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Physicochemical Formation Conditions of Seafloor Hematite–Quartz Edifices of the East Magnitogorsk Paleoisland Arc, South Urals*

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There are a lot of ferriferous–siliceous sediments in the Paleozoic island-arc complexes of the South Urals. They are combined with massive sulfide and gold-bearing deposits. Similar rocks are known in ore fields of the South Urals, Central Asian, Caucasus, and Pyrenees fold belts [6, 9]. Hematite–quartz rocks are the variety of ferriferous–siliceous sediments. There are two main groups of hematite–quartz bodies: (1) halmyrolitical beds associated with hyaloclasts [1] and (2) mounds occurring in the roof of volcanogenic strata and siliceous sediments [7]. According to geological and geochemical data, it is suggested that they have a hydrothermal genesis. The object of study is a determination of forming conditions for edifices at the southern flank of the East Magnitogorsk paleoisland arc based on fluid inclusion study. Such researches were made for the first time for hematite–quartz rocks of ore areas.

East Magnitogorsk paleoisland arc formed in the Devonian at the periphery of the Urals Ocean [13]. Volcanic complexes (rhyolite–basalts, andesibasalts) formed in submarine conditions in inter- and back-arc rifts. Gold-bearing fields including the multilevel Lis'y Gory ("Fox Mountains") paleohydrothermal field with hematite–quartz rocks, Mn mineralization, and Au-bearing silicified zones occur within andesibasalts of the Middle Devonian Gumbei Complex (Fig. 1).

Hematite–quartz rocks occur at two levels of siliceous–aleurolite sediments overlapping volcanogenic rocks and sericite–quartz altered rocks. They form lenticular and hill-shaped bodies with length of 40–200 m and thickness of 3–15 m (Fig. 2). At the foot of the largest hematite–quartz body (thickness 5–10 m, length about 270 m), there are incurrent zones occurring across the bedding of host aleurolites. They are about 3–5 m thick. These zones are interpreted as incurrent channels of the hydrothermal hematite–quartz edifice [7].

Rocks have homogeneous, spotted, and banded structures and globular, cocarde, and colloform textures with different hematite/quartz proportions. Their chemical composition is as follows (%): SiO_2 87–94, Al_2O_3 0.1–0.3, FeO_{tot} 4.3–11.1, MnO 0.1–0.4, and CaO 0.1–2.3. In the Al_2O_3/SiO_2 versus (Fe + Mn)/Ti diagram, their composition corresponds to hydrothermal siliceous–ferriferous rocks [8].

Quartz aggregates and veinlets, which compose from 5 up to 30% of rocks, are the important components of these rocks. Veins are curved "ptygmatite," branchy, mesh, and zonal hematite-containing bodies

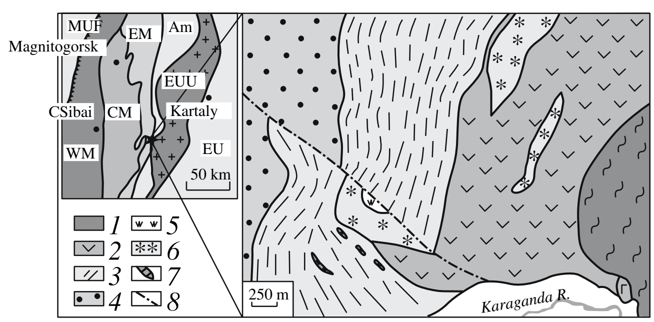

Fig. 1. Schematic geological map of the Lis'y Gory field (after V.V. Zaykov, E.V. Zaykova). (*1, 2*) Gumbei volcanic complex, Middle Devonian: (*1*) lower Gumbei stratum (basalts, quartzites, silicites), (*2*) upper Gumbei stratum (pyroxene and plagioclase–pyroxene andesibasalts); (*3, 4*) Novoburannaya suite: (*3*) lower Novoburannaya stratum (aleurolites, silicites, jaspers), (*4*) upper Novoburannaya stratum (sandstones, aleurolites); (*5*) sericitized quartzites; (*6*) limonitized and silicified rocks with iron ore lenses; (*7*) hematite–quartz bodies; (*8*) fault. (EU) East Ural Zone, (EUU) East Ural uplift, (Am) Amur Zone, (EM) East Magnitogorsk Zone, (CM) Central Magnitogorsk Zone, (WM) West Magnitogorsk Zone, (MUF) Main Ural Fault.

