Zero eclogites - half way between shallow mantle and deep crustal origins

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Eclogite xenoliths from ancient kimberlites are important indicators of early mantle processes, but their origins are still debated, with explanations ranging from subducted crust to igneous cumulates within the mantle. The eclogite suite from the ~1.6 Ga Zero kimberlite is unusually diverse, including bimineralic eclogites and orthopyroxene-bearing eclogites both with and without sanidine as well as a kyanite eclogite. This suite bears evidence for multiple P-T-t stages and shows mantle-like oxygen isotopic compositions. Hence, the occurrence of quartz, rutile and rare K-feldspar inclusions in the garnets of most eclogites may not necessarily indicate a crustal precursor. In-situ-trace element analyses of minerals show generally low trace element abundances including low Nb, Ta, Zr and Hf. REE abundances are close to, or even more depleted than primitive mantle, demonstrating that they represent either melts from a depleted source or are igneous cumulates. The LREE of most samples are overprinted by a late-stage metasomatic event. There is no indication of plagioclase in the protolith other than slight positive Eu-anomalies in the kyanite eclogite and one bimineralic eclogite. High Ni and Cr contents of some orthopyroxene-bearing eclogites indicate that olivine and chromium-spinel were present in their protoliths. Modelling of crystal accumulation from a range of potential parental magmas from basalt to komatiite using major and trace elements, leads us to conclude that the protoliths of the eclogites were generated by igneous cumulate formation from picritic magma at 1-1.5 GPa., or 30-50 km depth. These pressure conditions correspond to eclogite protolith formation within the sub-continental lithosphere or in the lower reaches of thickened oceanic crust at the end of the Archean.

The modelled cumulates consist of clinopyroxene and spinel in the presence of plagioclase, even though the presence of plagioclase is not obvious because positive Eu anomalies are lacking. Plagioclase requires that the eclogite source crystallized below 1.5 GPa and thus contradicts the hypothesis for eclogite crystallization at higher mantle pressures. The sanidine-bearing eclogites of the Zero suite are interpreted as forming from metasomatic veins consisting of phlogopite and clinopyroxene in close proximity to the plagioclase-bearing cumulates prior to metamorphism and eclogitization. These sanidine-bearing eclogites constrain the P-T-t path to include a high-pressure maximum of >7GPa before the 4GPa indicated by the bulk of the suite. This information can be used to constrain geodynamic processes at the western margin of the Kaapvaal craton during the early Proterozoic.

Environmental dependence of size in planktic foraminifers

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Planktic foraminifers are free-floating marine protists that are widely distributed in the surface waters of the world's ocean. Since their origin 140 million years ago, planktic foraminifers have grown from a negligible contribution to a major sink for pelagic carbonate. The excellent preservation of planktic foraminifers within Cenozoic marine sediments is one of the prime reasons for the extensive application in paleoceanographic studies. The analysis of species compositions, stable isotopes and other chemical tracers of foraminiferal tests, e.g. Mg/Ca and Cd/Ca ratios, have proven to be valuable tools for paleoclimatic and paleoceanographic reconstructions. These studies are all based on the assumption of an analogous environmental adaptation of the organisms in the past as in the present.

Here we use the test size of planktic foraminifers to define environmental preferences and to trace these back in time. To determine the influence of the environment on test size, globally distributed Holocene assemblages have been analysed using automated image analysis techniques. An average of 1700 randomly oriented specimens >150µm were measured from each of 100 sediment samples. The maximum diameter of each specimen was used as size parameter.

We observe that the maximum size and the maximum relative abundance of the 12 most abundant species occur at identical and distinct surface water temperatures. Below and above these optima, sizes and abundances of species decrease.

In the Holocene, geographical variation of total assemblage size is most closely related to temperature, resulting in an increase in size from poles to tropics. In the less stable frontal systems and upwelling areas the observed sizes are below the global temperature-related trend, suggesting that species populations are outside their environmental optima and near their biogeographic fringes.

The Holocene ecological optima also seem to have prevailed in the late Pleistocene. We have measured size in three sediment cores from the South Atlantic for the last 300 kyrs. We have compared these size changes with the best available paleotemperature proxies. The size response to temporal paleoenvironmental changes during glacial-interglacial cycles in the late Quaternary mimics the geographic Holocene size variations. Evolutionary adaptation of individual planktic foraminiferal species appears to occur on timescales longer than a few hundred thousand years.