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Long-term canyon incision from apatite 4He/3He and calcite (U-Th-Sm)/He techniques

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Long-term canyon incision can provide an effective archive of regional topographic growth in regions where incision responds directly to surface uplift. Low-temperature thermochronometers record transient thermal adjustment induced by canyon incision in areas where incision exceeds the initial depth of the closure temperature. This was demonstrated by published apatite (U-Th)/He data from Cotahuasi-Ocoña Canyon, Peru, which show a clear incision-related cooling signal starting at ca. 10 Ma. However, applying a similar approach in other canyons can be hampered by inappropriate lithologies or limited access in difficult terrain. We present data from two additional low-temperature thermochronologic methods that show great promise for provide information on long-term canyon incision in regions where sampling may be limited to the valley bottom, or where lithologies are dominated by carbonate rocks.

Apatite 4He/3He thermochronology and forward modeling of thermal histories performed on a subset of samples solely from the bottom of Cotahuasi-Ocoña Canyon show cooling histories on individual samples that are nearly identical to the regional cooling history constrained by the entire conventional apatite (U-Th)/He data set and regional landscape evolution modeling. This suggests that apatite 4He/3He analyses performed on a small number of samples provides information comparable to a much larger set of conventional apatite-He ages. In addition, local differences in thermal histories in space and time revealed by the 4He/3He thermochronology can reveal details of incision processes, potentially providing more information on the processes that drove incision.

Calcite (U-Th)/He analyses on carbonate samples collected along canyons from the deeply-incised southern margin of the Central Anatolian Plateau in Turkey reveal young ages (< 10 Ma) in the deepest reaches of the canyons, and much older ages (> 60 Ma) higher on canyon walls. Although data from this nascent technique have much lower precision than those derived from apatite-He techniques, initial results suggest that calcite (U-Th-Sm)/He thermochronology may be the first effective tool for investigating incision/exhumation histories in regions dominated by carbonate lithologies. Further studies using this new tool are expected to elucidate the evolution of topography in this young orogenic plateau.

Together, these methods substantially broaden the number of locations where long-term river incision can be explored through thermochronologic methods.