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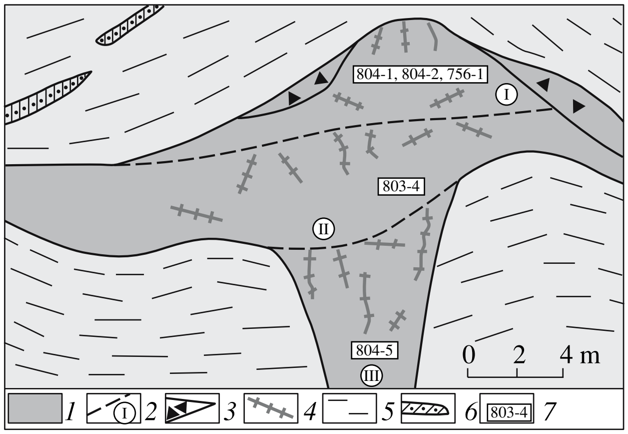

Fig. 2. Structure scheme of hematite–quartz edifice from the Lis'y Gory field (after detail mapping): (*1*) Hematite–quartz rocks; (*2*) suggested boundaries of edifice levels: (I) roof; (II) foot; (III) incurrent channel; (*3*) gravelstone with clasts of hematite–quartz with quartz veins; (*4*) quartz veins; (*5*) alternation of silicites and aleurolites; (*6*) siliceous–manganese interlayers; (*6*) samples.

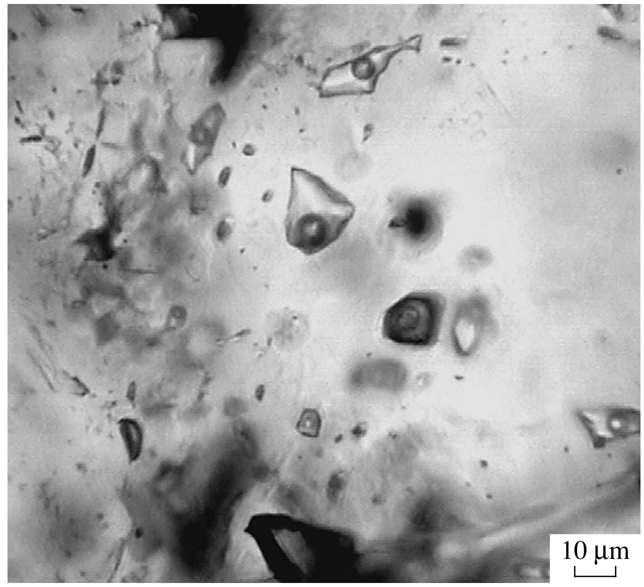

Fig. 3. Primary fluid inclusions in quartz veinlets from hematite–quartz rocks, Lis'y Gory field, the incurrent channel. Axiolab microscope (Carl Zeiss), Institute of Geology and Geochemistry, Ural Division, Russian Academy of Sciences (Yekaterinburg). Sample 804-5. Transmitted light.

with thickness up to 30 mm. Hematite and quartz form rhythmic zones parallel to contacts and isolations in axial parts of veins. Such vein morphology testifies to the formation of veins within the low-lithified matrix. In incurrent channels, hematite–quartz rocks are often transformed into quartzites with grained microtextures characterized by primary texture relicts with dustlike hematite. Thus, we suggest two main formation stages for hematite–quartz edifices. The first stage corresponds to accumulation of ferriferous–siliceous sediments; the second one, to the formation of quartz veinlets and quartzites. Host jaspers and aleurolites have not been silicified, but they are metamorphized in prehnite–pumpellyite facies. In the overlapping sediments, there are gravelstone interlayers with quartz veins and hematite–quartz clasts, which testifies about seafloor formation of hematite–quartz edifices and their submarine erosion during the accumulation of overlapping sediments.

For the determination of formation conditions, fluid inclusions in five quartz samples from the roof, foot, and incurrent channel have been studied. Fluid inclusions have been studied with cryometry and thermometry methods using LINKAM THMSG-600 in laboratories of Imperial College (London, UK) and the Institute of Geology and Geochemistry, Ural Division, Russian Academy of Sciences (Yekaterinburg, Russia). About 50–60 measurements have been done with every sample.

