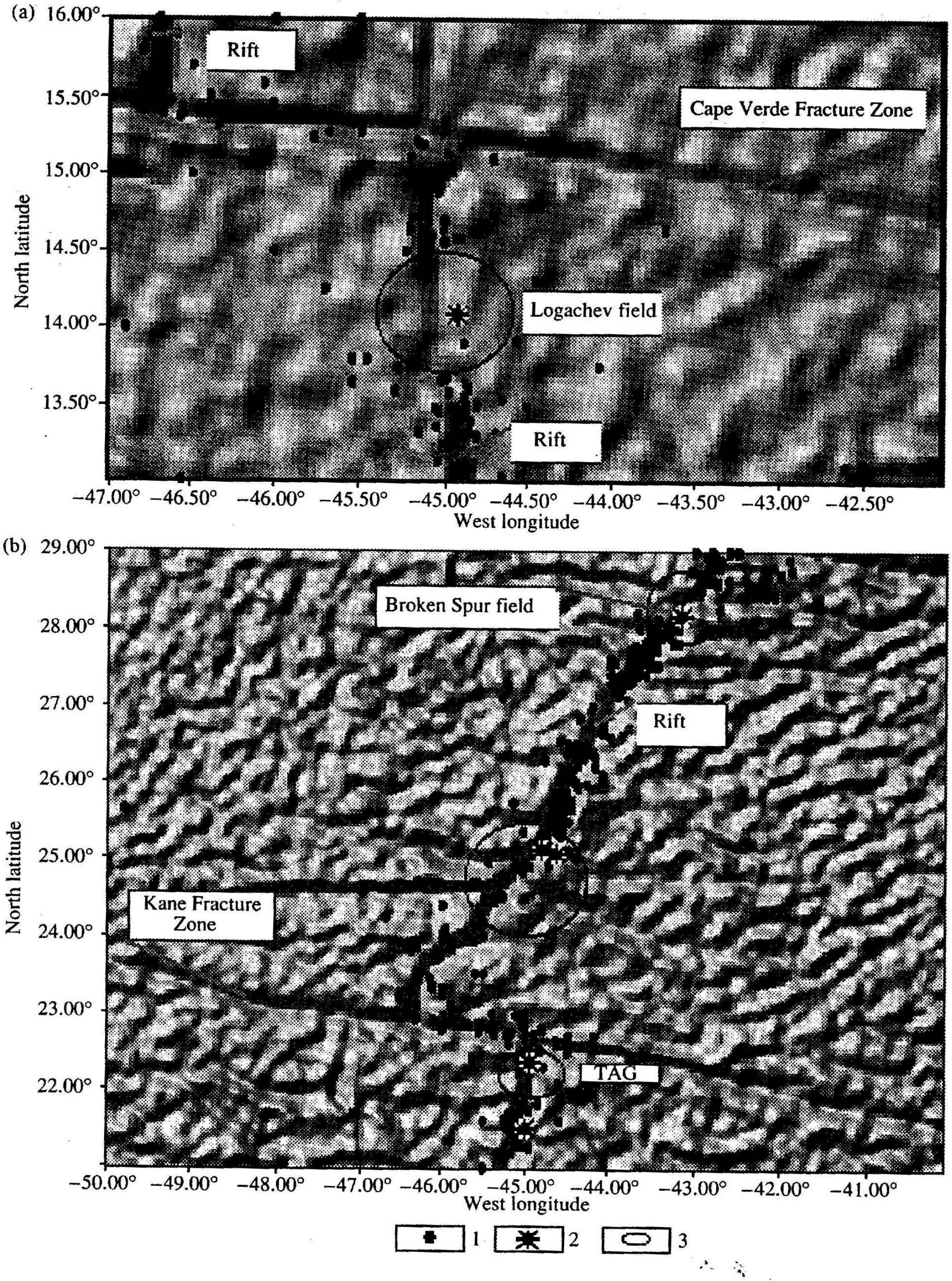

Fig. 1. Position of hydrothermal fields and earthquake epicenters in the areas of (a) Cape Verde and (b) Kane fractures. (1) Earthquake epicenters, (2) hydrothermal fields, (3) aseismic areas.

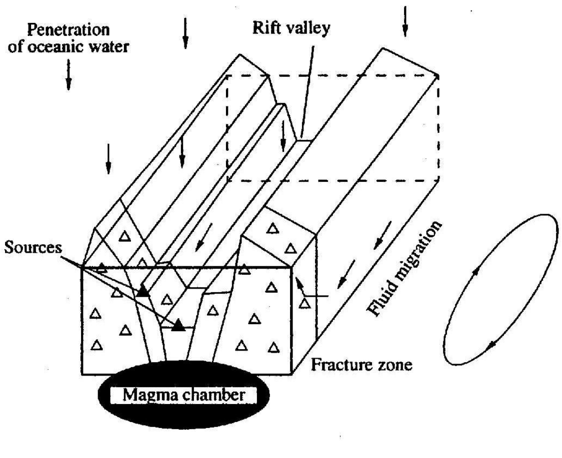

Fig. 2. Idealized scheme of migration of ore-bearing fluids (parallel to the rift valley strike) and discharge in the fracture zones.

