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U-Pb zircon, sphene and apatite ages from shear zone-hosted syenites: Constraints on the protracted reactivation of a mid-crustal shear zone and implications for Pb retentivity in magmatic and metamorphic sphene

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An apparently paradoxical feature of orogenic cycles is the development of major extensional structures within overall compressive systems. The significance of such structures is apparent because they appear to play a dominant role in the exhumation of high-grade rocks. In late-orogenic settings these extensional structures are confined to the waning stages of the orogeny, however in active mountain belts there is increasing evidence that these structures were active contemporaneously with crustal thickening. Sometimes, intrusion of magmas, either from the underlying crust or mantle, are connected with these zones of weakness. Consequently, the emplacement of mantle-derived magmas into the crust has become a fundamental component of petrogenetic models and it is becoming increasingly apparent that there is a spatial and often a temporal coincidence of plutonism with major shear zones in many orogenic belts. Detailed studies of U-Pb ages of accessory minerals are an essential prerequisite to understand tectonometamorphic processes. Shear zones are widespread in high-grade metamorphic belts and contain essential evidence on the temporal evolution of deep orogenic segments. However, structural, petrologic, and geochronological data obtained on shear zones offer sometimes incomplete information. Mapping of shear-sense indicators, if possible, allows determination of relative displacements. However, these displacements may only represent some final stages of shearing but earlier stages in the pressure/temperature evolution of a given shear zone are rarely preserved. Furthermore, shear zones are regions of weakness and it is very likely that they are prefer-

entially reactivated during several stages of metamorphism during orogeny. A usefull approach of dating the activity of shear zones is radiometric dating of suitable mineral phases on both sides of a shear zone. Alternatively, dating can be achieved by dating minerals that are interpreted to be unique to the shear zone, however, isotopic resetting makes it often impossible to constrain the high-temperature metamorphic and deformation history of a given shear zone.

In the Damara orogen (Namibia) U-Pb zircon ages obtained on syenites from within and outside a prominent shear zone yielded consistent ages of c. 520 Ma which are interpreted as the age of intrusion of the syenites close to the peak of regional metamorphism. Pb-Pb sphene ages obtained on xenocrystic dark brown sphenes from syenites from outside the shear zone yielded significantly older ages between c. 700 and 730 Ma similar to Pb-Pb zircon and sphene ages from syenites from the northern part of the orogen. The c. 730 Ma age is also similar to the inferred age of sedimentation which is constrained by a Rb-Sr whole rock age of the country rock metapelites. Therefore these sphene ages are not interpreted as metamorphic ages of the country rocks. Instead the xenocrystic dark brown sphenes are likely remnants of pre-existing syenites in the deeper crust which is constrained by their high REE concentrations measured with an ionprobe. Together these ages precisely define the onset of rifting and access to mantle sources during the early stages of orogeny at c. 730 Ma. Pb-Pb sphene ages obtained on light brown sphenes which occurred as mantles around the dark brown sphenes and as individual crystals define a large range of ages between c. 610 and 490 Ma. Ages older than 520 Ma are interpreted as inherited ages from the older dark-brown sphene population. The younger ages correspond either to another peak of regional metamorphism or define a time span (i.e. from 520 to 490 Ma) of intrusion of syenites within the shear zone. Together, the data indicate activity of the shear zone at c. 700 Ma (onset of rifting) and between 490 and 520 Ma (peak of regional metamorphism?, intrusion of syenites). Furthermore, for the syenites from outside the shear zone Pb retentivity in sphene is high indicated by the inheritance of older (igneous?) sphene in younger intrusive rocks. Lastly, for the syenites from within the shear zone the similarity of U-Pb apatite, sphene and zircon ages suggests that these ages rather represent magmatic ages then metamorphic ages implying fast cooling rates after intrusion.