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Monitoring of Corrosion in Fairy Chimney by Terrestrial Laser Scanning

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Abstract: Fairy Chimneys is only a riches of natural and cultural of world and is generally founded in Cappadocia Region of Turkey. Fairy Chimneys have a fairly important worth in point of historical and touristic. When geographic events have formed to fairy chimneys in historical period mankind built house and church inside of fairy chimneys. Mankind decorated these church and house with fresco. Mankind reached to these days more thousand civilization. Ago 60 billion years, region has been formed from softlayers, which being constituted from lava and ash spewed out by Erciyes, Hasan Mountain and Güllü Mountain, abraded by rain and wind along billion years. Faity chimneys have been constituted and disappeared by natural effects. In this study, deformation in a fairy chimney, which is located in Selime district of Aksaray province that is west door of Cappadocia region, has been investigated. Fairy chimney has been modelled as three dimensional by terrestrial laser scanning method in three periods. Volumes of fairy chimney have been computed from the same reference surface in every period. It was determined that deformation being or not from volume difference.

Keywords: Fair chimney, Cappadocia, Terrestrial Laser Scanning, Deformation

Introduction

Cappadocia Region is a place where nature and history unite. Erciyes, Hasan Mountain and Göllü Mountain in Cappadocia Region were all active volcanoes in geologic periods. In addition to these volcanoes, the eruption of many other volcanoes started during Top Miocene (10 million years ago) and continued till Holocene (to present day). Lavas emerging from the volcanoes under Neogene lakes, formed 100-150 ms thick tuff layers with differing hardness over plateaus, lakes and rivers (URL-1, 2008). The top of tuff layer was covered by a thin lava layer which had in some places hard basalt. Basalt was cracked and broken into pieces. Rain water leaked from these cracks and abraded soft tuff. Heated and cooled air together with winds also accompanied the formation. Thus cones which had hard basalt rock tops were formed. These rocks with unusual and interesting shapes were called "Fairy chimney" by local people (URL-2, 2008).

Fairy Chimneys, available in several places on earth, are most common in Cappadocia Region. Consequently they are named as one of the 7 Wonders of Earth. Depending on the strength of rock on top, fairy chimneys may have brief or long spans of life. In Cappadocia Region, fairy chimney types caused due to erosion are topped, coned, mushroom shaped, columned and sharp rocks. Diameter of fairy chimneys varies between 1 m and 15 ms. In cases when crack gap is lower than 1 m or bigger than 15 ms, no fairy chimney formation can be observed (URL-3, 2008) In this study, deformation in a fairy chimney which is located in Selime district of Aksaray city Güzelyurt town is investigated by employing Terrestrial Laser Scanning method.

Study Area (Selime)

The investigated fairy chimney in this study is located in Selime district of Güzelyurt town in Aksaray city which is gate of Cappadocia Region in the west wing (Figure 1). Selime district is 35 km away from Aksaray.

