# The estimated slip-rate and recurrence interval of the Doruneh fault, Khalilabad segment (NE Iran) using IRSL correction method

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## ABSTRACT

The slip-rate of the Doruneh fault (DF) and its recurrence interval, is one of the issues that have been widely studied in recent years. Different numbers are given for fault slip-rates (1-8 mm/yr) in different regions. Due to the obvious difference between the results of different methods for the presented numbers, recently the accuracy of the methods and the desired values have been considered. By re-examining the sediment samples collected from the Khalilabad area in western Kashmar, and also using the IRSL age correction method, we have corrected the previously calculated values. Based on our work, a slip-rate of 3.15 mm/yr was calculated for this segment of the fault, which confirms the previous results. Also, the recurrence interval of this segment of DF is 1270 years.

**Keywords:** Doruneh fault, Slip-rate, Khalilabad, IRSL

## INTRODUCTION

The DF extends 600-900 km in a curving form, from central Iran where it strikes SW-NE, through NE Iran where it strikes roughly W-E, and to the Iran-Afghan border where it strikes WNW-ESE (Javadi et al., 2015). Although the researchers consider this fault to be left-lateral, but along the fault, evidences of right-lateral movements has also been observed in the Holocene sediments (Torabi et al., 2022).

A lot of effort has been made to understand the behavior of DF in recent years, which has produced conflicting results. There is almost no consensus on any aspect of this fault's specification. From the length of the fault, for which different numbers between 400-600 and 900 km are reported, to the movement mechanism and also its slip-rate (Mousavi et al., 2021 and references therein). The last one has created more sensitivity among earth science researchers. Where the results of different methods of determining the slip-rate have shown contradictory results. Synthetic aperture radar (SAR) interferometry resulted in a left-lateral strain accumulation of 5 mm/yr, while campaign and permanent GPS measurements show maximum ~ 2 mm/yr. A similar apparent difference between Quaternary dating methods is also observed. The values obtained from the OSL method were between 2.5-3 mm/yr, however, the results of the TCN dating method show numbers between 3-8 mm/yr (Mousavi et al., 2021 and references therein).

In this article, we have tried to test the correctness of the previously reported results of the IRSL method by re-examining the sediment samples collected from the Khalilabad region (the central segment of the fault).

## LEFT-LATERAL OFFSET

The left-lateral movement of the DF in the west of Kashmar and in the Khalilabad region has displaced the late Quaternary alluvium deposits by about at least 60 meters. The values of these displacements were considered to be 50±10 meters (Farbod et al., 2011), while our measurements show that at least 60 meters of measurable displacement occurred. The 1940 earthquake with a magnitude of 6.5 near the village of Farsheh in the area shows an offset of 4 meters for the last movement of the fault (Farbod, 2011).

