The role of precise U-Pb geochronology in deciphering the evolution of orogens

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Orogenic belts such as Zagros evolve through a number of stages involving subduction, with development of ophiolites and magmatic arcs, followed by processes related to collision and in part delamination, which result in the build-up of magmatic complexes. The study of these evolutionary stages commences with mapping and basic geological analyses. On that basis geochronological work can then be employed to advance our knowledge. Important goals of geochronology include defining the exact timing of specific tectono-magmatic events, and rates of magmatic and tectonic processes. Zircon is the prime mineral commonly employed for dating a wide variety of rocks with the U-Pb method, thanks to its ubiquity, the fact that it incorporates U but no Pb at the time of formation, and the robustness of the mineral. The latter can have the benefit of preserving a record of multiple stages of zircon growth relevant for the history of a rock, but this can also complicate the analytical task when different growth phases cannot be easily separated. Microbeam techniques provide a useful approach by allowing one to target specific domains of zircon 50 to 10 micron across, but they are handicapped by the lower precision achievable. The alternative is ID-TIMS geochronology, which counterbalances the lower spatial resolution with a superior analytical precision and temporal resolution. Besides zircon, minerals such as titanite and monazite provide useful temporal information. In the recent decade there have been some important advances in the treatment of zircon for analysis, especially the chemical abrasion method of Mattinson, which now accompanies the air abrasion of Krogh and makes it possible to greatly minimize the effects of Pb loss in zircon. Additional progress has been achieved in modern ID-TIMS through the intercalibration of tracer solutions among major laboratories, the general reduction of the blank to sub-picogram levels, and advances in instrumentation, which make it possible to analyze small amounts of Pb. A typical application of modern ID-TIMS is in establishing the detailed chronology of magmatic systems, such as large batholiths emplaced piecemeal over period of 100 ky to 10 my. Such information can then be paired with petrological and other isotopic constraints to understand the processes of generation and emplacement of the magmas. Another important area of application is in evaluating the evolution of metamorphic complexes, both high-pressure and high-temperature types. In such situations zircon can be very complex and a resolution of the timing of specific events can greatly benefit from the use of other geochronometers. Evolution of an orogen is automatically connected to processes of refinement and concentration of metals, which build economic mineral deposits. Depending on the type of deposit, dating can contribute knowledge by constraing the age of deposition of the ore, indirectly by dating host-lithologies and cross-cutting intrusions, and directly by dating minerals (such as rutile), which are part of the ore-paragenesis.