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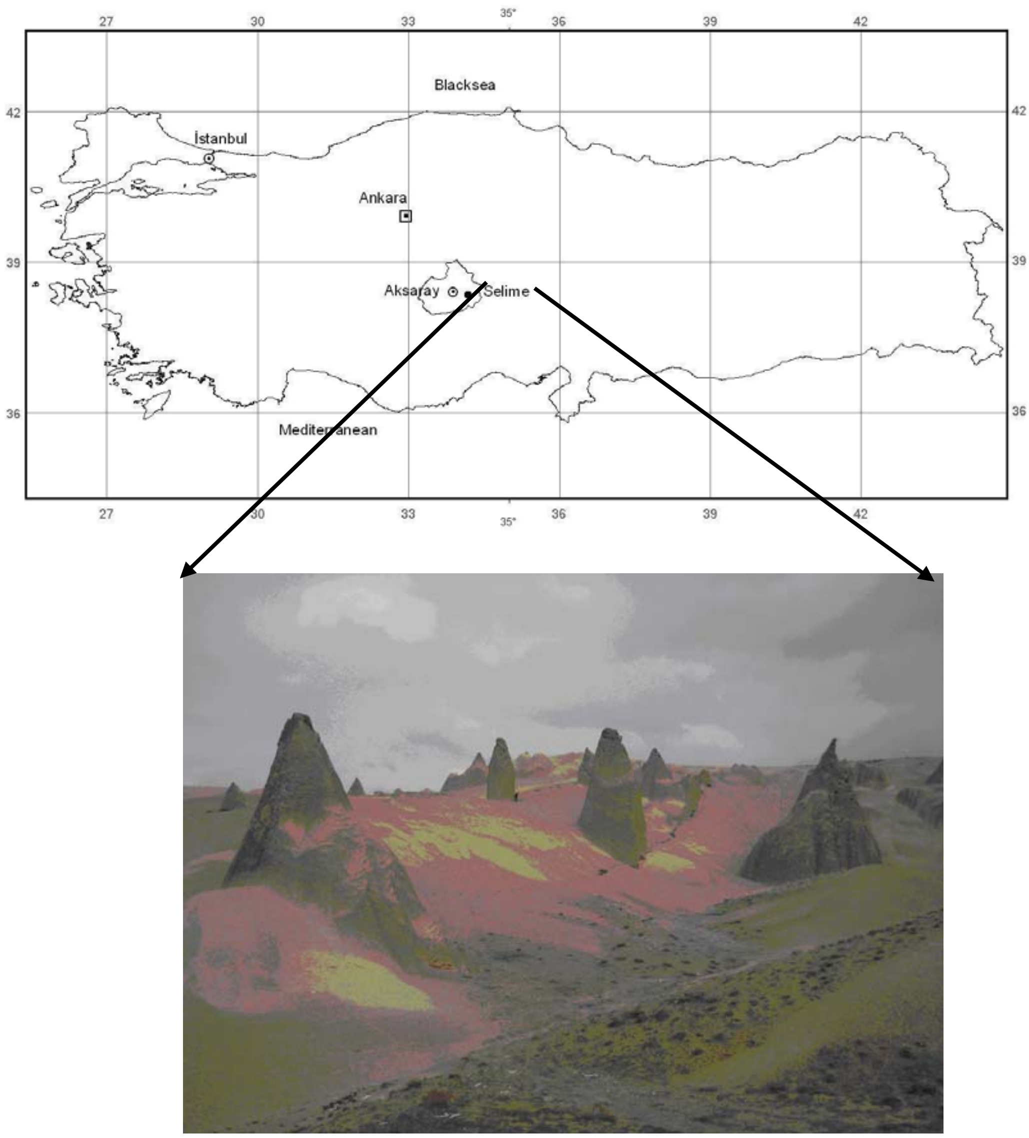

Figure 1. Location of Selime District and Study Area

Terrestrial Laser Scanning Method

For the past few years, 3D (three dimensional) terrestrial laser scanning systems have been employed very successfully in many engineering applications. These scanning systems allow the user to survey structural surfaces and 3D bodies. The data is then transferred to computer where it is converted into accurate three dimensional models. The high quantity and precision of the measured points enable the user to generate realistic, 3D illustrations of complex structures (Shulz & Ingesand, 2004). 3D terrestrial laser scanning techniques are an effective method of creating complete, 3D documentation of the spatial geometries of an object. They yield a maximum of information and have unsurpassed accuracy to within a few millimetres. The recording techniques are hands-free which allows hazardous sites to be easily documented from a distance of more than 100m. The 3D data recorded during terrestrial laser scanning can also be simultaneously converted into detailed, photo-realistic 3D illustrations. This is achieved by combining real colours information from images taken using a high resolution digital camera with the data from the 3D laser scan (Demir *et al.,* 2004)**.**

3D terrestrial laser scanning is considerably more economical than conventional techniques thanks to accelerated surveying procedures and the reduction in time spent on site. Once data retrieval has been completed, all further measurements are carried out on the model. Repeat recordings on site are rendered completely unnecessary. 3D coordinates in terrestrial laser scanning are obtained as point clouds. Many 3D coordinates on an object's surface is measured in a very short time. Important object features, such as corner points or edges, are not directly recorded; instead they have to be modelled from the point clouds in a separate process. While it is possible to record the same object several times from different observation points, it is impossible to record the very same points in these repeated surveys. Therefore, deviations can only be noticed after objects have been extracted from the point clouds and modelled. If the geometric properties of the object are known, however, the deviation of single points from the object's surface may be an indication for the accuracy. Using a plane surface would be the simplest case, but cylinders, spheres or irregular surfaces can also be considered (Ingensand *et al.,* 2003).

