Zircon (U-Th)/He dating of collisional stages in Ligurian Alps

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This study aims at using thermochronometry, coupled with a field investigation, to constrain the tectonic processes controlling the orogen evolution. Zircon (U-Th)/He thermochronometry has been applied to constrain low-temperature metamorphism and associated deformation phases. The project focuses on the Briançonnais units of the Ligurian Alps where the timing of Alpine tectono-thermal evolution is inferred only from pre- and post orogenic sediments.

1 Introduction

The time of tectonics that drives the stages of exhumation of orogenic belts is difficult to resolve, especially in complex polyphase metamorphic areas where the lack of stratigraphic record precludes the possibility of dating the phases of deformation. In these cases the opportunity to date the low-temperature metamorphic phases provides fundamental data to unravel the cooling history experienced by rocks in the upper crustal levels. (U-Th)/He thermochronometry represents a major tool to supply these information. In order to identify the timing and the areal distribution of the low T metamorphism we carried out zircon (U-Th)/He analyses. The low closure temperature of He in zircon - c. 180°C [1] - makes it a powerful tool to determining the timing of low temperature metamorphic events. Samples from volcanic formations preserved in all the outer, intermediate and inner Briançonnais units were analysed. These determinations, coupled with geological mapping and structural investigations, provide new insights for the interpretation of the tectonic events that controlled the later deformation phases and the exhumation of the whole Ligurian Alps.

2 Geological setting

The Briançonnais units form the base of the Penninic nappe pile of the Ligurian Alps (Figure 1). Following the Eocene stacking toward the SSW (D1 phase), the whole pile experienced a backfolding event (D2 phase) [2]. Mineral assemblages show that D1 was related to an early metamorphic event that was characterised by high P-T conditions in the internal units (up to 1.3 GPa, 400 °C) decreasing towards the outer sectors (0.3 GPa, < 200 °C) [3]. New structural investigations, integrated with the existing dataset, show that the intensity of the D2 backfolding event also increases towards the inner parts of the chain, where the associated metamorphic parageneses indicate decompression (0.5 GPa) accompanied by a slight temperature increase. The timing of the high temperature (> 300°C) metamorphic events of the internal units are relatively well constrained, between 50-34 Ma [4]. The low temperature metamorphic/deformation events and the cooling history are poorly constrained: few zircon and apatite fission-track (ZFT and AFT) ages range between 35 and 24 Ma [5, 6].

3 Method and results

Zircon (U-Th)/He ages were determined on the following lithologies: calc-alkaline granodioritic bodies (U-Pb ages: 300-294 Ma), rhyolitic pyroclastites (285.6±2.6 Ma), rhyodacites/rhyolites (272.7±2.2 Ma), and K-alkaline rhyolites (258.5±2.8 Ma) [7]. Crystals were selected on the basis of size, morphology,  © 2008 Università degli Studi di Pavia
colour and abundance of inclusions. He age determinations were performed at the Scottish Universities Environmental Research Centre. Two to three crystals were selected for each aliquot. Helium measurement protocols followed those of [8] and U and Th concentrations were obtained using the procedure described by [9]. Zircon (U-Th)/He ages from 9 samples ranging between 33.5±1.9 and 26.1±1.5 Ma are shown in Figure 1.

4 Timing of deformation phases and exhumation

Zircon (U-Th)/He ages decrease from the western to the eastern sector, suggesting a diachronous cooling history of the two blocks. In the western sector, the ages (36-30 Ma) of the tectonically outermost unit (Location 1, Fig. 1) are consistent with the D1 event, possibly associated with a <6 Km lithostatic load, represented by the Helmintoyd Flysch. In the eastern sector, the outermost unit (Mt Carmo - location 5) yielded younger He ages (27-25 Ma). This suggests that the eastern sector was buried by a thicker lithostatic load than the western counterpart. In both sectors, the internal units (locations 4, 6, 7, 8 and 9; Fig. 1) yielded He ages that are consistently younger than the D1 event (from 32 to 27 Ma) suggesting a strong influence of the D2 backfolding event.

An inverse modelling of the ZHe ages (Fig. 2) that includes all the geological and stratigraphical constraints resulted from observations in the field and in rock thin sections indicates that the internal units were exhumed very rapidly (ca. 3 mm/yr).
5 Conclusion

This study highlights the potential of zircon (U-Th)/He dating as an important tool for understanding complex polyphase metamorphic terrains.

The 32-27 ages defined for zircon (U-Th)/He analyses for the inner Briançonnais units indicate the end of ductile deformation (D2) associated with greenschist metamorphic facies. These ages are within error of depositional age of underlying post collisional sediments suggesting a very rapid exhumation rate for Ligurian Alps in the Early Oligocene. Rapid cooling/exhumation rates were evaluated for the internal eclogite facies and HP/UHP units of the Western Alps in previous studies [6, 11].

References