Identifying paleoseismic information from limestone normal faults with a handheld XRF

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Ruben Fritzon[1,2], Arjen P Stroeven[1], Alasdair Skelton[3], Brad WGoodfellow[1] Marc W Caffee[4]
INSTITUTIONS:1. Physical Geography and Quaternary Geology, Stockholm University, Stockholm, Sweden. 2. Research School focusing on Natural Hazards, Stockholm University, Stockholm, Sweden. 3. Geological Sciences, Stockholm University, Stockholm, Sweden. 4. Physics, Purdue Universtiy, West Lafayette, IN, United States.

1. Introduction

Aim of our study

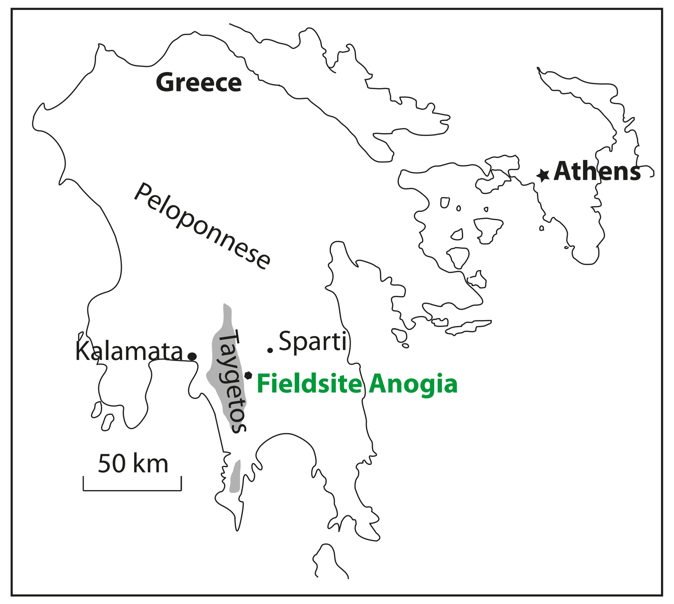
In this study we measure earthquake periodicity of the Sparta Fault through geochemical analyses. We do this using a handheld X-ray fluorescence (XRF) device, which can instantly determine the geochemistry of the rock surface. This method requires no drilling and it is possible to analyse the results 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.

Introdution

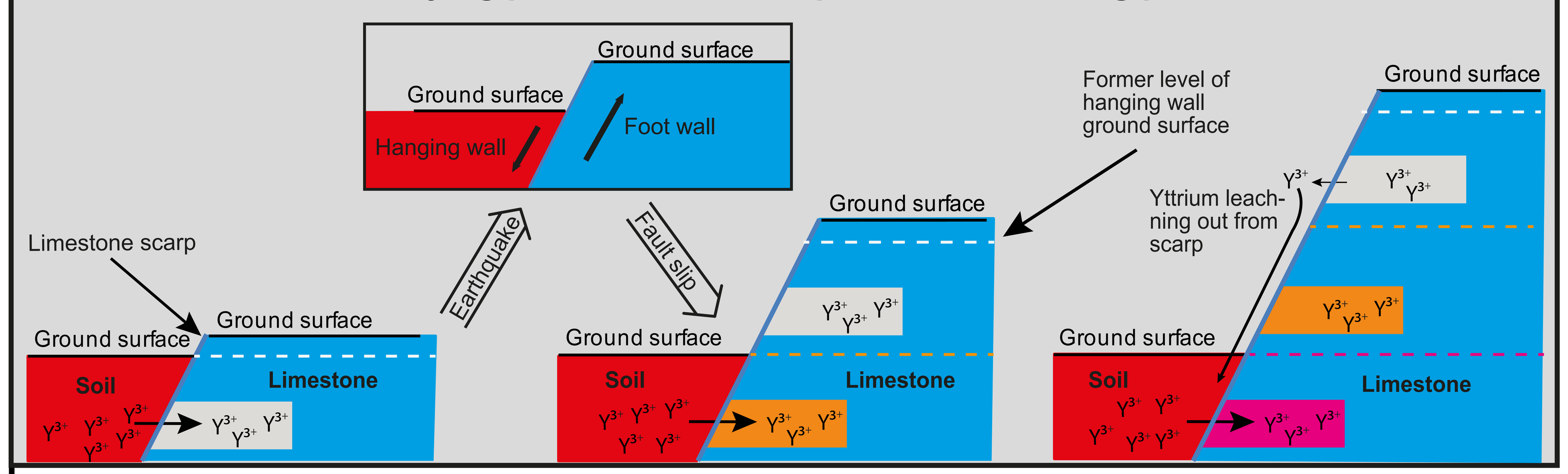
When it comes to paleoseismic studies of normal faults with limestone scarps , Zreda and Noller (1998) introduced a method using ^{36}Cl cosmogenic exposure dating to determine the slip history of such faults.. This method was later used by several authors; Mitchell et al. (2001), Benedetti et al. (2002), 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 requires drilling or cutting of bedrock for sampling which is both complicated and time consuming since the subaerially-exposed footwalls are steep and long.

