
SHORT
COMMUNICATIONS

The Content of Gold in Lower Paleozoic Phosphatized Biogenic Remains in Baltoscandia

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Abstract—According to instrumental neutron activation analysis (INAA) data, the average content of Au in conodont elements and phosphate brachiopod shells from Lower Paleozoic sections in Baltoscandia is 4.9 and 0.79 $\mu\text{g/g}$, respectively. Concentration of Au in phosphatized biogenic remains suggests that they served as an important intermediate concentrator of this metal in the sedimentary cover of the East European Platform.

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Gold occurs as particles approximately 1 μm across together with terrigenous quartz and/or authigenic iron and manganese hydroxides in phosphorites of different types and ages (Baturin and Dubinchuk, 2006; Baturin et al., 2006). Despite signs of roundness in some gold particles, absorption of its compounds on phosphate grains and their subsequent reduction to the metallic state is considered the major mechanism responsible for Au concentration in phosphorites (Turlychkin and Gorenkov, 1999). Gold particles up to 2 mm across (fineness 775–910) were extracted from ore concentrate of the Kingisepp coquina-type phosphorite deposit located in the northwestern part of the East European Platform (Konstantinov et al., 2005). Since gold particles were found in ore flotation concentrate of the latter deposit, which could include clastogenic gold, concentration of this metal in phosphatized biogenic fragments remains an open issue.

The present communication reports data on the Au content in phosphate material of biogenic remains from the Baltoscandian Upper Cambrian–Ordovician sections extending from the southern Ladoga region to Sweden. Host rocks and location of sampled sections are described in (Sturesson et al., 2005). Gold contents were determined by the instrumental neutron activation analysis (INAA) method using epithermal neutrons according to the procedure described in (Felitsyn, 2006) at the Institute of Precambrian Geology and Geochronology, St. Petersburg. Conodont elements and fragments of phosphatized brachiopod shells (obolids, lingulids, and acrotretids) were extracted from host limestones (by acid maceration) or quartz sands (using mechanical technique).

Among 127 samples of Upper Cambrian–Ordovician biogenic remains analyzed, the Au content in 52% samples was 10^3 – 10^4 times higher than the detection limit of the INAA method (0.0005 $\mu\text{g/g}$). The Au con-

tent in conodont elements varies from 0.324 to 18.9 $\mu\text{g/g}$ ($n = 31$, average 4.9 $\mu\text{g/g}$); in phosphate brachiopod shells, from 0.056 to 2.42 $\mu\text{g/g}$ ($n = 35$, average 0.79 $\mu\text{g/g}$). The distribution of Au in phosphatized biogenic remains from the Baltoscandian Lower Paleozoic sections is characterized by the following features:

(1) The concentration of Au demonstrates correlation with its particle size: the average content is 0.35 $\mu\text{g/g}$ ($n = 22$) in phosphatized brachiopod shells 5.0–10.0 mm across, 1.1 $\mu\text{g/g}$ ($n = 13$) in smaller shells (1.0–5.0 mm), and maximal (5.0 $\mu\text{g/g}$) in conodont elements 0.05–1.0 mm across. In this respect, phosphorites of biogenic remains are principally different from their sedimentary nodular counterparts, in which the Au content is uniform in both central and peripheral parts of different-size spherical nodules (Felitsyn, 2006). Maximal Au concentrations are found in conodont elements *Oistodus lanceolatus* from the terrigenous Volkhov Formation (Stage 3, lower Middle Ordovician) of the Leningrad region (14.1 $\mu\text{g/g}$) and in unidentified conodont elements from the upper Lanna limestones (stratigraphic analogue of the Volkhov Formation) recovered in the Gulhogen Quarry near Skovde in the Lake Siljan area, central Sweden (18.9 $\mu\text{g/g}$).