Fluid inclusions have been found in transparent coarse-grained quartz aggregates. They have dimensions from 5–7 up to 20–30 μm, round shape, sometimes with crystal elements. Fluid inclusions have two phases—light liquid and vapor bubble. Vapor bubbles are often large (up to 20% of inclusion) (Fig. 3). Fluid inclusions freeze at –43 to –55°C. Fluid inclusions in coarse-grained quartz from a branchy veinlet have been found at the roof of the edifice. At its foot, quartz from the veinlet (thickness 1–2 cm) in lilac breccia-type jasperites has been studied. Fluid inclusions in quartz from zonal hematite-containing veins have been measured in the incurrent channel.

Microthermometry results are presented in the table. According to obtained first melting temperatures (from –20.6 to –21.3°C), NaCl prevails in solution composition [3]. At the foot and in the incurrent channel of hematite–quartz rocks, salinity of solutions is constant (2.9–3.5 wt %). At the roof of the edifice, the salinity interval is wider (1.5–6.5 wt %). Maximal temperature of homogenization is in the incurrent channel (290°C). The temperature decreases to 180°C toward the roof (Fig. 4).

We compare obtained results with fluid inclusion data from gold–quartz (Berezovsk, Kochkar), massive sulfide (Yaman-Kasy, Aleksandrinka, Balta Tau) deposits, and modern sulfide edifices. The Berezovsk and Kochkar gold-bearing deposits have solutions with high salinity (17.0–8.4 and 15.7–6.3 wt % for the Berezovsk and Kochkar deposits, respectively) and more complex chloride–magnesium composition [2, 10]. Hydrothermal solutions of the Yaman-Kasy, Aleksandrinka, and Balta Tau massive sulfide deposits have the NaCl composition of solutions and seawater-type salinity (1.5–5 wt %) [5, 11, 12]. Modern hydrothermal fields (Rainbow, Broken Spur, Vienna Woods) have wide range of salinity (1.6–8.5 wt %) (Fig. 4). This could be related to phase separation during solution

Micrometry results of hydrothermal minerals from different deposits

Objects	T_{fm}, °C	T_{fin}, °C	C, wt %	T_{hom}, °C
Hematite–quartz edifice, Lis'y Gory field				
Roof	–20.6…–21	–0.8…–4.5	1.5–6.5	180–190
Foot	–21.2…–21.25	–2.3…–2.8	2.9–3.3	200–204
Incurrent channel	–20.8…–21.3	–2.5…–4.0	2.9–3.3	260–280
Massive sulfide deposits of the Urals				
Yaman-Kasy [11]	–28.0…–20.0	–0.4…–4.6	3–8	100–200
Aleksandrinka [5]	–	–	–	320–340
Balta-Tau [12]	–	–	3–4.5	100–170
Gold–quartz deposits of the Urals				
Berezovsk [2]	–28…–37	–	17.0–8.4	300–390
Kochkar [10]	–35…–37	–14.2…–5.6	15.7–7.7	180–370
Modern sulfide edifices				
Rainbow [4]	–22..5…–23.6	–2.7…–5.6	4.1–8.5	140–230
Broken Spur [4]	–21.4…–22.0	–2.0…–2.5	3.0–3.9	270–280
Vienna Woods [4]	–22.2…–25.7	–3.4…–4.6	2.7–6.9	185–300

Note: (T_{fm}) First melting temperature; (T_{fin}) final melting temperature; (C) salinity of solutions; (T_{hom}) temperature of homogenization; (–) no data.

boiling, mixing of different fluids, or their hydration during the reaction with host rocks [4].

Thus, obtained data showed that hematite–quartz edifices of the Lis'y Gory field formed due to low salt hydrothermal solutions. The formation was initiated by NaCl-fluids with salinity close to seawater (3–3.5 wt %). Their minimal temperatures vary from 290°C in incurrent channels to 180°C at the roof of edifices. Composition and temperatures of solutions are similar to those in solutions of massive sulfide deposits of the South Urals. This could testify to the same source of hydrothermal solution for them (seawater). Our data differ significantly from those for the gold-bearing deposits in the Urals because of the magmatic origin of their solutions. New data are important for understanding hydrothermal processes in paleoceanic structures and prospecting for ore-bearing paleohydrothermal fields.