The Sparta fault

Our sample 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 ^{36}Cl 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 13 ka with a range of intervals from 500 yr to 4500 yr. Benedetti et al. (2002) also dated one event 2800 ± 300 yr 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 prehistoric 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) based on chemical analysis of drilled cores, both from the fault scarp and an excavated part of the rock at the bottom of the scarp.

Fieldsite

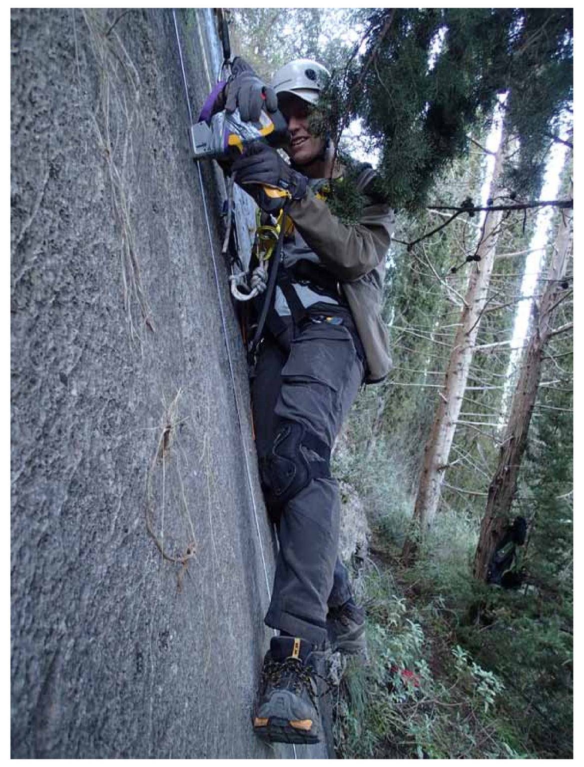
Our fieldsite is located in Anogia, adjacent to the Benedetti et al. (2002) site. Our hypothesis is that we can detect fault slips from scarp surface measurements. We assume from, ^{36}Cl cosmogenic dating (Benedetti et al. 2002) that the scarp represents a history of 13 kyr. With respect to relatively 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) study we observe what appears to be recent weathering and erosion patterns such as water channels, vegetation, fissures and weathered pockets. We established our field site about 30 m South of here on a section of scarp surface on which these features are absent.

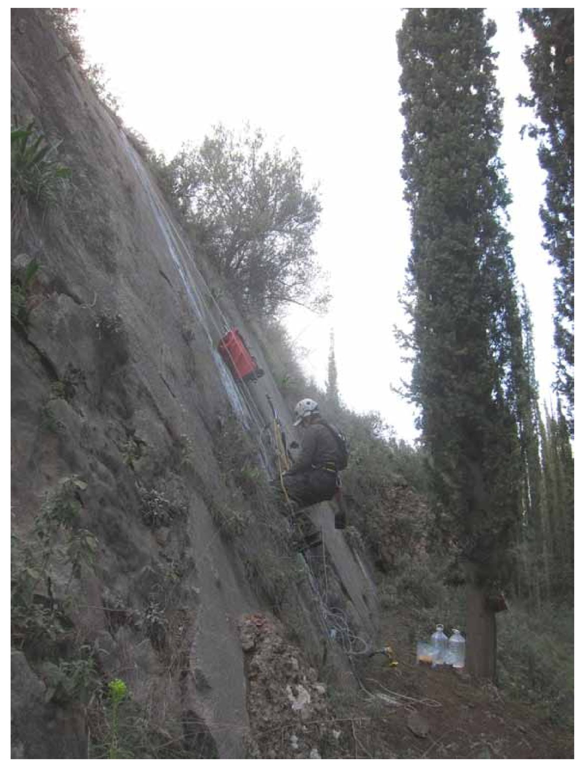
2. Method

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

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

Feature:
- Instant result
- Non-destructive
- 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)

