

VARDZIA CAVE TOWN (GEORGIA) AND THE ENVIRONMENTAL PROBLEMS CAUSED BY FIBROUS ZEOLITES

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The Cave City of Vardzia combines urban, monastic, and defensive complexes and is located in Meskheta (South Georgia), on the left bank cliffs above the river Mtkvari, at an altitude of 1300 meters above sea level. King George III began its construction in the 50s of the 12th century, and it was completed during the reign of his daughter Queen Tamara. The time was a period of Georgian Revival, and this huge fortress-city, carved into the rock (Fig. 1) is monumental proof of this. For nearly three and a half centuries, an intensive economic, scientific, cultural, and educational life was conducted in the fortress-city of Vardzia. Queen Tamara was fond of the city and spent much time; especially, of her early years there.



Figure 1. View of the Vardzia Cave Town, central part.

The complex consists of 13 floors with a total area of over 5,000 m². It includes 120 dwellings, 420 pantries, among them 25 special storage facilities for wine (Marani), a pharmacy, and 4 Christian churches. Next to the main church there are springs, and a 3.5 km long water channel was carved into the rock, providing drinking water to the complex. In 1283, after a strong earthquake, the cave complex was severely damaged, but it did not cease its operation. In 1553, the Persian army destroyed it, and in 1578 the Ottoman Empire captured Meskheta, after which the complex was abandoned. In 2007, Vardzia, together with Khertvisi fortress, were designated by UNESCO as World Heritage Sites.

The rocks into which the complex of Vardzia was carved are identified as the Vardzia Horizon (Ustiev and Jigauri, 1971), which represents caked flow tuffs with a thickness that varies from 45 to 60 meters. The Vardzia Horizon is overlain by andesitic tuffs, and in direct contact, a zone of ignimbrites developed, which serves as a natural upper boundary for the Vardzia complex. The Vardzia flow is not graded and mainly consists of medium- and poorly-caked tuffs, the color of which depends on the degree of sintering and varies from pink to white. The size of the tuff debris ranges from 0.1 to 3 cm and is mainly composed of hypersthene-hornblende, rarely of biotitic andesites, in which the average content of

SiO₂ is 61.0%. Together with andesite hornblende, biotitic dacites are marked, in which the average content of SiO₂ corresponds to 65.0%. Binder material basically consists of volcanic ash, which, as a result of low-temperature hydrothermal processes, was transformed into a zeolite, in particular, mordenite. Vardzia flow tuffs are very easily cut with a knife, a fact that was successfully applied by ancient builders, but of course they did not know anything about the geo-environmental hazard posed by the fibrous zeolites in these rocks. The World Health Organization classified fibrous zeolites (erionite, mordenite, ferrierite, mazzite, offrerite, and roggiannite) as one of the most carcinogenic natural minerals to human health. According to this classification, erionite is the most dangerous toxic mineral, 50-100 times more toxic than asbestos-chrysotile. Modern research shows that fibrous zeolites caused a regional epidemic of malignant neoplasias (bronchial carcinoma, malignant mesothelioma). The first such epidemic occurred in Cappadocia, Turkey, where the populations of several villages suffered from pleural mesothelioma, and more than 50% of the inhabitants died because of it (Baris et al., 1978).

Zeolites are formed in volcanic ash and pyroclastic rocks as a result of diagenetic and hydrothermal alteration. Erionite and other fibrous zeolites are formed in the mixed environment of volcanic ash and clay. Fibrous zeolites are often found in association with other zeolites, precisely with clinoptilolite and chabazite.

In Southern Caucasus, volcanic formations are widely spread and occupy about 30% of the total area. Zeolites have been studied quite extensively in Georgia (Skhirtladze, 1991), but identification of fibrous zeolites hasn't carried out, as nothing was previously known about their danger. Despite this, zeolites with erionite and mordenite are found in the Mtkvari, Enguri, and Algeti river gorges, at the zeolite deposit of Tedzami, the barite-polymetallic deposit of David-Gareji, and the copper polymetallic deposit of Abulmulak, and also in the area surrounding the villages of Askana, Vardzia, Bolnisi, Ratevani, Abrameti, Samshvilde, and Nichbisi. Based on the above, these areas most likely represent the greatest "zeolites danger" for the population.

Climatic conditions and petrographic structure of the sintered tuffs of the Vardzia flow, which extends more than 20 kilometers in distance, are very similar to those of volcanic rocks common in the province of Cappadocia (Turkey). This suggests the possibility that the local Cappadocian population is or was getting sick from mesothelioma.

For the investigation of this question, we examined the historical sources of the region (Okrostsvardize et al., 2011) and discovered that the life expectancy of people living there did not exceed 50-55 years. More information exists about the disease of Queen Tamara. It is known that she died at the age of 53 and was ill only during the last two months of her life (Samushia, 2010). In addition, all her symptoms coincide with those of typical mesothelioma, which was probably caused by her long-term living in Vardzia.

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