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Actions of factors caused by lightning on historical and cultural monuments and the possibilities of their prevention on the example of Abuli fortress

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Abstract: Among the natural and anthropogenic factors affecting historical and cultural monuments of particular interest are the damages caused by lightning, which are still not well studied. Due to the fact that lightings are very common for the region, it is very important to study the historical and cultural monuments located here.

As a subject of research, we propose the Abuli megalithic fortress and the place of a former settlement located in the south of Georgian highland. The climatic conditions of this region, as well as the structure and composition of construction materials were studied (using physical-chemical methods of research). Damage to the fortress caused by lightings has been established and procedures have been proposed to prevent it. Such approach can be used in any region of the world, where there is a danger of damage from lightings in order to protect cultural heritage sites.

Keywords*:* Abuli fortress, ecology, lightning, lighting conductor, megalithic monument, the south of Georgian highland,.

I. INTRODUCTION

Historical and cultural monuments are an essential part of world civilization, so the care, protection and preservation of these monuments for future generations are an important and responsible task. Damage to monuments is mainly due to natural and anthropogenic factors [1]. In general, these factors equally affect the monuments in every part of the world, although the location of the monument is of great importance.

Lightning is a frequent event in Georgia. Therefore, damages caused by lightning is very important for some regions of Georgia. The study of lightning processes has always been relevant in our country. The period of regular meteorological observations of atmospheric conditions in Georgia is counting 100 years.

Lightning is a dangerous phenomenon of nature. It negatively affects human life and wildlife. As a result of a lightning strike, people are dying, agricultural objects, cultural and historical monuments, airplanes, oil and gas pipelines are being destroyed, radio communications and electricity supply are interrupted, forests are burnt by fire etc. On average, a lightning strike on earth occurs 8 million times a day. The corresponding area varies from $40 \cdot 10^4$ km^2 (at 4 am) to $110 \cdot 10^4$ km^2 (at 14-20 am) [2]. Changes in lightning strikes are associated with global climate changes. In particular, according to NASA (National Aeronautics and Space Research), the number of lightning on earth has increased 100 times in the last decade [2].

Lightning is a giant electric spark arising between the fields of opposite charges. According to laboratory research, for the formation of an electric spark, an electric field between sky and earth with a voltage of 30 000 volts per meter is needed. At this critical moment, intense ionization of air begins. These ions and electrons acquire high velocities in a narrow channel, where the air is strongly heated and electron charge - the predecessor of lightning (the so-called leader) moves through this channel from the cloud. The leader of the lightning is developing in jumps and in one jump, which occurs in tenths of a second, passes 50-100 m. As soon as the channel approaches the earth, a flow of opposite charges goes out to meet him. The speed of these flows reaches several tens of thousands of km/h. An electric current of great strength and high power is formed. The length of lightning ranges from 2 to 20 km, and sometimes up to 50 km. During one lightning 50-60 strong discharges may occur. The current strength reaches 25000–60000 A, and sometimes even 200000 A. At this time, the voltage is several million volts [2, 3].

The southern part of the highland of south Georgia, covering an area of 5,700 km^2, is the most dangerous in terms of lightning in Georgia. In some years the number of days with lightning was 95-96.
Mountain slopes oriented towards humid air masses is characterized by the largest number of days with lightning. At this time, dynamic turbulence increases and the upward flow on the mountainside forms an additional impulse of powerful convection processes that enhance lightning [4, 5].

An increase in the number of days with lightning is observed up to 2400-2600 m height. Above this height, the effect of lightning decreases, which is associated with a decrease in air temperature. There are two periods with maximum lightning days in Georgia: one in June-July and the second in August. The minimum daily lightning hours throughout Georgia is 6-12 hours. The maximum duration occurs in the second half of the day. The maximum duration of lightning is 140-1250 hours. This value is observed in the mountainous region of southern Georgia [6].

