Measuring earthquake periodicity of the Sparta fault with a handheld XRF

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1. Introduction

Aim of our study

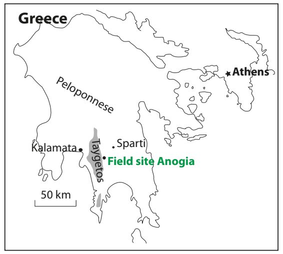
In this study we measure earthquake periodicity of the Sparta fault using a handheld X-ray fluorescence device (XRF) for geochemical analysis. A handheld XRF device can instantly determine the geochemistry of the rock surface. This method requires no drilling and it is possible to analyse the results in field at the fault scarp. Using a handheld XRF to determine weathering patterns would still require exposure dating to yield earthquake periodicity, but the number of sampling points could be highly reduced since it would be possible to pin-point the sample locations.

Introduction

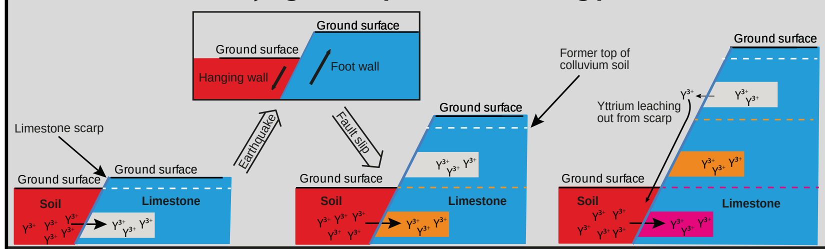
For paleoseismic studies of normal faults with limestone scarps, Zreda and Noller (1998) introduced a method using 26Cl cosmogenic exposure dating to determine the slip history of such faults. This method was later used by several authors; Mitchell et al. (2001), Benedetti et al. (2002), Palumbo et al. (2004), Benedetti et al. (2013). Since the analysis for cosmic ray exposure dating is costly, Carcaillet et al. (2008) instead used geochemical analyses to identify the weathering profile of the fault scarp in order to count the number and magnitude of slips. Both of these methods require drilling or cutting of bedrock for sampling which is complicated and time consuming since the faults are exposed step faults.

The Sparta fault

Our samples site is located close to the town of Sparta on the peninsula Peloponnesus in southern Greece. The Sparta fault scarp delineates a 64 km long normal fault formed in minimally-weathered limestone adjacent to the boundary between the Taygetos Mountains and the Sparta basin. Benedetti et al. (2002) determined the slip history of the Sparta fault with 36Cl cosmic ray exposure dating. They found that the fresh scarp was a product of six major earthquakes, each of them causing a slip of 1.2-2m, during the last 13ka with a range of intervals from 500yr to 4500yr. Benedetti et al. (2002) also dated one event 2800±300yr ago which corresponds to the Ms~7 earthquake, 464 BC (Armijo et al., 1991), which demolished Sparta and perhaps killed up to twenty thousand people (Papazachos and Papazachou, 1997).



Identifying fault slips from weathering profile



Illustration

The hypothesis for our study, first introduced by Stewart (1996), is that the fault plane underneath the colluvium at the bottom of the scarp will interact with the soil in the colluvium. This interaction will leave a chemical imprint in the fault scarp which makes it possible to determine former contacts with the colluvium soil up along the fault scarp. This hypothesis was subsequently supported by a study from Manighetti et al. (2010).

Field site

Our field site is located in Anogia near at the same place site for Benedetti et al. (2002). Our hypothesis is that we can detect fault slips from scarp surface measurements. We assume from 36Cl cosmogenic dating (Benedetti et al., 2002) that the scarp represents a history of 13 kyr. With respect to relatively high weathering rates of limestone, we need to take extra precautions when selecting the scarp section for our study. At the field site used in Benedetti et al. (2002), at Anogia, study we observed what appears to be recent weathering and erosion patterns such as water channels, vegetation, fissures and weathered pockets. Approximately 30 m south of this field site we observed a section off the scarp that shows fewer weathering features where we established our field site.

