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*Journal of Applied Spectroscopy*, Vol. 84, No. 2, May, 2017 (Russian Original Vol. 84, No. 2, March–April, 2017)**MOESSBAUER STUDY OF SPHERO-CONICAL VESSELS FROM BOLGAR****A. G. Ivanova,\* A. R. Nuretdinova, A. V. Pyataev,  
S. I. Valiulina, and E. V. Voronina**

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*Samples of sphero-conical vessels found in mass quantities in the ancient settlement Bolgar were analyzed by Moessbauer spectroscopy. Wares with relatively low annealing temperatures  $<500^{\circ}\text{C}$  and having a ratio  $\text{Fe}_{\text{par}}^{3+}/\text{Fe}^{2+} \leq 1.11$  in transmission spectra were differentiated from those with high ones. The detected value of  $\text{Fe}_{\text{par}}^{3+}/\text{Fe}^{2+}$  was considerably less than the value of 2.69 that was characteristic of raw materials for pottery production in the vicinity of the selected settlement. This indicated that other non-local sources of raw materials existed in the medieval handicraft center.*

**Keywords:** *sphero-conical vessel, Bolgar, Toretsk settlement, pottery, medieval craft, raw materials, Moessbauer spectroscopy, illite.*

**Introduction.** Small vessels (8–15 cm in height) with a round body and conical bottom, i.e., sphero-conical vessels (SC) (Fig. 1), are special ceramics of medieval technology that are well known in the Islamic East. SC are traditionally categorized as technical ceramics although a functional use of the vessels consistent with the technical properties cannot yet be established by purely archeological methods. Over 20 versions of the possible uses of SC are known, e.g., containers for mercury transport and storage, vessels for beverages, vials for perfume, lamps, architectural decorations, etc. [1].

Large numbers ( $<5000$  specimens) of SC were found in eastern Europe at monuments of Volga Bulgaria. SC were used in the Central Volga territory from the end of the Xth to the dawn of the XIV–XV century. However, SC were produced in Bolgar in the second half of the XIII to the XIV century [2]. Several pottery kilns, i.e., firing furnaces, that produced assorted items including SC existed in the settlement. The distribution pattern of SC in the Golden-Horde stratum of Bolgar settlement indicated that this vessel was ubiquitous in both living and working quarters. Apparently, this was due to their use in crafts, alchemy, medicine, perfumery, and the household. The majority of SC from the Golden-Horde era are red-clay glazed local SC. Red-clay enameled SC are especially interesting. The morphological and technical signatures of SC with opaque turquoise enamel are the same as a group of items from Central Asia and lower-Volga Golden-Horde cities. They arrived there through trade or could be produced on site using Central-Asian examples by local or immigrant masters. It has not yet been proven that glazed ware was manufactured in Bolgar settlement. Therefore, the preparation site of enameled SC and the raw materials used in them are still being discussed.

Herein, ceramic SC are studied using Moessbauer spectroscopy in order to identify the manufacturing details and features, to determine the raw materials and role of intercultural exchange in ceramics manufacturing, and to demonstrate the technical level of the craft.

The analyzed set included six samples, four of which were SC with granitic sand and green enamel (sample 1), with turquoise enamel (samples 4 and 6), and a bare one typical of Golden-Horde strata of Bolgar (sample 5). Samples of the wall of a molded vessel with crushed shell (Prikamsky-Priuralsky region) from Bolgar (sample 2) and vessel walls with granitic sand from Toretsk settlement (sample 3) were used as references. A preliminary laboratory examination usually characterized pieces with nonuniform coloring as poorly (unevenly, insufficiently) fired. Sample 6 of this type was included in our set.

**Experimental.** Moessbauer spectra were obtained on an MS-1104Em No. 40-12 rapid spectrometer (Research Institute of Physics, Southern Federal University, Russia) with constant acceleration at room temperature using a symmetric

\*To whom correspondence should be addressed.