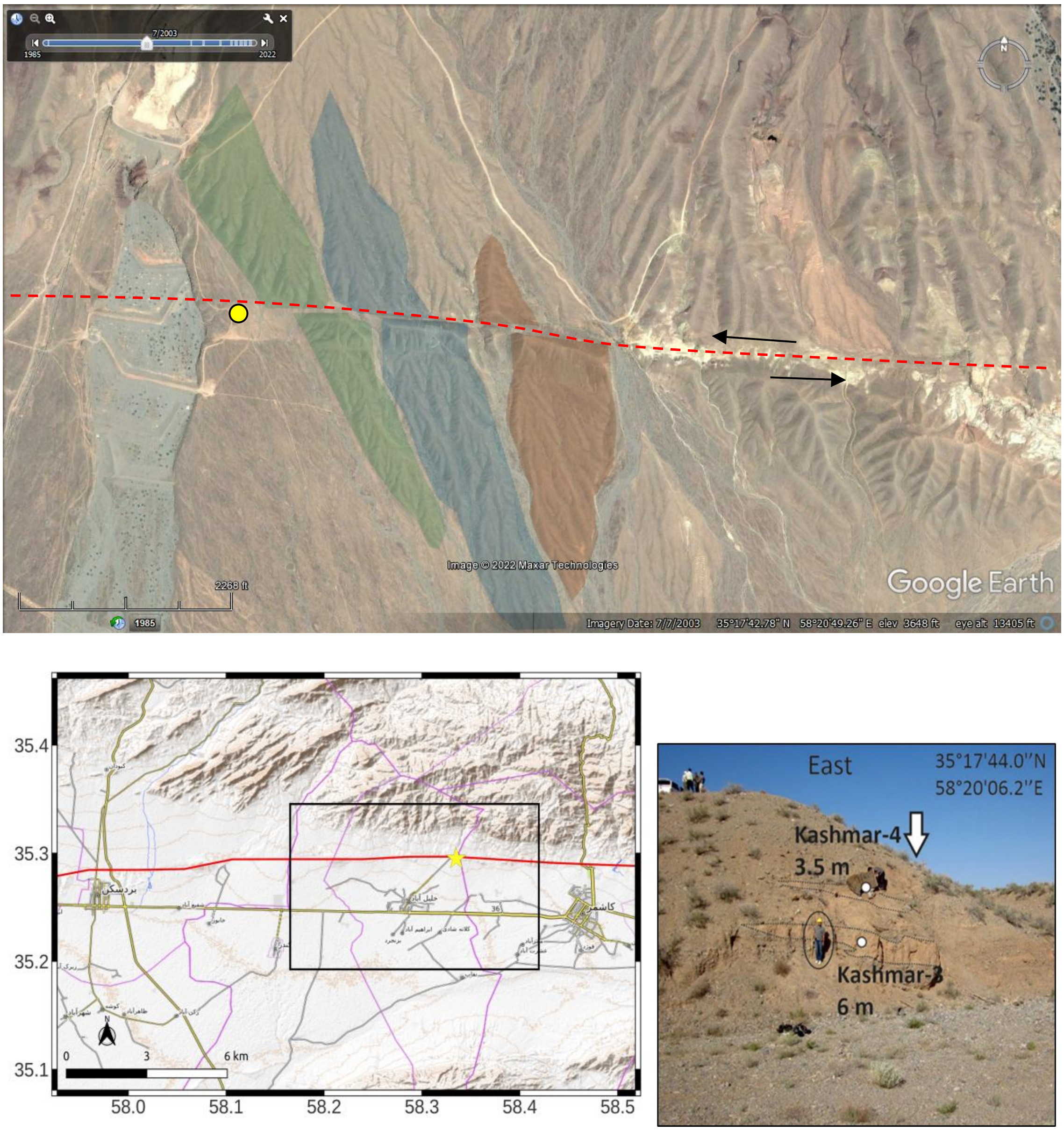


**Figure 1.** **Google earth view of study area and map of the Kashmar-Khalilabad. The DF left-lateral movement created offsets of ≈ 60 m on the late Quaternary river terraces and alluvial fans. Yellow circle represent the sampling location for Q3 and Q4.**

## IRSL CORRECTION METHOD AND DATING RESULTS

To constrain the timing of the offsets, two IRSL samples (Q3 and Q4) were collected under a lightproof tarpaulin fabric by hammering stainless steel tube horizontally into freshly cut vertical section of the alluvial deposits (depth of IRSL samples were 3.5 and 6 m respectively) and then covered with an aluminum foil soon after taking it from the section, then sealed in a black plastic bag. All the luminescence measurements have declared here were carried out in a Risø (Model TL/OSL-DA-15) automated TL/OSL system (fitted with a 90Sr/90Y beta source delivering ~5 Gyr min-1) equipped with an IR laser diode (= 830 nm) as stimulation sources.

The De of feldspar grains (60-90μ) was obtained using single-aliquot regeneration methods (Table 1). An example of decay curve signals and curve fittings of feldspar gains of this samples are shown.

**Table 1.** Generalized single-aliquot regenerated sequence of feldspar grains (Fattahi et al., 2007).

| Step | Treatment | Observed |
|---|---|---|
| 1 | Give dose | - |
| 2 | Pre-heat (240-320 ºC) 260 ºC | - |
| 3 | Stimulation (at 125ºC) | Lx |
| 4 | Give test dose | - |
| 5 | Heat (240-320 ºC) | - |
| 6 | Stimulation (at 125 ºC) | Tx |
| 7 | Return to 1 | - |

Ideally, the ratio between the measured dose and the laboratory dose (recycling ratio) should be 1. In practice, this value can change between 1.1 and 0.9. Larger or smaller values of this ratio indicate that this aliquot should be excluded from further measurements. It is usually possible to improve the recycling ratio by changing the pre-heat temperature. Here, all preheat temperatures succeeded in correctly recovering the dose. But according to the measurements, the temperature of 260 degrees was chosen as the most suitable pre-heat temperature. For IRSL dating, we need two parameters. Equivalent dose (De) and dose rate. The results of the De are shown for three methods: weighted mean, histogram and radial plot.

