



Experimental studies on ignimbrite and the effect of lichens and capillarity on the deterioration of Seljuk Gravestones



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ABSTRACT

Ignimbrites are used extensively in masonry and decorative cladding not only in historical structures, but also in residential houses recently as well as monuments around Ahlat (Bitlis-Turkey) region because of their light weight, softness and insulating properties. The most famous architectural monument is the Ahlat Seljuk Tombs, in which ignimbrites were used for the structure. These are thousand year old gravestones that have been subjected to significant degradation over time caused by many physical and chemical effects. The aim of this study is revealing the mineralogical, petrographical, petrophysical and mechanical properties of fresh ignimbrites as well as determining the effect of lichens and capillarity on the deterioration of Seljuk gravestones in accordance with laboratory studies and field observations. A total of four different ignimbrite levels have been evaluated, which are widespread in the region and named as N1 (reddish brown), N2 (dark brown), N3 (yellowish gray) and N4 (black), respectively. Among these ignimbrites, the samples of N1 and N2 were employed in the construction of Seljuk gravestones. The lithic material content and welding degree are the main controlling factors of the engineering properties of ignimbrites. Laboratory test results indicate that high porosity of ignimbrites and transport of water mediated by capillarity accelerate the deterioration of ignimbrites. Furthermore, lichens play a preventive role in the deterioration mechanism of ignimbrites rather than disintegrating the tombstones.

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1. Introduction

Natural stones have been widely used by the mankind in the history. Especially, easily processed stones have been preferred in numerous historical structures, which reflect the cultural habits of the societies lived in the period of the construction. Additionally, natural stones, used as building material, have been employed for decorative purposes after a certain period. Lightness, strength and good heat-insulation have been the most important characteristics of these stones considered during the selection phase. Many of these natural stones have been either deteriorated or completely destroyed under atmospheric conditions. Accordingly, so many studies have been conducted to reveal the physico-mechanical properties as well as the deterioration mechanisms of natural building stones in the preserved historical structures (Topal and Doyuran, 1997; Siegesmund et al., 2002; Aydan and Ulusay, 2003; Topal and Sözmen, 2003; Şimşek and Erdal, 2004; Öner et al., 2006; Yaşar et al., 2007; Binal, 2008; Koralay et al., 2011).

Ignimbrite is one of the most preferred building stones in the natural stone market because of its lightness and structure that can be easily processed. Besides, they have been also used in numerous

historical structures. In this study, the ignimbrites used in the Ahlat Seljuk Tombs have been investigated. The Ahlat Province is located on the western shore of the largest lake of Turkey, the Lake Van. The Seljuks settled in Anatolia in 1000s, especially around Ahlat and its vicinity. The graveyard is located on a flat terrain between the Lake Van and the Nemrut Caldera (Figure 1). Ahlat is located at approximately 1700 m above average sea level. The regional climate may cause intensive deterioration for the ignimbrites. The winters are rainy and snowy, whereas the humidity levels are low during the summer in the region. Based on the meteorological observation between 1967 and 2012, an arid climate was dominant throughout the region. The year of 2000 was extraordinarily arid with the annual temperature of 10 °C and average annual rainfall of 103 kg/m², approximately. Detailed temperature and precipitation data of the study area have been obtained from Meteorological Agency of Turkey given in Table 1 (www.meteor.gov.tr). The region is exposed to freezing–thawing cycles under saturated condition. These freezing–thawing cycles can be considered as one of main factors of the degradation process which is observed in the Seljuk gravestone as well.

The ignimbrites used in Ahlat Seljuk Tombs, which look like an open-air museum with historical importance, have been deteriorated under atmospheric conditions in the course of time (Figure 2a and b). The ignimbrites were not widely used only in the construction of gravestones,