Lightning is especially dangerous in the mountains. A lightning strike is associated with a landscape. It is known that the edges and peaks of the mountains attract and accumulate a charge of lightning. Any bulge on the mountainside is most likely a place for a lightning strike. It should be noted that the lightning current is very dangerous and not well studied. When the lightning strikes the top of a mountain, the forming current looks for a path with minimal resistance and goes to the surface of the rocks, penetrates into cracks. Therefore, all these places during a lightning are dangerous to humans [7].

To determine the probability of lightning processes on the southern slopes of this region, observations of 7 meteorological stations for 60 years were analyzed. It turned out that compared with other areas of this region the probability of lightning is very high. The probability of days with lightning varied from 0.27 to 0.61, and in the case of the maximum number of days with lightning - from 0.37 to 0.75. Thus, there are favorable conditions for the formation of lightning processes, and therefore from this point of view the above mentioned region appears to be especially dangerous [6,7].

II. EXPERIMENTAL OR MATERIALS & METHODS

Megalithic cultures are the common name of archaeological cultures, which covers the Eneolithic and Bronze Age (in some cases, the Neolithic period, too). They are found in almost every region of the world (except Australia). Characteristic monuments of these cultures are: Dolmen, Mengir, Krommhel, Kvakuti (The tomb is made of stone tiles) and stone-covered corridors [8] **(Fig. 1)**.

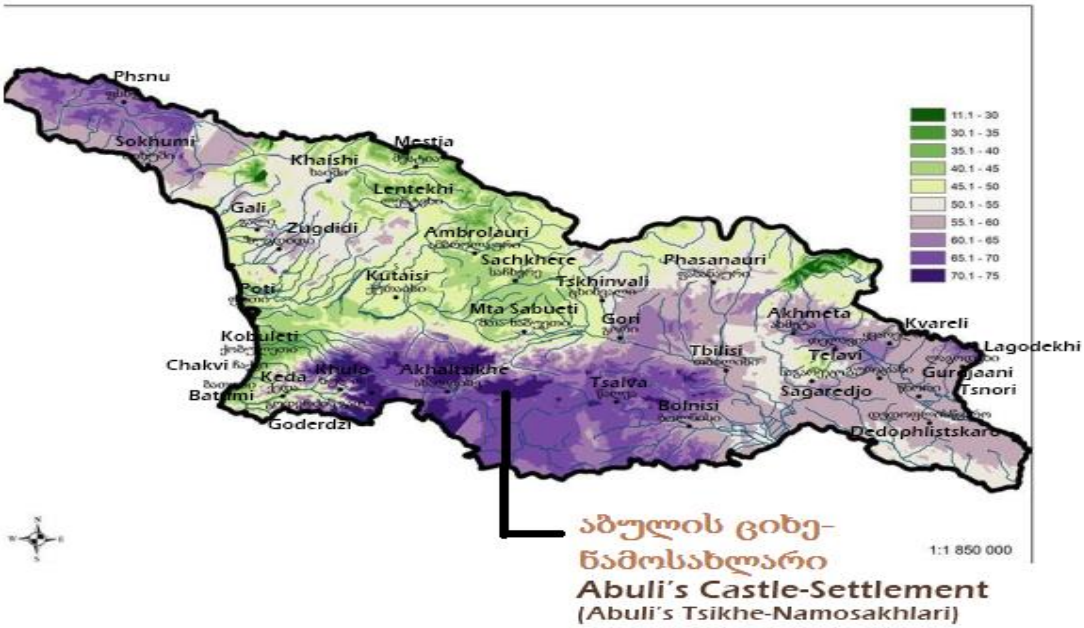

Fig. 1. The annual distribution of lightning on the territory of Georgia [6].

Megalithic monuments in Georgia are distinguished by their scale, monumentality and versatile purpose. They had both residential and defensive, as well as religious functions [9]. Due to their uniqueness, these monuments have acquired international significance from both historical and scientific points of view. In addition, monuments are of great importance for the development of tourism in our country.