The results obtained indicate that hydrothermal fields gravitate to the relatively stable parts of rift zones, which are obviously most favorable for the stable circulation of hydrotherms under the conditions of spreading at low velocities. Such regions are situated in the discontinuity areas.

The general scheme of formation of hydrothermal solutions is well known and reduced to the following. Within the boundaries of rifts, oceanic water penetrates into the crust via the system of open cracks (gjars) and is heated to near-critical temperatures (over 400°C) due to its interaction with rocks of the oceanic crust and magma chambers. Thereafter, ore-forming hydrothermal solutions enriched in various elements penetrate to the surface and are discharged as "black smokers" and other polymetallic ore occurrences (Lisitsyn *et al.*, 1990; Rona, 1986; Karson and Rona, 1990; etc.). The tectonic position of hydrothermal fields, established by the authors, can refine the existing models.

Open cracks within the rift zone are oriented subparallel to its strike. It would be reasonable to suggest

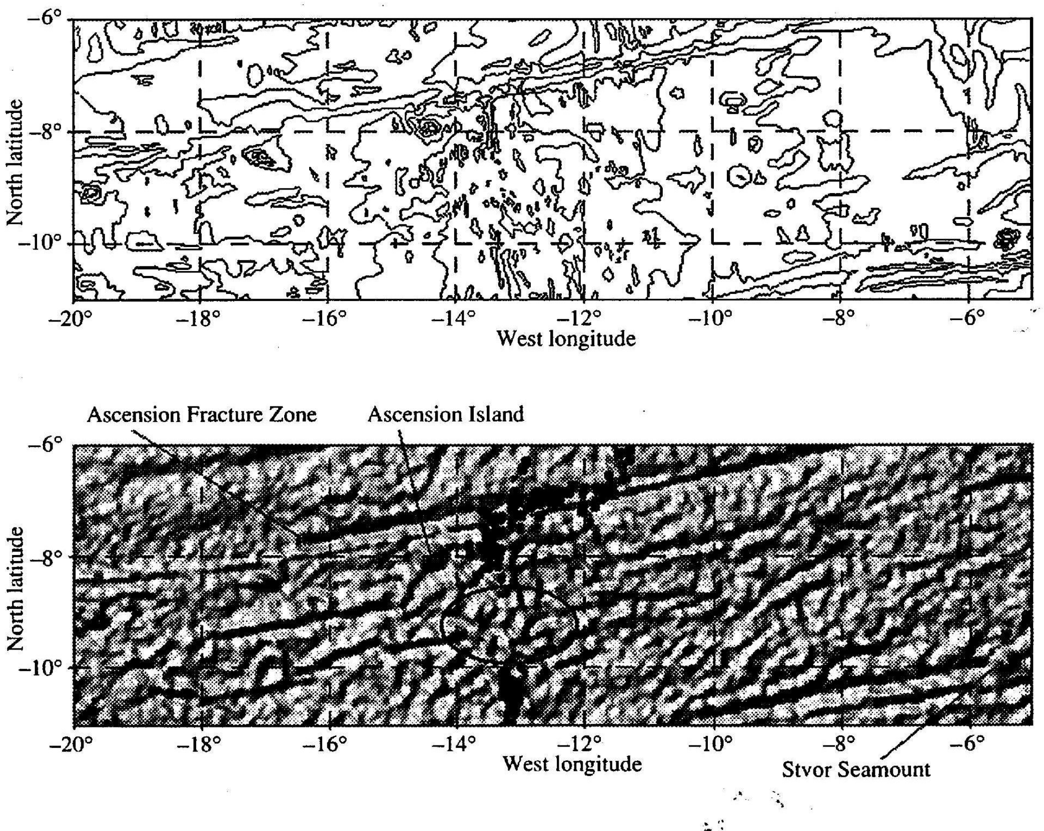

Fig. 3. Fragment of the bathymetric GEBKO map and the map of gravitational anomalies based on the data of satellite altimetry (Sandwell and Smith, 1997) for the Mid-Atlantic Ridge 11°–6°S and 20°–5°W. Notation is the same as in Fig. 1.

that the solutions will migrate not across the rift, as is commonly believed, but in the directions with the best conditions of permeability, i.e., along the rift strike (similar to the fractured reservoirs in oil traps). It is possible that this motion is directed toward the most uplifted parts of the rift valley. In this case, the hydrothermal discharge zones must be situated in the most stable areas, where the favorable conditions for the long-term (up to tens of thousands of years) stable circulation of hydrothermal solutions exist. Such ascending "jets" are situated precisely within the regions with zero or reduced seismicity revealed by the authors. The discontinuities seem to represent the regions with an increased amount of breccias, in other words, with the increased open porosity and permeability.

CONCLUSION

The major circulation of oceanic water and its transformation into ore-forming solutions proceeds along the strike of rift zones with the subsequent discharge in relatively stable areas.

Analysis of the arrangement of earthquake epicenters on the Mid-Atlantic Ridge between 30°N and 15°S shows that there are a number of regions within the specified boundaries (south of the Ascension Fracture Zone and others) with reduced seismicity or altogether without it (Fig. 3), which coincide with the discontinuity areas. We assume these are the most promising areas for the discovery of hydrothermal fields.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research, project no. 97-05-65359.

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