Application of IRSL Method for Dating of the Suleghan Landslide: The 23 February 958 M_S 7.1 Ray-Taleghan/Ruyan Earthquake

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ABSTRACT

Study of earthquakes in mountainous ranges suggests that large magnitude earthquakes have usually caused multiple landslides. The southern part of central Alborz contains many landslides. Several seismic events have occurred in this area. Without having the absolute age of each individual landslid it is not possible to attribute the landslide to specific seismic events. So, we are faced with a completely unknown seismic event which has triggered the mass movements. To evaluate the potential of luminescence dating for finding the absolute age of landslides in Alborz, we decided to initiate our work with dating two large landslides (Suleghan and Keshar-e Sofla) in the north of the Tehran megacity, which had the potential of being earthquake-induced landslides. We used Suleghan landslide dammed-lake deposits to obtain the age of seismic event employing the Infrared Stimulated Luminescence (IRSL) for feldspar grains. We obtained the age of the mass-movement event less than 1.03 ± 0.08 ka. Our result suggests that the Suleghan landslide was triggered by the 23 February 958 M_S 7.1 Ray-Taleqan/Ruyan earthquake. Based on this work, careful study of landslides using OSL dating methods can lead to determining the age of other mass movements in Iran. Multiple landslides with identical age will be attributed to a seismic event. That seismic event can be a known earthquake or an unknown earthquake. Finding an unknown earthquake will complete the earthquake catalogue and a better hazard assessment.

Keywords: (Mass movements, IRSL, Suleghan, Ruyan Earthquake)

INTRODUCTION

Study of large earthquakes in mountainous ranges suggests that moderate to large earthquakes have usually caused multiple landslides (McCalpin, 2009). A classic example is the Roudbar-Manjil earthquake (A magnitude 7.3 earthquake on June 20, 1990 in the Alborz mountain range). More than 100 landslides were triggered by the earthquake, of which some were catastrophic. Therefore, landslides can be analyzed to determine the likelihood of seismic triggering. Due to their importance, McCalpin (2009) has dedicated one chapter of his book entirely to explain how to use landslides for Paleoseismic analysis.

Earthquake induced landslides (EILs) are among the greatest geological features for paleo seismological purposes, because they are present in all climates and can be preserved for millions of years in geological records. Recognizing the seismic origin of ancient EILs is the biggest challenge facing these studies, after which the next step is to calculate the age of the landslide to determine the timing of the earthquake that created it. This paper attempts to examine the potential of Landslides for paleoseismic analysis along the North Tehran Fault (NTF). We used Infrared Stimulating Luminescence (IRSL) dating method to study the lake sediments developed by an ancient EIL along the NTF.

GEOTECTONIC SETTING

Torabi et al. (2018), conducted extensive literature review in the North of the Tehran Megacity to find suitable sediments to be dated with OSL dating methods. They have tried i) to choose a region that is close to the NTF, ii) an attempt has been made to select a region that has reports of historical earthquakes, iii) a cluster of landslides has taken place in a nearby area, and iv) the seismic origin for landslides can be interpreted. They suggest a segment of the NTF with the approximate east-west trend which is located in the meisoseismal area of the 958 AD Ray-Taleghan/Ruyan earthquake, and in the vicinity of it, in the Kan-Suleghan area (Fig. 1).

