UNIQUE CAVE CITY VARDZIA, GEORGIA – GEOLOGY, DESTRUCTION PROCESSES AND PROTECTIVE MEASURES

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Keywords: cave city, volcanic tuff flow, destructive processes, protective measures

Introduction

Vardzia is a unique cave city of the 12th century combining an urban, defensive, and monastic complex hewn into the volcanic tuff flow of Pliocene andesitic-dacitic composition. In 1283, after a strong earthquake, the cave complex was severely damaged, but it did not cease operation. Results of geological investigation showed that the Vardzia area has a complex geological structure. It is situated on the eastern slopes of the Erusheti ridge, hewn into a 900 m long tectonic block, which is detached from the main rocks and is gradually subsiding towards the Mtkvari gorge. In addition, the Vardzia block is split into several microblocks by a joint set, and thereby its stability lessens. The matter is made worse by the fact that an active deep fault runs along the Vardzia complex in the Mtkvari gorge and presents a potential earthquake source. For this reason, it is clear that this important monument of Georgian cultural heritage is in danger of gradual natural destruction and earthquake hazards.

Methodology

The work was carried out with the application of classical geological methods as well as high sensitivity modern tools. To determine the exact hypsometric location and vertical displacement, a differential high accuracy DGPS, Leica Viva GS15, was used. At the same time, monitoring of the dynamics of the front part of Vardzia is being carried out continuously by stationary IBIS-FM radar.

Geological characterization of the Vardzia region

Vardzia region is constructed of subaerial Pliocene volcanogenic-sedimentary rocks of andesitic-dacitic composition: the so-called Goderdzi suite (Fig. 1).

Figure 1. Panoramic view of the Vardzia region. In white color is the volcanic flow of andesitic-dacitic composition. At the top of the flow is the upper part of the Goderdzi suite. At right can be seen the Vardzia cave city.

This suite is located discordantly on the mid-Eocene tuff-breccias and sandstones and is also discordantly covered by a thick flow series of Quaternary dolerites (Skhirtladze, 1958). The Goderdzi suite is strictly divided into two major parts: the lower part with a thickness of 200-250 m is built up of pyroclastic formations in which mainly dark, weakly cemented, coarse material of hypersthenic and 2-pyroxene andesitic and andesitic-dacitic composition prevails. Somewhere in this coarse tuff suite one can mark rare cenotypal thin-layered pyroxene andesitic flows; above this part, there is a 20-80 m thickness of slightly welded, fine-grained

andesitic-dacitic tuff flow (the Vardzia horizon). It was within the segment of the volcanogenic rocks where the Vardzia complex was hewn beginning in the 12th century.

The Vardzia horizon presents fine-grained andesitic-dacitic, slightly welded tuffs (Branney and Kokelaar, 2002). It is well observed in relief because of its whitish color. Its thickness in the Vardzia section is 40-60 m and is different in the northern and southern directions. It should be noted that the horizon outcrops mainly on the left benches of the Mtkvari River, while it is marked fragmentarily on the right ones. Tuffs of the Vardzia flow are rather soft rocks. They make one's fingers dirty, although it is impossible to crush them by hand. Their color changes from lateritious-pink to light grey-white. In the petrographic sense, these tuffs can be divided into three parts: lithoclastic, porphyroclastic, and cementing materials.

Tectonic structure of the Vardzia region

The tectonic structure of the Vardzia region is rather complex (Gamkrelidze, 2000). There, tectonic faults of two types can be distinguished (Fig. 2): (1) faults produced by regional geological processes and (2) those conditioned by local gravitational phenomena.