2. Method

- **Chemical analysis in field every 5 cm along the 6.8m vertical profile with handheld XRF**
- **Rock sampling every 10 cm along the 6.8m vertical profile with portable drilling machine**
- **Chemical analysis of drilled cores with protable XRF in lab**

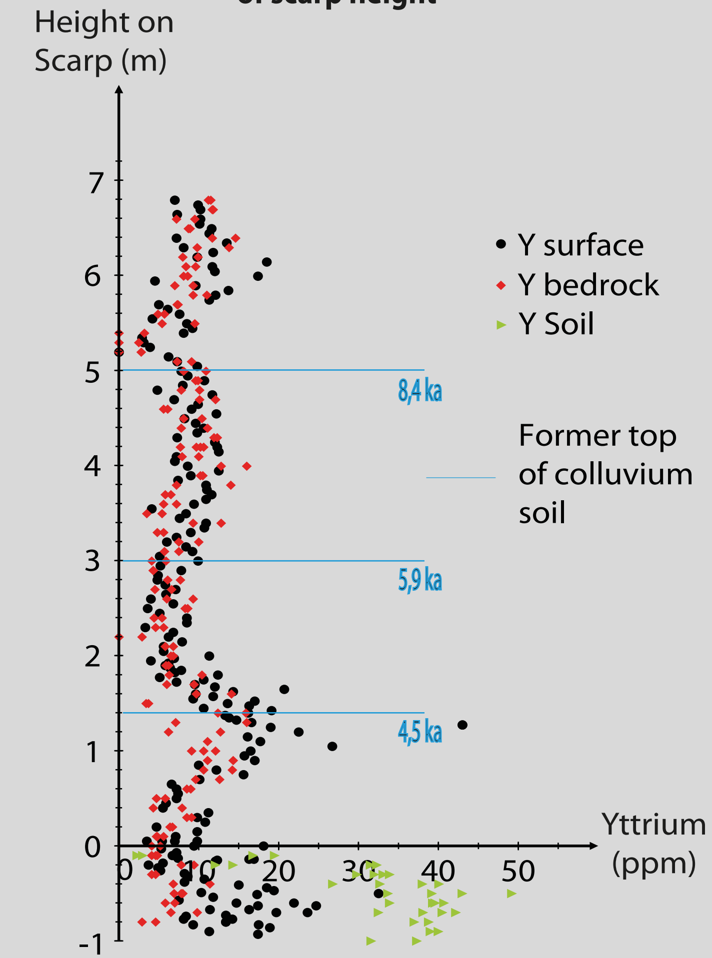
Instrument:
Olympus Innov-X DeltaTM (40kV) handheld X-ray fluorescence device (XRF)

Features:
- Instant result
- Nondestructive
- 60 s per analysis
- Elemental analysis of elements heavier than sodium
- 8 mm diameter sample spot
- Penetration: <1mm (Potts et al., 1997)

3. Result/ Conclusion

- Strong yttrium signal in scarp surface
- Yttrium peak in scarp surface below the current ground surface, repeated up along the profile
- Strong correlation in yttrium concentration between scarp surface and 0.5-1cm into the scarp (bedrock)
- Correlation in yttrium concentration between scarp surface below current ground surface and excavated soil profile
- Indicating correlation with prehistoric fault slips proposed by Benedetti et al. (2002)

Yttrium concentration as a function of scarp height



Plot

Plot showing yttrium concentration (ppm) as a function of height on scarp. All measurements are done with an Olympus Innov-X DeltaTM (40kV) handheld XRF. Black round dots show surface measurements and red diamonds show the measurements from drilled cores 0.5 -1 cm into the bedrock of the scarp. Green triangles show measurements from excavated soil profile. The horizontal blue lines show former top of colluvium soil (ground surface) according to Benedetti et al. (2002).

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