Subject of our interest - megalithic monument - cyclopean fortress of Abuli located in the southern mountainous region of Georgia - historical province Javakheti, on the southern slopes of small Abuli mountain, at an altitude of 1670 m above sea level **(Fig. 2)**.

Fig. 2. Abuli fortress

The monument is large and quite well preserved. It consists of a fence, an inner fortress and dwellings built to its walls from inside. The height of the dry ground walls in some places reaches 5 m, the width is 3 m. The "Inner castle" occupies an area of about 40x60 m. The inner fortress from outside is surrounded by rooms and caches in the form of terraces, which had a stone roofing [10,11].

III. RESULTS

As mentioned above, the monument is located on the southern slopes of the South Caucasus Mountains. These places are characterized by frequent lightning strikes, which damages the monument. During lightning strikes, stone tiles are crumbling - they are broken. Therefore, most of the monument is a cluster of broken stones. A lightning strike is also dangerous for visitors - tourists and interested people. Therefore, creating a relatively safe environment for people is important.

The southern slopes of the small Abuli, where the fortress is located, are covered with moraines of volcanic origin. Builders used these stones during construction. The construction material looks homogenous, although dark pink, light pink and gray tones stand out. A petrographic study of stones has shown that construction material is andesite and in some cases pyroxene. The main material is the mineral plagioclase, rarely monoclinic pyroxene and amphibole. Secondary mineral is chlorite and carbonate.

Mineral structure is porphyrial, with the main mass of microlite. Texture is fluidal.

Rock is mainly represented by volcanic glass, middle plagioclase, chlorite and ore mineral. Percentage of pyroxene and amphibole is small and in total - less than 5%.

The plagioclase is found in the form of thin and elongated idiomorphic and sometimes - xenomorphic grains. Rarely it is represented in the form of porphyrial buildups. Its size varies from 0.01 mm to 0.8 mm.

Pyroxene and amphibole are found in the form of xenomorphic grains ranging in size from 0.08 mm to 1 mm. Pyroxene is mainly in the form of rounded buildups. Amphibole is in the form of individual rounded and opacities grains.

Chlorite is formed on the basis of volcanic glass pyroxene and amphibole. It occupies the vacant space between the grains. The mineral of the ore is probably represented by pyrite-pyrotin.

The study of construction stones (gray, dark pink and light pink samples) of Abuli fortress using X-ray diffractometer and infrared spectroscopy methods showed that the structure of the main minerals is identical (**Fig. 3**).

