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Exhumation of the Shaxdara gneiss dome, Pamir Mts.: tectonics versus erosion

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Gneiss domes are found both in extensional and contractional geodynamic settings. Kinematic models ranging from duplex-formation to low-angle detachments and fault-unrelated systems have been devised to explain exhumation from middle or lower crustal depths. The relative contributions of erosional versus tectonic exhumation are often assessed by thermochronology, increasingly in conjunction with numerical simulations.

We examine the exhumation history of the huge (300 x 100 km) Shaxdara gneiss dome in southwestern Tajikistan, which is one of several synorogenic gneiss domes that underlie large parts of the Pamir Mts. north of the western Himalayan syntax. The Shaxdara dome is bound by large-scale normal faults / shear zones with displacement concentrated along its southern side. Structural, petrologic, geo- and thermochronologic data indicate that doming and exhumation of high-grade metamorphic rocks is the result of syn-convergence extension since the Miocene. We propose the Shaxdara dome formed as a result of footwall exhumation along a low-angle detachment fault.

Taken alone, a large set of apatite fission-track (AFT) ages suggests middle to late Miocene exhumation. These low-temperature thermochronologic data suggest exhumation resulted from tectonic movements with only minor accompanying erosion. This interpretation is consistent with thermo-kinematic models of tectonic exhumation via a low-angle detachment produced using the Pecube software (J. Braun). Thermo-kinematic modeling is also used to examine the development of the high topographic relief within the dome and to assess its relation to dome formation.

Contrary to the low-temperature thermochronologic results, Ar/Ar and zircon (U-Th)/He ages show that doming may have started by the early Miocene and terminated in the middle Miocene. Thus, intermediate-temperature geo/thermochronology suggests that the apatite fission-track cooling ages postdate the tectonic exhumation of the Shaxdara dome and should be interpreted as the result of erosion of several km of upper crust within the dome. Pecube models adjusted to this scenario of early Miocene doming and high subsequent erosion predict ages showing an equally good fit to the AFT data, while also providing a satisfactory fit to the intermediate-temperature data.

This study demonstrates how the interpretation of even extensive thermochronometer data sets can lead to erroneous conclusions about the tectonic/erosional evolution of areas undergoing rapid exhumation. It illustrates the limitations of numerical simulations in predicting or testing proposed tectonic scenarios, and the clear dependence of the results of such simulations on the input data. Most importantly, this study suggests that the potential for misinterpretation of numerical simulations can be minimized by integrating detailed knowledge of the regional tectonic history with data sets comprising multiple geo/thermochronometers and other geologic observations such as structural, petrological and geophysical data.