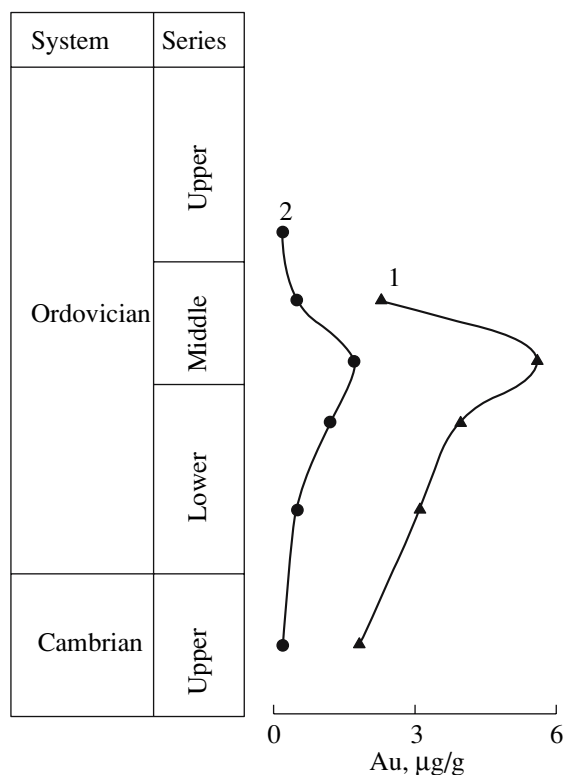
(2) Highest Au concentrations are observed in phosphatized biogenic remains from Lower/Middle Ordovician boundary strata (figure) regardless of their nature (phosphate brachiopod shells or conodont elements) and composition of host rocks (quartz sands or limestones). In phosphate brachiopod shells from the Lower Ordovician Floian Stage and Middle Ordovician Stage 3 of southern Sweden, northern Estonia, and the Leningrad region, the average Au content (1.2 and 1.7 $\mu\text{g/g}$, respectively) is an order of magnitude higher than in shells from the under- and overlying sediments. Proportions of different-size brachiopod fragments are approximately similar in each stage.

The role of sedimentary phosphorites as intermediate Au concentrators is known long ago (Yasyrev, 1971). However, the maximal Au content in phosphatized biogenic remains from the Baltoscandian Upper Cambrian–Ordovician sections is substantially higher than its maximal values (n $\mu\text{g/g}$) in Phanerozoic nodular phosphorites (Baturin et al., 2006).

Absorption of Au-bearing compounds by phosphate matter during diagenesis is the most probable mechanism responsible for the concentration of Au in brachiopod shells and conodont elements from the Baltoscandian Lower Paleozoic sections (Yasyrev, 1971; Turlychkin and Gorenkov, 1999; Konstantinov et al., 2005). Such a possibility is confirmed by correlation between the Au content in examined samples and size of phosphatized biogenic remains: its maximal concentration is observed in conodont elements, which are characterized by the maximal surface/volume ratio, which indicates the decisive role of Au sorption at the solution/solid phase interface.

The studied phosphatized biogenic remains characterize shallow-water facies with low carbonate or terrigenous sedimentation rates (Felitsyn et al., 1998; Sturesson et al., 2005). The condensed patterns of Lower–Middle Ordovician sections with members of well-sorted fine- to medium-grained quartz sandstones indicate that the peneplain of the Baltic Shield served the source of clastic material at that time. The formation of thick weathering crusts on the Baltic Shield and their subsequent erosion are traditionally considered as factors responsible for the concentration of Au at some stratigraphic levels in the sedimentary cover of the East European Platform (Kal'nichenko et al., 1995). The presence of weathering crusts at the Lower/Middle Ordovician boundary in many regions of different continents indicates their global development (Akul'shina, 1985). Assumption of the increased influx of Au in the clastogenic material and/or water-soluble compounds into coastal facies at the Lower/Middle Ordovician boundary due to the erosion of weathering crusts in provenances seems valid, because the crust formation and sedimentation occurred synchronously.

The presented data imply that, relative to nodular phosphorites, phosphatized biogenic remains played a more significant role as intermediate concentrators of Au in the sedimentary cover. Coquina-type phosphorite deposits represent unique accumulations confined to the sole Ordovician–Silurian stratigraphic interval. The dominant part of coquina phosphorites is localized in two Early Ordovician (Baltic–Ladoga and Lena–Tunguska) phosphorite basins (Yanshin and Zharkov, 1986). Concentration of Au in biogenic remains from the Baltoscandian Lower Paleozoic sections allows us to consider phosphorites of these basins as potential concentrators of Au that was mobilized during the formation of weathering crusts in the Ordovician in stable



Distribution of Au in (1) conodont elements and (2) phosphate brachiopods in the Baltoscandian Cambrian–Ordovician section. The Cambrian/Ordovician boundary is accepted at 488.3 Ma; the Lower/Middle Ordovician, at 471.8 Ma; and the Middle/Upper Ordovician, at 460.9 Ma (Gradstein et al., 2004).

basement areas of the East European and Siberian platforms.

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