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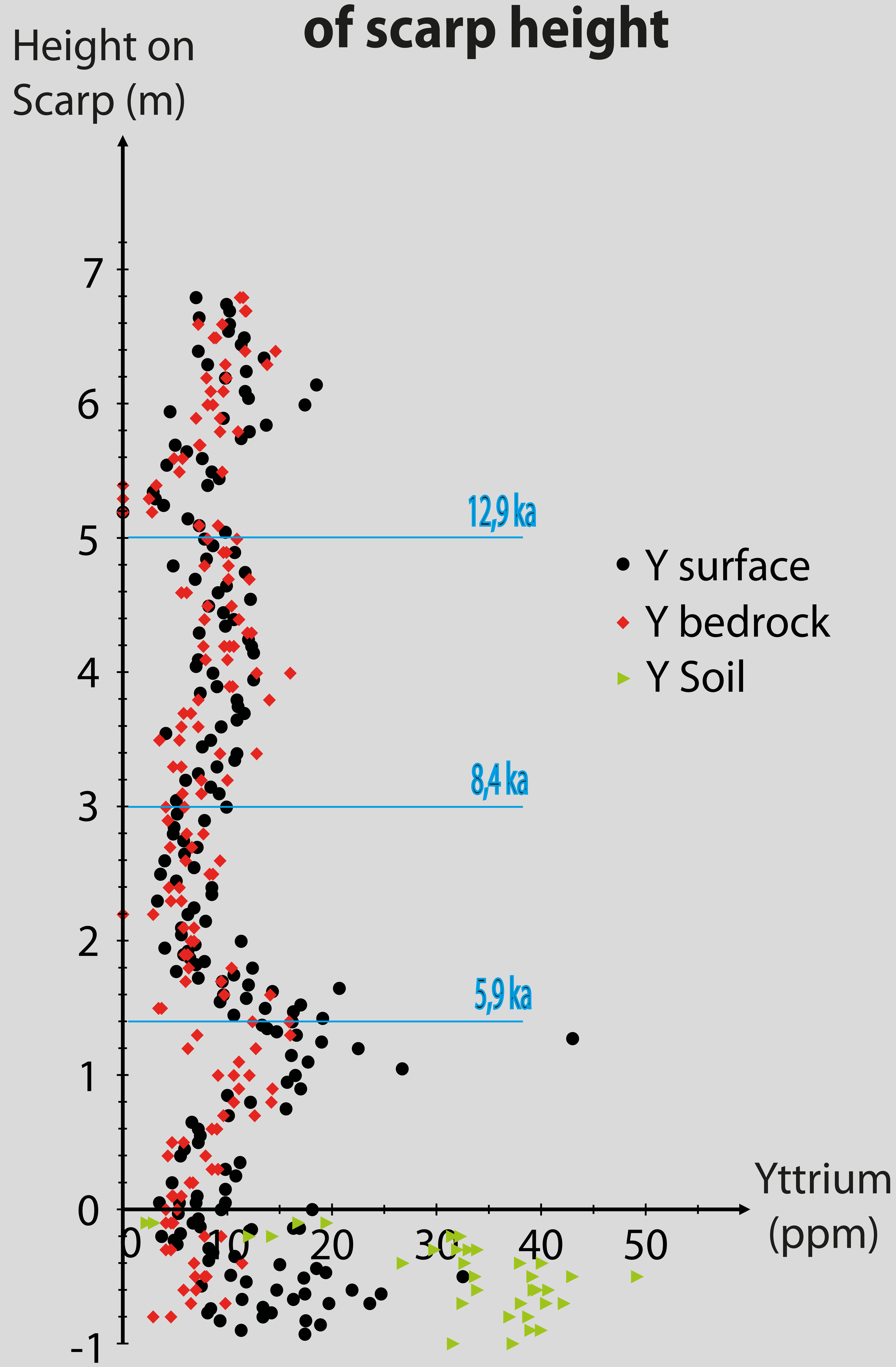
Yttrium concentration as a function of scarp height



Plot

Plot showing yttrium concentration (ppm) as a function of height (m) on scarp. All measurements are done with a Olympus Innov-X DeltaTM (40kV) handheld XRF. Black round dots showing surface measurements and red diamonds showing the measurements from drilled cores 0,5-1 cm into the bedrock of the scarp. Green triangular shows measurements from excavated soil profile.