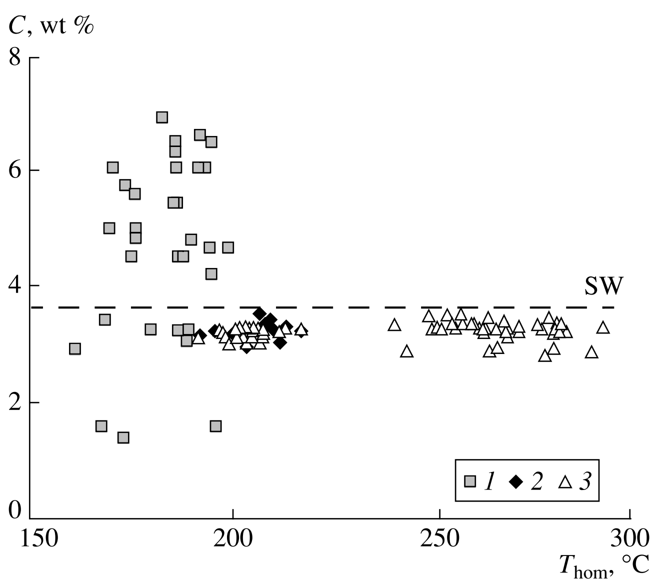

Fig. 4. T_{hom} vs. salinity of fluid inclusions in quartz from the hematite–quartz edifice: (*1*) roof; (*2*) foot; (*3*) incurrent channel.

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REFERENCES

1. N. R. Aupova and V. V. Maslennikov, *Halmyrolytes of the Uzel'ga Massive Sulfide-Bearing Field* (Ural. Otd. Ross. Akad. Nauk, Miass, 2005) [in Russian].

2. I. A. Baksheev, V. Yu. Prokof'eev, and V. I. Ustinov, in *Materials of Uralian Summer Mineralogical School-98* (UGGGA, Ykaterinburg, 1998), pp. 41–49 [in Russian].

3. A. S. Borisenko, Geol. Geofiz, No. 8, 16 (1977).

4. N. S. Bortnikov, V. A. Simonov, and Yu. A. Bogdanov, Geol. Ore Dep. **46** (1), 64 (2004) [Geol. Rudn. Mestorozhd. **46** (1), 74 (2004)].

5. I. V. Vikent'ev, *Formation and Metamorphism of Volcanic-Associated Sulfide Deposits* (Nauchnyi Mir, Moscow, 2004) [in Russian].

6. V. V. Zaykov, *Volcanism and Sulfide Edifices of Paleoceanic Margins (with Massive Sulfide-Bearing Zones of the Urals and Siberia as Example)* (Nauka, Moscow, 2006) [in Russian].

7. E. V. Zaykova and V. V. Zaykov, in *The Metallogeny of Ancient and Modern Oceans-03: Formation and Opening up of Deposits in Island-Arc Systems* (Inst. Miner. Ural. Otd. Ross. Akad. Nauk, Miass, 2003), pp. 208–215 [in Russian].

8. E. V. Zaykova, *Siliceous Rocks of Ophiolite Associations (with the Mugodzhary as Example)* (Nauka, Moscow, 1991) [in Russian].

9. V. V. Maslennikov, *Lithogenesis and Formation of Massive Sulfide Deposits* (Ural Otd. Ross. Akad. Nauk, Miass, 2006) [in Russian].

10. V. Yu. Prokof'ev and E. M. Spiridonov, in *Petrography at the Eve of XXI Century: Materials of II All-Russia Petrography Meeting* (Syktyvkar, 2000), Vol. 3, pp. 88–90 [in Russian].

11. E. O. Terenya, V. V. Maslennikov, V. A. Simonov, and S. P. Maslennikova, in *The Metallogeny of Ancient and Modern Oceans-05: Formation of Deposits from Oceanic Margins* (Inst. Miner. Ural. Otd. Ross. Akad. Nauk, Miass, 2005), pp. 64–69 [in Russian].

12. N. G. Holland, S. Roberts, A. J. Boyce, and R. J. Herrington, in *Mineral Exploration and Sustainable Development* (Millpress, Rotterdam, 2003), Vol. 1, pp. 123–126.

13. V. A. Koroteev, H. de Boorder, V. M. Necheukhin, and V. N. Sazonov, Tectonophysics **276**, 291 (1997).