Terrestrial laser scanning technology seems to be a very promising alternative for many kind of surveying applications. Terrestrial laser scanners allow acquiring very quickly a huge amount of 3D data which can be often profitably combined with colour high resolution digital images to provide a 3D representation of the environment where we live. As a major advantage of this approach, real objects can be represented more adequately than through a single picture or collection of pictures, by providing a higher level of detail together with a good metric accuracy. These models are currently used for cultural heritage, industrial, land management or also medical applications. In the cultural heritage field, 3D models represent an interesting tool for as-built documentation and interactive visualization purposes, e.g. to create virtual reality environments. In some cases (El-Hakim, 2001) 3D models obtained by laser scanning were used to fill a virtual environment with real objects, in order to get a faithful copy of a real environment, such as the interior of a museum or historical building. Nowadays, the use of laser scanner based 3D models in VR systems (i.e. a cave) opens new perspectives both for entertainment applications and for scientific research, though different information content is required. Indeed, while in the former case the interest is pointed mainly towards to the visual appealing (viewing quality) of the model, for scientific applications the geometric accuracy of the 3D plays the main role, regardless the size and shape complexity of surveyed object.

Laser scanning means the deflection of a laser beam by moving (sweeping or rotating) mirrors, the reflection of the laser beam on object surfaces, and the receiving of the reflected laser beam. In opposite to measurements on reflectors, the accuracy of distance measurements depends on the intensity of the reflected laser beam. Physical laws describe the functionality between accuracy and intensity (Gerthsen, 1993). Main parameters in these functions are the distance, the angle of incidence, and surface properties (Ingensand *et al*. 2003) (Shulz & Ingesand, 2004).

Geologic Structure of Study Area

The schist observed regionally in study area and its surrounding is located within the geologic unit which is defined under Central Anatolian Massive. Litostratigraphy units of study area are formed by Selime tuffs, Kızılkaya ignimbrite and alluvium (Figure 2).

It is probable that Selime tuff was formed as an outcome of proclastic materials which emerged due to volcanism, sedimentation on a lake-like basin. In topography as well, the presence of cracks and fractures which are on the whole formed because of cooling in every direction and the steep nature of slope inside the ignimbrites which are characterized with mesa shaped plains caused the fall of many rocks in study area. In study area Kuvaterner old alluviums are observed as unstuck pebbles, clay, sand and soil around Melendiz stream. The modern formations are represented by different sized pebbles gathered on slopes of tall hills and their feet (Güncüoglu *et al*. 1991, 1992).

The formation of a fairy chimney is diagrammed in Figure 3. It is observed that in the first phase, over tuff ignimbrites are formed, in the second phase falls due to abrasions caused by natural elements are experienced, in the third and fourth phases abrasion keeps on and in the last phase a fairy chimney which is partially completed can be seen.

