Absolute Dating of Neotectonic Events: A Feasibility Study on Gouge Material from the Nojima and Asano Faults, NW Awaji Island, Japan

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Determining the absolute age of the past faulting activity is crucial for assessing seismic hazards in a particular area. Historical records can be used for such purposes, however they only provide a relatively recent picture of fault activity, which is generally inadequate for drawing concrete conclusions on the seismicity of an area. As such, geochronology approaches try to address this problem using appropriate dating techniques on earthquake-disturbed materials prior to the time of recorded information.

The employment of the luminescence dating techniques is now widely applied to variety of materials and sedimentary environments (e.g., quartz and feldspar from heated archaeological material, sand-dunes and fluvial sediments), their application however on fault-deformed materials still limited, since full resetting (due to mechanical crushing/sliding or frictional heat) of their luminescence signal, during a rupture event, cannot be easily established (e.g., Toyoda et al., 2000), but also due to the limited access to appropriate material (e.g., fault gouges; crushed and ground-up rock produced by friction between the two sides when a fault moves). No systematic effort has been made up to now on the use of luminescence in directly dating material from the brittle zone of a fault which is related to faulting or the earthquake event.

To this end, the current study explore the use of both Isothermal Thermoluminescence (ITL) and Optically Stimulated Luminescence (OSL) to date past seismic deformed features which are directly linked to past seismic events and develop detailed protocols and methodological approaches on the use of the two techniques, so that the long-term temporal behavior of seismically active faults could be realistically evaluated and modeled. This work is part of a feasibility study using fault gouge and breccia material acquired from a drilled core of the Nojima Fault Zone, as well from an exposed outcrop of the Asano Fault, which belong in one of the most active fault systems in southwest Japan (Research Group For Active Faults of Japan, 1991). Our approach is based on an enhanced chronological model which builds on the earlier set of luminescence ages on quartz and feldspar produced by Tsakalos et al. (2018).

Microstructural observations on the Nojima Fault core revealed that the fault gouge zone is made of thin layers (mm to cm) of different colour, with each layers most probably corresponding at least to one seismic slip event (Lin and Nishiwaki, 2019). Thus, to assess the age of the gouge layers, we tried to sample each one individually. As for the Asano Fault, sampling was achieved by hammering steel cylinders in an exposed gouge formation. In the case of Asano, gouge layering was not very clear and thus collected sub-samples most probably contained several gouge layers. Intercalated breccia samples were also collected from both faults.

The Single-Aliquot-Regenerative-dose (SAR) approach (Table 1 and 2) was employed for both ITL (Choi et al., 2006) and OSL (Murray and Wintle 2003) measurements on quartz and feldspar.

Table 1. The SAR-OSL protocol applied to quartz grains.

Step	Treatment
1	Give dose
2	Preheat, 10 s at 240 ˚C
3	Blue-LED stimulation, 40 s at 125 ˚C
4	Give test dose
5	Cut-heat, 0 s at 200 ˚C
6	Blue-LED stimulation, 40 s at 125 ˚C
7	IR diodes stimulation, 100 s at 125 °C
8	Return to Step 1

Table 2. The SAR-ITL measurement protocol applied to quartz and feldspar grains.

Step	Treatment
1	Give dose, D_i [(a)]
2	Heat to 310°C, (hold for 300 s)
3	Give test dose, D_t [(b)]
4	Heat to 310°C, (hold for 300 s)
5	Return to step 1

[(a)] *D_0 = natural dose;* [(b)] *D_t= Fixed test dose*

Typical examples of decay and growth curves of the ITL and OSL signals appear in Fig. 1. Their natural dose and their dose response curves are well described by fitting of a saturating exponential function.

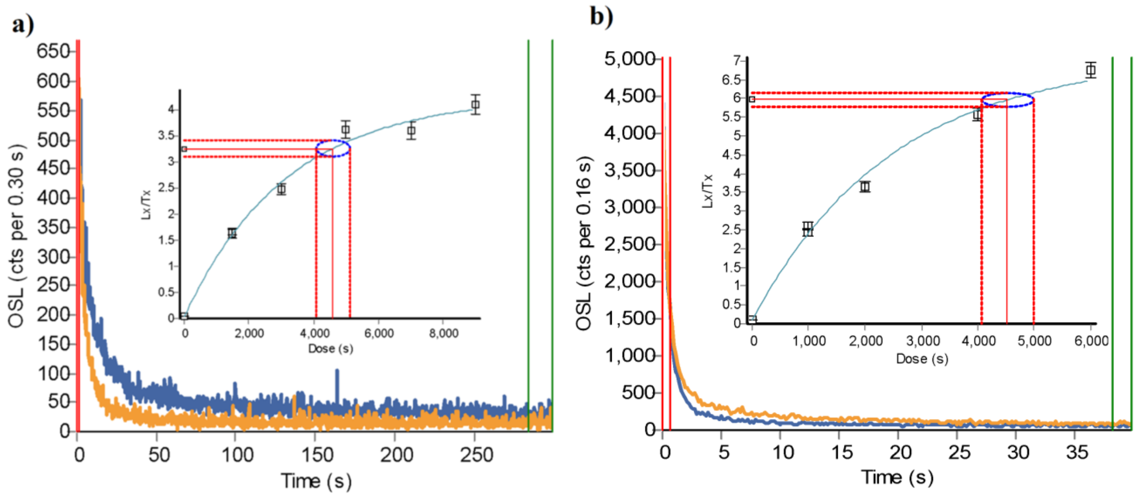

Figure 1. Representative dose response curves and luminescence decay curves for the ITL and OSL signal measured in a) feldspar and b) quarts grain aliquots. Lx/Tx is the corrected luminescence signal for the equivalent radiation dose (D_E).

Luminescence dating results on fault gouge revealed that both techniques could produce reliable results giving very similar ages on the same samples and indicating a continuing activity of the two faults during the Middle-Upper Pleistocene. However, ITL ages were slightly older than the OSL ages, most probably suggesting partial resetting of the ITL signal. It should also be stressed here that, some mixing of the different gouge layers during sub-sampling might be apparent and thus gouge ages may represent a mixture of fault raptures. On the other hand, observations of the OSL and ITL signals of breccia samples appear unusual, not following the expected signal decay behaviour and thus they were excluded from further analysis.

This study is a fundamental advancement in the field of palaeoseismology, as it provides evidence of the potential of the luminescence dating techniques to be used for assessing the neotectonic activity of an area while its methodological approach could become a principal part for geo-hazards evaluations.

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