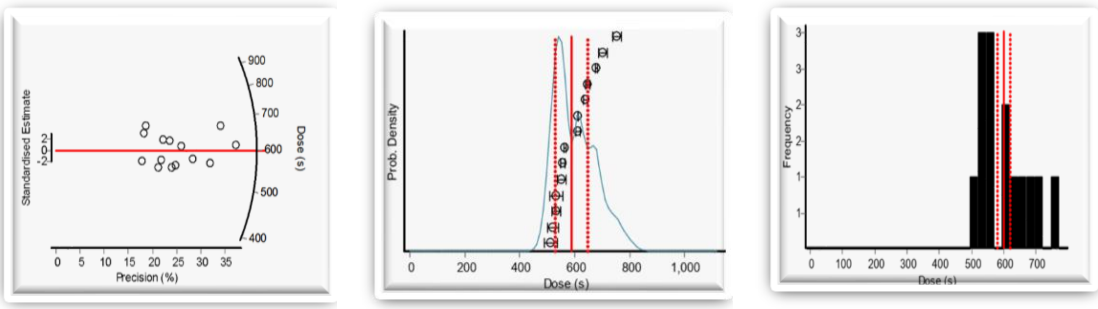


**Figure 2. Left: Radial plot, middle: Weighted mean, and right: Histogram of Q4 sample for De determination.**

The uncorrected ages of 16 (Q4) and 20 (Q3) ka, after correction using the g-value method showed values of about 19-26 ka, respectively. The anomalous fading test and g-value measurement protocol have referred to the Fattahi et al.(2007). According to the age-depth profile, the last period of sedimentation in the region was calculated as 10-19 ka BP (Before Present). Therefore, the maximum age of the surface layer is estimated to be 19 ka, and if we divide this number by the calculated offset of 60 meters, the slip-rate equal to 3.15 mm per year is calculated for this segment of the fault. Our results are in agreement with other values presented for the slip-rate of the middle segment of DF (Mousavi et al., 2021; Walker and Fattahi, 2011; Fattahi et al., 2007).
According to the displacement of 4 meters resulting from the last movement of the fault near Farsheh village, and also by dividing this displacement by the calculated slip-rate, the recurrence interval of earthquakes larger than 6 for this area will be 1270 years.

**Table 2.** To report accurate ages corrected for anomalous fading, we calculated the g-value and then corrected our results.

| Sample | Uncorrected ages (ka) | | g-value | Correction factor | Corrected ages (ka) | |
|---|---|---|---|---|---|---|
| Q3 | Histogram | 20.11±1.1 | 3.2 | 1.3 | Histogram | 26.14±1.4 |
| | Weighted mean | 19.93±2.1 | | | Weighted mean | 25.90±2.7 |
| | Radial plot | 16.33±1.0 | | | Radial plot | 26.07±1.43 |
| Q4 | Histogram | 16.33±1.0 | 2 | 1.2 | Histogram | 19.59±1.2 |
| | Weighted mean | 15.98±1.9 | | | Weighted mean | 19.17±2.28 |
| | Radial plot | 16.20±1.0 | | | Radial plot | 19.44±1.2 |

## CONCLUSIONS

By using the IRSL correction method, we were able to correct the ages obtained from the Khalilabad samples, and report the corrected slip-rate value for this segment of the DF. Age correction and also the age-depth profile show that the age of the upper layer is at most 19 ka. Also, at least 60 meters left-lateral offset can be seen in the area, which by dividing it by the age of the overlying layer, we can expect a slip-rate equal to 3.15 mm/yr. According to the displacement caused by the last movement of the fault in the region (4 meters), the recurrence interval of earthquakes greater than 6 can be estimated as 1270 years.

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