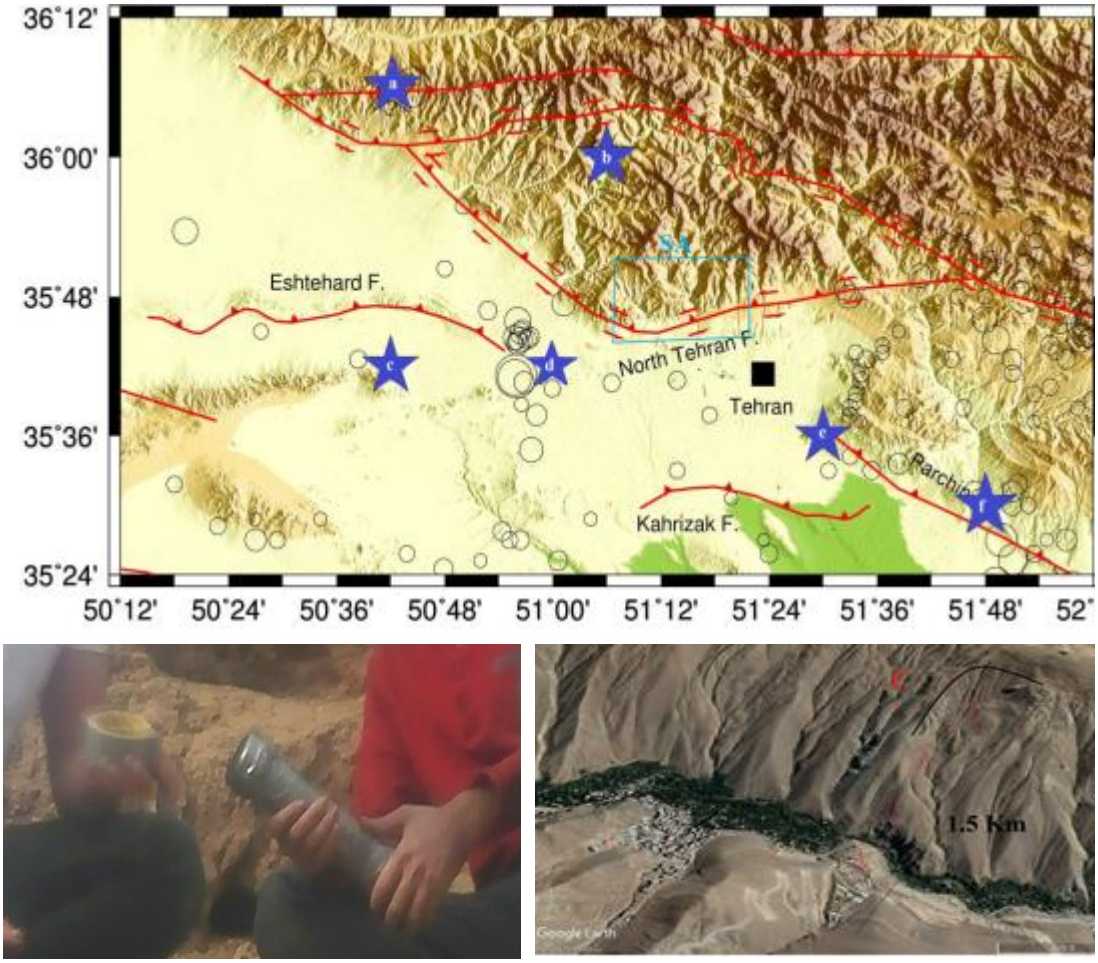

Figure 1. Top) Sothern part of Central Alborz region (North of Tehran), and its major faults. Hollow circles are Instrumental earthquakes and blue stars are Historical earthquakes (Ambraseys and Melville, 1982; Berberian and Yeats, 1999). Blue stars: a 958AD, b 1830 Damavand-Shamiranat, c1177 East Buyin Zahra, d 312-280BC, e 855AD and f 743AD. The blue rectangle represents the study area (from Torabi et al., 2018). Bottom/ right) Suleghan landslide. Bottom /left) IRSL sample.

We used their suggestion and we collect a sample for IRSL dating methods from Suleghan landslide dammed-lake sediments. Torabi et al. (unpublished) showed that the movement of rock and soil in Suleghan landslide was very fast. The displacement in the Suleghan landslide occurred at a slope between 15-20 degree. Considering the length (~1000m), width (~500m) and scarp height (~40m) components of the Suleghan landslide, about 20 million cubic meters of rock materials has been displaced. The displacement of this volume of sediment and rock on a gentle slope indicates the role of a seismic shock. There were also signs of rapid movement in field studies. The rounded slabs on the dam deposits were raised from the river bed by landslides, about fifty meters high on the western wall of the valley. Considering these observations, we decided to select the lake sediments for our study, since the zeroing of the luminescence clock for other

sediments was unlikely. Sulaghan lake sediments are located in both sides of valley and in the thickness between 50 cm-2 m.

IRSL DATING

The IRSL sample was transferred to the Luminescence Laboratory of the Institute of Geophysics, University of Tehran and all the experiments reported here were carried out in a Lexsyg Smart reader (one of the most sensitive TL/OSL reader, fitted with a beta ^{90}Sr-^{90}Y; 1.6 GBq irradiation unit) equipped with LEDs with an emission bandwidth of 50 to 150 nm and laser diodes for some excitation bandwidths of 2-5 nm as optical stimulation sources. The IRSL sample was collected under a lightproof tarpaulin fabric by hammering stainless steel tube horizontally into freshly cut vertical section of the Suleghan dammed-lake deposits and then covered with an aluminum foil soon after taking it from the section, then sealed in a black plastic bag. The IRSL sample preparations was conducted in subdued red light condition and each end of the sample was scraped away for water content and dose rate measurements. One kilogram of the sample (contains sediments from each end of the stainless steel tube) was sent to Zarazma Lab, Tehran, Iran to calculate the percentage of radioactive elements (U, Th and K) using ICP-MS method for calculating dose rate.

The single-aliquot regenerative (SAR) dose protocol of quartz (Murray and Wintle, 2000) was applied to aliquots (200 aliquots) of 90–150 μm feldspar, which were prepared by wet sieving, HCL and H_2O_2 treatment, followed by heavy liquid separation ($<$2.58 g cm^{-3}). Then the feldspar separates were mounted as a monolayer (approximately 5 mg/disc) on 10 mm diameter aluminum discs using a silicon spray as an adhesive.

The final results of this sample are shown in Tables 1 and 2. Our results suggest the occurrence of an earthquake around 1.03 ± 0. 08ka which is the 23 February 958 M_S 7.1 Ray-Taleghan (Ambraseys and Melville, 1982)/Ruyan (Berberian, 2014) earthquake.

Table 1. Values used to calculate luminescence age from Suleghan sample.

Depth (m)	±	Water (%)	±	K (%)	±	U (ppm)	±	Th (ppm)	±	Cosmic (Gy/ka)	±
0.45	0.05	5.00	0.40	2.04	0.05	2.10	0.05	5.31	0.16	0.26	0.03

Table 2. Equivalent dose results of feldspar gain of the Suleghan sample.

Sample ID	De (Gy)	±	Total (Gy/ka)	±	Age (ka)	±
IRSL 50	3.71	0.25	3.59	0.11	1.03	0.08

CONCLUSIONS

In this study, we have collected and dated a sample of the earthquake-induced Suleghan landslide dammed-lake deposits in the north of the Tehran megacity using IRSL dating method. We obtain an age of about 1.03 ± 0. 08ka for the feldspar grains (stimulation at 50ºC). Our results indicate that the 23 February 958 M_S 7.1 Ray Taleghan / Ruyan earthquake have triggered the Suleghan landslide. Therefore, careful study of landslides using OSL dating methods can lead to recognition of historical and prehistorical unknown earthquakes and a better hazard assessment.

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