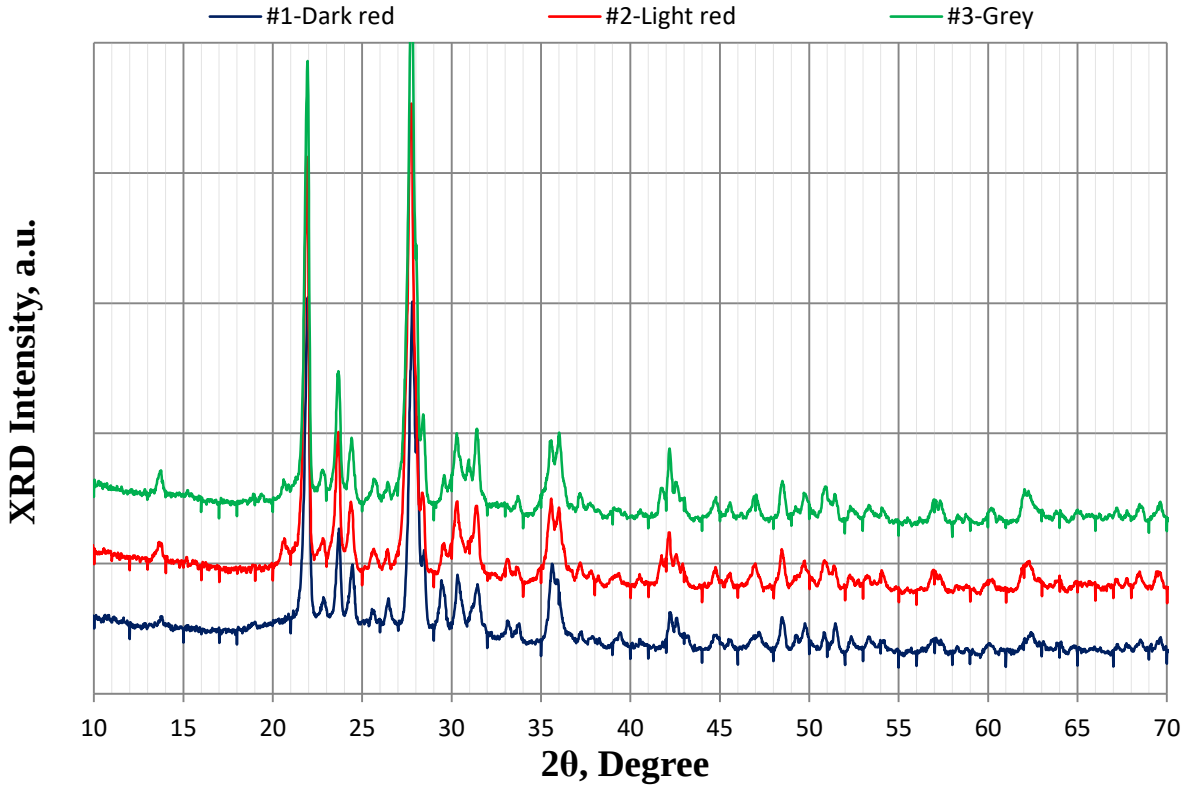

Fig. 3. X-ray diffractogram from Abul's fortress construction stones (Pyroxenic Andesite) Range: #1 - Dark red; #2 – Light red; #3 - Grey.

It consists of the mineral anorthite [12], but there is the existence of other minerals (pyroxene, amphibole, chlorite, pyrite, pyrocin, etc.). The various contents in these minerals of iron, magnesium and aluminum determine minor structural changes. This causes the visual difference between the stones and the different intensity or complete absence of some frequency lines in the IR spectra. For example, in all three spectra, the bands at 543, 584 cm^{-1}, corresponding to Al, Mg, Fe – O bonds have different intensities, and the spectrum band at 384 cm^{-1}, which is fixed in a dark pink sample, corresponds to the bond of the compound of iron and sulfur [13,14] (**Fig. 4**).

