Thermochronomentry of metamorphic rock complexes on the SE Peloponnese, Greece, using thermoluminescence (TL): preliminary experiments

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Introduction

- Many studies have shown that thermochronometry can reveal the thermal history of rocks in the lithosphere by measuring radioactive decay products within the rock, which start to accumulate as the rock passes through different temperatures (cf. Ault et al.,2018).
- The infrared-stimulated luminescence (IRSL) signal from feldspar grains has been exploited as an alternative low-temperature thermochronometer (e.g. Herman et al.,2010; Guralnik et al.,2015). Nevertheless, typical dose rates encountered in metamorphic rocks limit the application of IRSL to a few hundred thousand years.

Scope

- In the current study, we explore the usefulness of the thermoluminescence (TL) signal of quartz as a thermochronometer to resolve thermal histories of rocks in the upper crust.
- Despite the substantial stability of the TL signal over geological timescales on the order of billion years, the secular environmental dose rate prompts saturation of the TL signal within a few hundred thousand years (Pleistocene). If *extremely-low* radiation environments can be ensured within heated rocks then the TL signal may be allowed to grow on longer time scales (Pliocene or even earlier) and, thus, quartz-TL may be established as a thermochronometer for the Neotectonic period.

Geological Setting & Sampling

- Samples were collected from the center of sizable lumps (a few decimeters in diameter) of quartz cropping out in the “Arna» Unit” (known also as the “Phyllites-Quartzites Unit”) of the southern Peloponnese (Tainaro and Neapolis areas) (red circles in maps).

- Quartz is characterized by remarkably low radionuclide concentrations. If the size of the quartz is such (e.g. a radius of a few decimeters as in current study) that it ensures insulation from any external radiation then the interior of the quartzitic lump can indeed become an extremely-low radiation environment (receiving the influence of the cosmic rays only).

Methodology

Equivalent dose (De) determination

- All analyses were undertaken using an automated system Risø TL/OSL reader DA-20 installed at the Archaeometry Center of the University of Ioannina, Greece using a Schott BG-39 and Corning 7-59 filters.
- A SAR protocol for TL measurement was adopted (Table 1)(Hong et al., 2006) in order to generate growth curves and calculate the equivalent dose by interpolation of the sensitivity corrected natural TL.

Table 1

Step	Sequence	TL
1	Preheat at 200°C	L_x
2	TL measurement from 0° C to 570°C	
3	Test dose irradiation	T_x
4	Preheat at 200°C	
5	TL measurement from 0° C to 570°C	
6	TL measurement from 0° C to 570°C	
7	TL measurement from 0° C to 570°C	
8	TL measurement from 0° C to 570°C	

Dose rate determination

- The dose rate, which is the rate at which energy (alpha, beta and gamma dose rates) is absorbed from the flux of surrounding sediments, is measured at the Archaeometry Center of the University of Ioannina, Greece. Counting the radioactivity with γ-spectrometry, we can determine the U, Th and K concentrations. Moreover, the concentrations of these elements were calculated by ICP-MS technique at the ACME lab, Canada (Table 2).

Results

- The figure 1 illustrates a typical natural TL signal (blue line) and the subsequent test dose signal (orange line). The background remains nearly zero over the range of useful traps (up to 400-450 °C) and, hence, its interference with the signal (natural or regenerated) is deemed negligible.

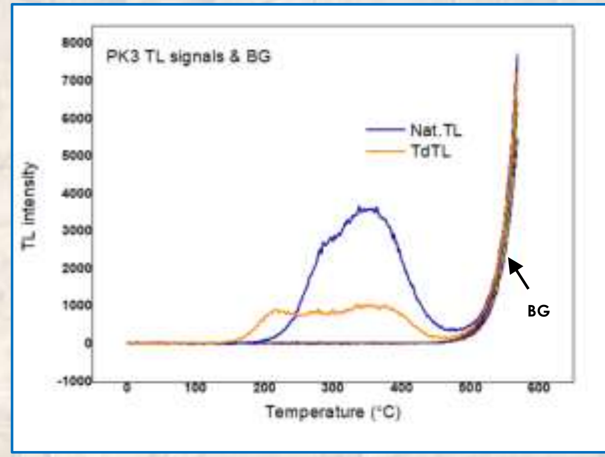

Figure 1

- After the application of a full SAR on several quartz aliquots, we discovered equivalent doses (De) substantially below the saturation levels (typically, a saturated growth curve would be expected for rocks of Oligocene age) (Fig.2). The De proved to be a function of the integrated temperature (i.e. deeper traps yielded higher equivalent doses) (Fig.3).