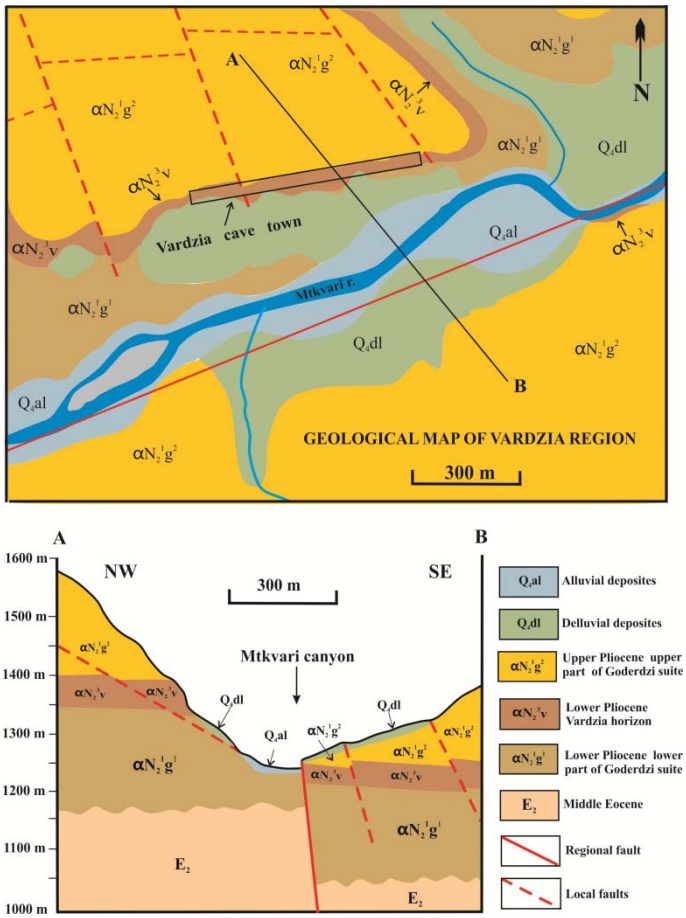

Figure 2. The geological map of the Vardzia area, and its cross section.

The basic tectonic structure of the area is a deep fault, which traces SW-NE and actually runs along the Mtkvari River gorge. Along the fault, the Vardzia area is divided into two large geoblocks: a western block – Vardzia (Erusheti) and an eastern block – Javakheti. After the Vardzia horizon was formed (beginning of the Pliocene), a significant vertical displacement was created along the fault.

We determined the exact heights asl of the upper border of the Vardzia horizon in the exposures on both sides of the Mtkvari River using a high accuracy differential GPS. As a result, the Vardzia horizon in the Vardzia complex is situated higher in comparison with the

right riverside by 127 m (Okrostsvaridze et al., 2016). Apparently, the center of Vardzia's destructive earthquake in 1283 was located right along this fault.

Destruction processes

Destructive processes of the cave city of Vardzia conditioned the type of rocks in which it is built and its complex tectonic structure. It is hewn into the weakly cemented volcanic tuff flow of andesitic-dacitic composition. Tuffs of the Vardzia flow are rather soft rocks, and therefore they suffer constant weathering and destruction. These rocks can be cut even with a simple iron knife, and this very factor must have been one reason to excavate the Vardzia complex into these rocks.

No less important a role is played by the destructive processes of the Vardzia complex tectonic structure. The 900 m long tectonic block of Vardzia, which is detached from the main rocks and is gradually subsiding towards the Mtkvari gorge, is split into several microblocks (Fig. 3), and therefore its stability is reduced even further. Also, strong erosional processes taking place along the Mtkvari gorge cause significant destruction.

Figure. 3. Microblocks in the SW part of the Vardzia area: the light colored, fine-grained, andesitic-dacitic welded tuffs.

Conclusion

This study has shown that Vardzia is hewn into the weakly cemented volcanic tuff flow of andesitic-dacitic composition, and therefore, it suffers constant weathering and destruction. Also, the tectonic structure of the Vardzia region is rather complex. Exact measurements carried out with GPS showed that the 900 m long Vardzia block has sunk by 30.6 m in comparison with the adjacent block. In addition, Vardzia's situation is made worse by the fact that an active deep fault runs along the Vardzia complex in the Mtkvari gorge and represents a potential earthquake source. If we take into consideration the rather strong erosional processes taking place along the Mtkvari gorge, it is clear that this important monument of Georgian cultural heritage is in danger of gradual natural destruction and earthquake hazards. The only factor contributing to the relative stability of the Vardzia cave city is the somewhat harder basalt-andesitic lava-flow existing beneath it.

Protective measures

Due to the fact that the Vardzia region is characterized by a complicated tectonic and geological construction, protective measures are difficult. We consider that fortification of the sliding blocks with traditional concrete reinforcement constructions should be used. Besides, clefts that are present in the andesitic-dacitic slightly welded tuffs should be sewn up using high temperature by heating them over 1000°. At places where these clefts are wide, they should be filled with the same material brought from other exposures, and afterwards be heated.

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