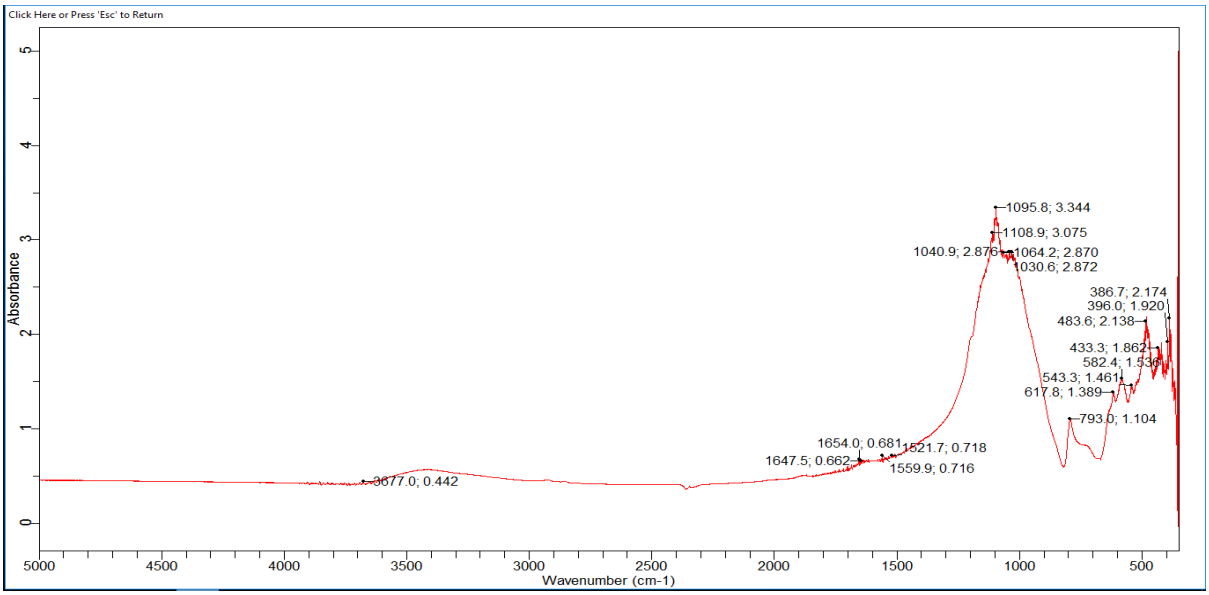

Fig. 4. I.R. Spectra from Abul's fortress construction stone (Pyroxenic Andesite) Range

Examination of samples by X-ray diffraction analysis confirmed the results of IR spectroscopy. X-ray diffractogram of all three samples with $Cu_{k\alpha}$ emission were taken. X-ray fluorescence spectrum were taken using the Soler method with the БСВ-19 (Mo-anode) tube. Monochromator: graphite monocrystal with (002) plane (**Figs 5-7**).

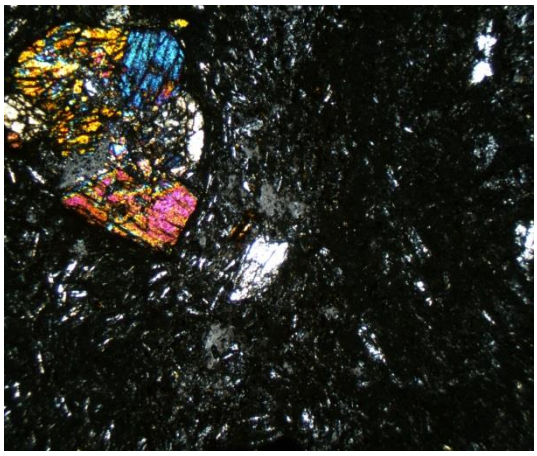

Fig.5 Pyroxenic Andesite

Fig. 6. Andesite

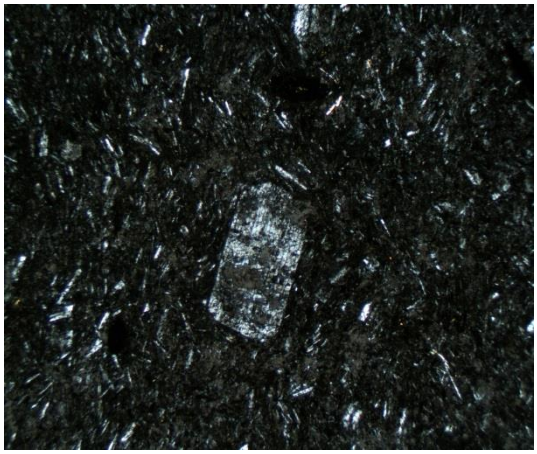

Fig.7. Andesite

The different intensity and shape of the x-ray diffractogram peaks in the 2θ range of 29-45° indicate a change in the concentration of cations in the anorthite mineral from Ca to Na and vice versa. In addition, the X-ray fluorescence spectrum showed a certain amount of iron in the mineral composition. It is interesting to note that the mineral also contains strontium.

IV. CONCLUSION

Thus, the damage of Abuli megalithic fortress caused by lightning processes is caused not only by the location of the fortress, but also by the composition of construction materials. In order to avoid damage to the fortress caused by lightning processes and to protect tourists and scientists visiting the monument, it is necessary to install lightning arresters on the monument, as it is done around the world [15].

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