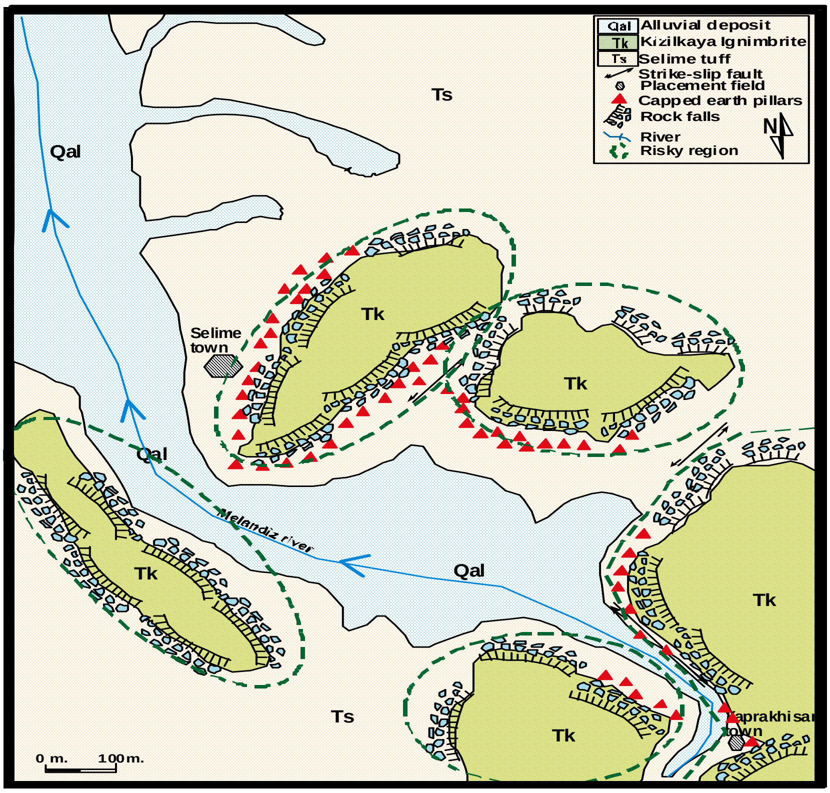

Figure 2. Geological map of the study area

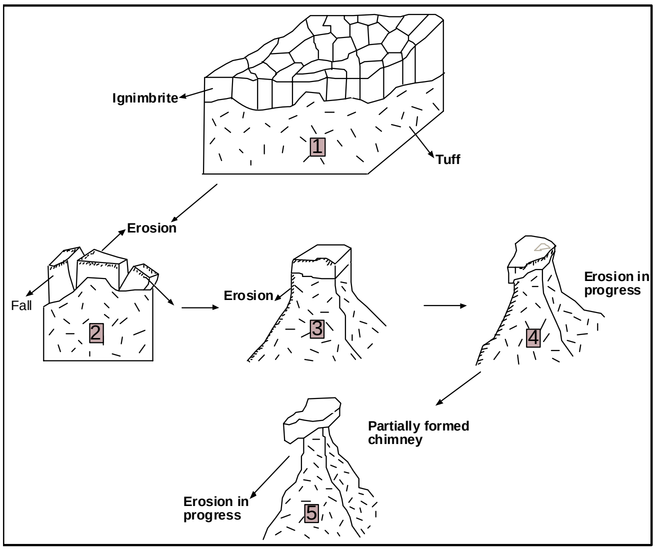

Figure 3. A schematic representation of the formation of a fairy chimney

Application

The fairy chimney selected for application was scanned by Optech terrestrial laser scanner during May and October 2007 and May 2008 with 1cm scan intervals. Data obtained by scanning were evaluated in Polyworks software. Gathered cloud findings were combined by employing cloud uniting points. By means of employed control points, data were transferred into local coordinate system established in land. In both periods, volumes of fairy chimney were calculated from the same reference height. The existence of deformation in fairy chimney was investigated according to volume differences. At the end of terrestrial laser scanning, 3-D model of fairy chimney formed by point cloud obtained and reference surfaces employed in volume calculations are given in Figure 4. In all three periods, volumes of fairy chimneys were calculated according to five reference surfaces. Obtained volume values and differences between periods are given in Table 1.

