Dating ultra-deep mine waters with noble gases and ^{36}Cl, Witwatersrand Basin, South Africa

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Concentrations and isotopic ratios of dissolved noble gases, ^{36}Cl, δD and δ^{18}O in water samples from the ultra-deep gold (0.718 to 3.3 kilometers below the surface) in the Witwatersrand Basin, South Africa, were investigated to quantify the dynamics of these ultra deep crustal fluids. The mining activity has a significant impact on the concentrations of dissolved gases, as the associated pressure release causes the degassing of the fissure water. The observed under saturation of the atmospheric noble gases in the fissure water samples (70 to 98%, normalised to ASW at 20°C and 1013 mbar) is reproduced by a model, that differentiates between diffusive degassing and solubility equilibration with an gas phase at sampling temperature. Corrections for degassing result in ^{4}He concentrations as high as $1.88\cdot10^{-1}$ cm^{3}STP^{4}He g^{-1}, ^{40}Ar/^{36}Ar ranging between 760 and 10,800, and ^{134}Xe/^{132}Xe and ^{136}Xe/^{132}Xe ratios above 0.4.1 and 0.37, respectively. The nucleogenic ^{4}He/^{40}Ar, and ^{4}He/$^{134(136)}$Xe ratios generally indicate that these gases are not produced in situ but have an external source. They are also inconsistent with average crustal production and require both confinement in the liquid phase as well as temporal variability of the release rate by fracturing. Residence times based on a range of assumptions range from 3 to 418 Myr. The low ^{36}Cl-ratios of $(4\text{-}37)\cdot10^{-15}$ and comparatively high ^{36}Cl-concentrations of $(8 - 350)\cdot10^{-15}$ atoms ^{36}Cl l^{-1} indicate that the fissure water samples are all older than 1.5Myr or 5 times the half-life of ^{36}Cl and reflect subsurface production in secular equilibrium fixing an absolute minimum on fissure water ages. We cannot exclude the possibility of mixing and that small quantities of younger water have been mixed with the very old bulk.

Melting Relations of Pyrolite in CMAS-H$_2$O System up to 25 GPa

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Recent experimental and theoretical studies propose that water plays an important role in the constituents of the upper and possibly lower mantle. Existing of the hydrous magma ocean (Abe et al., 2000) and distribution of water into crystallizing phases could have caused hydrous magmatism in the Archean. Some authors have considered hydrous origin of the Archean komatiitic magma (e.g. Shimizu et al., 2001). Asahara and Ohtani (2001) reported melting phase relations at 4-8 GPa for hydrous pyrolite and found significant differences in melting relations under the dry and hydrous conditions. We extend this study and made experiments up to 25 GPa.

Phase relations and melt compositions in the CaO-MgO-Al$_2$O$_3$-SiO$_2$-pyrolite under hydrous (+2% of H$_2$O) and anhydrous conditions have been determined at 10-25 GPa and temperatures from 1400 to 2400°C. At the pressure of 16 and 25 GPa the apparent solidus temperatures for the hydrous system are about 200°C and 100°C lower than the solidus temperatures for the dry system, respectively. The apparent solidus temperature changes drastically from 1600°C at 13.5 GPa to about 1850°C at 16 GPa. Majorite is a liquidus phase in the hydrous pyrolite from 10 to 25 GPa. The liquidus phases in the dry pyrolite are olivine at 10-14 GPa, majorite at 14-20 GPa, and periclase at pressures above 20 GPa.

Compositions of partial melts formed by low degree of melting (10-20%) have Al$_2$O$_3$-depleted and CaO-rich compositions up to 22 GPa and enriched in Al$_2$O$_3$ (5-7 wt%) and CaO at 25 GPa. At 10 GPa, dry and hydrous melts formed by low degree of melting have high SiO$_2$ (48-51 wt%) and relatively high Al$_2$O$_3$ (3.5-5.2 wt%). Their compositions are generally consistent with those of aluminum-depleted komatiite. At 13-22 GPa, dry and hydrous melts have low SiO$_2$ (44-49 wt%) and Al$_2$O$_3$ (1.7-3.0 wt%) and high CaO contents (9-15 wt%).

An essential depression of the apparent solidus temperature in the hydrous deep upper mantle compared to that in the transition zone provides the dehydration melting of the hydrous plume. The present results support a model of komatiite genesis by dehydration melting of rising wet plumes at the base of the upper mantle.

References

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