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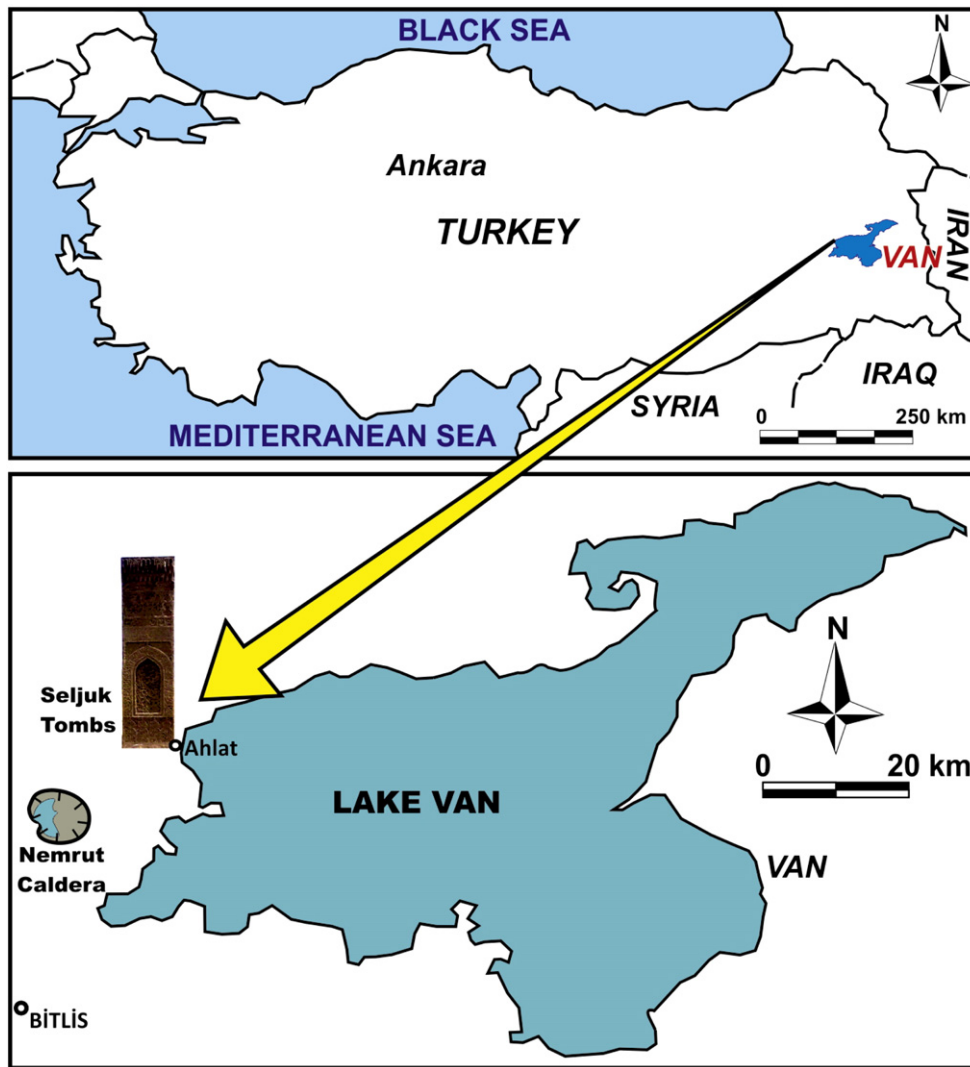


Fig. 1. The location map of the Ahlat Seljuk Tombs.

but also used in the important structures of Seljuks called as kumbets and baths (Figure 2c). The ignimbrites, which can be easily affected by chemical and mechanical weathering, are the products of Nemrut Volcano (Aydar et al., 2003; Karaoğlu et al., 2005; Özdemir et al., 2006). They have different colors such as gray, reddish brown, brown and black. Reddish brown and dark brown ignimbrites were widely used in the structures of Seljuks during their period of ruling.

These cultural heritage tombstones have been threatened by significant deterioration. For this reason, the weathering performance of natural stones used in cultural structures like Ahlat cemetery should be well-defined for the protection purposes. Similar to all stone types used in historical structures, lichen colonization is widespread on the Seljuk tombstones especially in the close vicinity of the settlement, in which the air is also arid and carbon-rich. It should be noted that the lichens are not observed on the lower levels of the gravestones, whereas

different type of lichens are extensively observed on the upper parts. As known, lichen reproduction may alter the appearance and original properties of the natural building stones in the course of time (Garty, 1992; Lisci et al., 2003). However, in some cases, lichens covering the surface of the rocks may also protect the rock against physical weathering (Garcia-Valles et al., 2003).

As seen in Fig. 2b, Seljuk tombs have been subjected to degradation caused by some physical and chemical effects. According to field observations performed on the Seljuk graveyard in Ahlat (Turkey), the tombstones were broken approximately from the middle section as well as discoloration and lichen colonization are the most remarkable problems seen on the surface of these historical structures. However, most of the inscriptions on the gravestones have been preserved despite the aforementioned effects. Then, what could be the principal cause for the disintegration of tombstones leading to discoloration and particularly

Table 1
Average temperature and precipitation for the city of Ahlat.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average (°C)	−3.0	−2.1	1.7	7.6	13.2	18.5	22.8	22.3	17.6	11.3	4.7	−0.8	9.48
Average maximum (°C)	1.2	2.3	6.1	12.9	19.3	25.4	30.4	30.7	26.3	18.6	10.3	3.4	15.57
Average minimum (°C)	−6.3	−5.7	−2.0	3.2	7.4	11.5	15.6	15.2	10.7	6.3	0.8	−4.1	4.38
Average precipitation (kg/m ²)	154.1	178.4	175.2	170.2	101.2	23.4	5.8	4.2	18.0	93.0	149.6	158.8	102.65

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