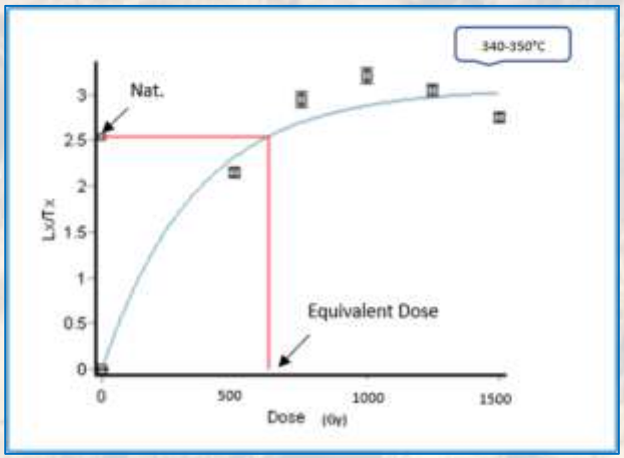

Figure 2

Table 2 Radioactive elements' concentrations of the studied samples

Sample's name	PK1	PK2	PK3	ELK	KK
U (ppm)	<0.1	<0.1	<0.1	1.8	<0.1
Th (ppm)	<0.2	<0.2	<0.2	6.9	<0.2
K_2O(%)	<0.1	0.01	<0.1	0.01	<0.1

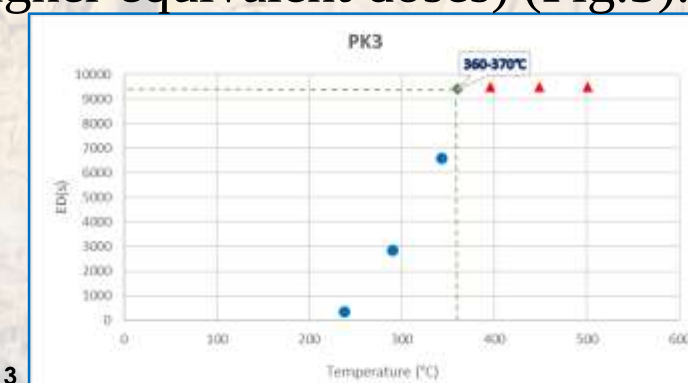

Figure 3

Conclusions

- The *extremely low* radiation environment that predominated in the center of the sampled quartz lumps (Table 2) due to the substantially low radioelement concentrations (U ≤ 0.1 ppm, Th ≤ 0.2 ppm and K below the detection limits) allows the TL signal to grow on longer geological timescales (Fig. 2), well beyond the Lower Pleistocene (if one considers the quotient of the two quantities), but still below the metamorphic age.
- Since the De seems to be a function of the integration temperature, the unsaturated TL signals from the deeper traps may allow to estimate the time the samples crossed the corresponding temperatures in the crust (Schmidt et al., 2015).
- Despite the promises, further experiments are required to validate the reproducibility of the untypically high doses involved here, accurately control the environmental dose rates (e.g. cosmic ray contribution), test the datable traps for any (thermal or athermal) signal losses and generate a statistically robust set of aliquots so that age models can be applied.
- Once the material passes all the aforementioned criteria then the TL from metamorphic quartz may be established as a geo-thermo-chronometer to generate exhumation rates (owing to either erosion or normal faulting) on the SE Peloponnese (and in similar context elsewhere) for the Neotectonic period.

References

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