Table 1. Volumes measured in fairy chimney

May 2007-October 2007-May 2008	Fairy Chimney				
	Volume (m^3)			Differences (cm^3)	
Period /Reference Surface	**Period I**	**Period II**	**Period III**	**I-II**	**II-III**
RS 1	61.402565	61.402417	61.402257	148	160
RS 2	21.477905	21.477831	21.477750	74	81
RS 3	2.563191	2.563171	2.563147	20	24

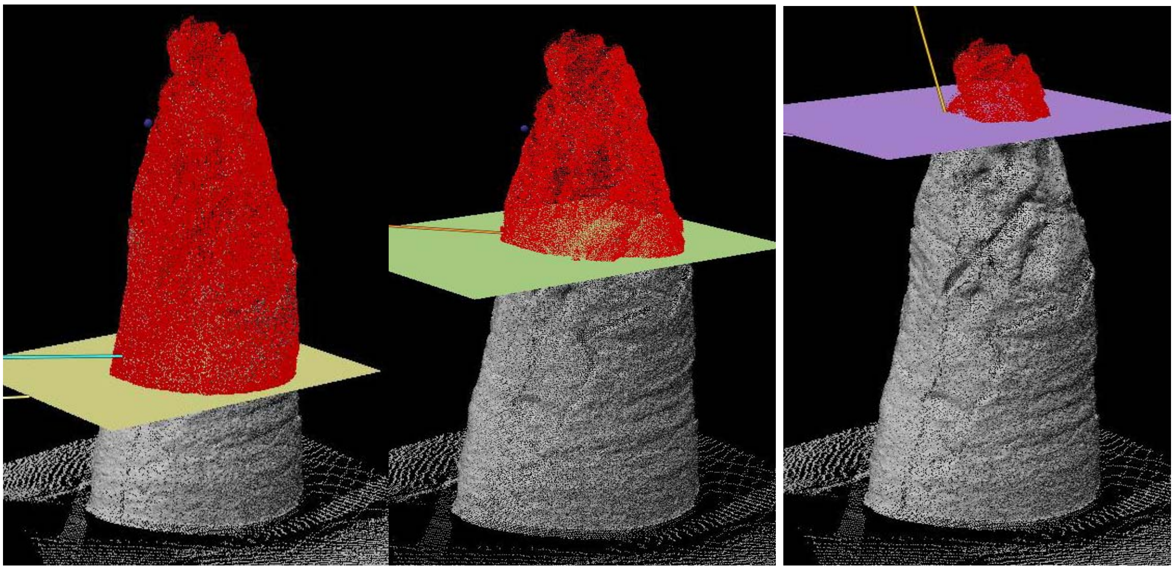

Figure 4. *3-D* point cloud of fairy chimney and reference surfaces

It is seen that there are very small changing on Fairy Chimney according to Table 1. Volume differences are into error limits. According to these values, it is not say that there is continuous corrosion on Fairy Chimney.

Results

Fairy Chimneys are amongst the most significant historical and cultural entities world possesses. They offer historical, touristic and economical contributions to the regions they are in. Fairy Chimneys were formed long ages ago due to natural phenomena. Similar to living beings, they also are formed by natural causes, they develop and after a certain period of time they disappear. In time, depending on geologic structure, deformations take place on fairy chimneys as an outcome of natural phenomena such as rain, wind or humidity. Besides, in the end either due to these natural causes or physical interventions, they disappear. In this study it was investigated whether or not any deformation took place on a fairy chimney during a six-month period and terrestrial laser scanning method was employed for that purpose. Terrestrial laser scanning method is a technology which creates three dimensional points with accuracy in mm level. Fairy chimney was scanned in different periods with 1 cm horizontal and vertical intervals. The existence of partial erosion was investigated according to volume differences. At the end of study, it was detected that there was a partial erosion in fairy chimney and this erosion was caused by the physical intervention on fairy chimney. In order to detect the possible erosion on fairy chimney more accurately, measurements should be performed in more frequent intervals and the amount of deformation, if any, should be connected with meteorological data so that more accurate and scientific results can be obtained in terms of the relation between natural phenomena and formation and disappearance of fairy chimneys. Additionally, it is considered that laser scanning method which can detect thousands of points of which three dimensional coordinates are known in a short time with mm sensitivity is one of the most appropriate methods to obtain three dimensional models of objects with irregular surfaces, such as fairy chimney, and perform process in line with these measurements.

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