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Open system Hf isotope homogenization by a DISPOREP process under amphibolite-facies conditions, an example from the Limpopo Belt (South Africa)

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Isotope homogenization in metamorphic rock is a prerequisite for precise isochrone dating. However, whether or not homogenisation occurs during a metamorphic overprint dependent on several parameters and processes, which compete with each other and comprise at least (i) volume diffusion, (ii) dissolution-re-precipitation, (iii) intergranular diffusive or fluid enhanced transport, and (iv) metamorphic mineral reaction(s). Isotope homogenisation is commonly reached in high-grade (granulite-facies) metamorphic rocks, where diffusion is fast, and mineral reactions and dissolution-re-precipitation accompanied or maintained by a melt phase, but it is incomplete in low-grade to amphibolite-facies rocks, in the presence of an aqueous fluid phase. This holds true, in particular, for the Lu-Hf isotope system, which is mainly controlled by accessory zircon, which is very resistant against dissolution in aqueous fluids and has slow diffusivity for Hf, U, Pb. Thus zircon often maintains it primary U-Pb-Hf isotope composition obtained during previous magmatic crystallisation (i.e, magmatic grains in orthogneisses or detrital magmatic grains in paragneisses), even under very high-grade metamorphic conditions >1000°C. However, results of recent isotope studies show, that the U-Pb and Lu-Hf isotope systems of zircon-bearing ortho- and paragneisses can homogenize completely (on hand specimen scale) even under amphibolite facies $T-P$ conditions of <630°C/ <7 kbar, in the presence of an aqueous fluid phase. This is well supported by U-Pb and Lu-Hf isotope data obtained by LA-ICP-MS from a fast number of metamorphic zircon grains (n=30) of a 2.04 Ga-old garnet-amphibolite from the Venetia diamond mine (Limpopo Belt, South Africa), having all identical initial ^{176}Hf/^{177}Hf of 0.28124 ± 0.00004, i.e. less than 1.5 epsilon unit variation. Furthermore it is reflected by a six point Lu-Hf isochrone (comprising garnet - whole rock - metamorphic zircon), which yield a precise age of 2039.7 ± 3.4 Ma and shows, within error, the same initial ^{176}Hf/^{177}Hf of 0.281257 ± 0.000011 (ca. ±0.3 epsilon units). Identical initial ^{176}Hf/^{177}Hf, as well as the finding of chlorite inclusions in zircon additionally indicate that the metamorphic zircon grains formed newly during the amphibolite-facies metamorphic overprint (controlled by the mineral reaction Chl + Hbl + Qtz = Pl + Grt + Cumm + H$_2$O), and didn't result from a pseudomorphic dissolution-re-precipitation process of pre-existing (magmatic) zircon grains. Thus, textures and isotope data support the conclusion that these zircon grains result from a DISPOREP process, which comprises **dis**solution of older (xenocryst) zircon grains, followed by (far distance) trans**po**rt, isotope homogenization and new zircon **re-p**recipitiation in an aqueous environment. Far distance transport of Zr and Hf from an external source (perhaps a surrounding tonalite) is supported by the enormous misfit between calculated (0.28150) and measured (0.28126) initial ^{176}Hf/^{177}Hf. Apatite-rims around contemporaneous monazite grains (also with chlorite inclusions) in adjacent Pl-free metapelitic rocks point to the infiltration of a Ca-rich aqueous fluid.