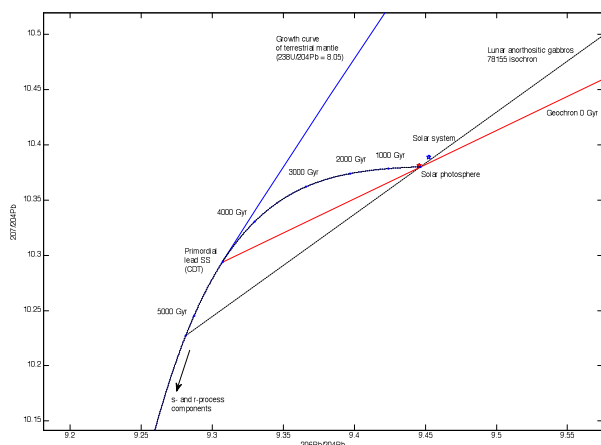


## The age of the Moon from U-Th-Pb systematics on terrestrial and lunar primitive mantles

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U-Th-Pb systematics of the primitive mantles reflect early mantle differentiation and core formation processes and may provide key constrain on the genetic relationship between the different planets. Here, we show that the Pb data for the terrestrial and lunar primitive mantles define a system of isochrons centred on unequilibrated primitive meteorites (e.g.; Mezo Madaras meteorite), which suggests that the Earth and Moon were formed at different times by direct accretion from the solar nebula. Following this result, we determine the age of the Moon to be exactly 5.13 Gyr. In principle, this new method of portraying a solar system by secondary isochrons centred on unequilibrated primitive meteorites can be used for precise dating all other objects in the solar system provided they are formed by direct accretion from the collapse of solar nebula and have experienced core-mantle segregation early in their planetary evolution. An other example is Mars whose Pb data for its primitive mantle might be available in the near future.



**Figure 1:**  $^{206}\text{Pb}/^{204}\text{Pb}$  vs.  $^{207}\text{Pb}/^{204}\text{Pb}$  plot for 4.55 Gyr geochron, including data point of terrestrial mantle calculated with  $\mu = 8.05$  (Rochd, 2009), and 5.13 Gyr lunar isochron, including data points of plagioclase ( $\rho < 2.89$ ) from Apollo 17 anorthositic gabbro 78155 (Nunes, 1975).

[1] Nunes, Tatsumoto, and Unruh (1975) Proc. Lunar Sci. Conf. 6<sup>th</sup>, 1431-1444. [2] Rochd (2009) Geochim. et Cosmochim. Acta, **73**, 13, A1109-A1109.

## Carbonation of cement within a repository for radioactive wastes: Impact of CO<sub>2</sub> on cement mineralogy and permeability

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Large quantities of cementitious materials will be used for radioactive waste repository construction and buffer/backfill. Degradation of organic material within the waste will produce CO<sub>2</sub>, leading to cement carbonation. This will reduce its capacity to maintain highly alkaline conditions, thus possibly aiding radionuclide migration. Conversely, some carbonation reactions might improve material properties, e.g. by reducing cement permeability. Currently, it is unclear whether the overall changes due to carbonation will be beneficial or deleterious to long-term radionuclide immobilisation.

As part of the pan-European FORGE project we have undertaken a laboratory study to examine the impact of carbonation on 'Nirex reference vault backfill' (NRVB) cement. Aims for the work were to quantify changes in cement mineralogy, structure, porosity/permeability, and the composition of coexisting aqueous fluids. Lab investigations exposed samples of cement to free phase and dissolved CO<sub>2</sub> under a range of potential *in-situ* conditions; 20°C or 40°C, 4 MPa or 8 MPa, 'young' (Na/K/Ca-rich) or 'evolved' (Ca-rich) cement porewaters. The experiments involved static and flowing experiments lasting 10-365 days.

Reaction was rapid in all experiments, with samples increasing in weight by up to 9% with no change in overall size. Key reactions were breakdown of portlandite and calcium silicate hydrates and formation of carbonates and silica. Reaction fronts moved through the cement over time, demarking regions of low, partial and full carbonation. The fully carbonated zone showed evidence for higher-density carbonate-filled fractures and concentric 'relic' reaction fronts, which separated areas having lower-density and high porosity. Appreciable amounts of a Cl-rich phase formed in the partially carbonated zone.

Controlled flow-rate experiments revealed decreases in overall sample permeability for gaseous, supercritical and dissolved CO<sub>2</sub>. Carbonation was fastest with supercritical CO<sub>2</sub>, but the greatest permeability reduction occurred with dissolved CO<sub>2</sub>. Permeability decreases reflect porosity reduction due to conversion of portlandite and CSH to secondary carbonate minerals. The greatest reductions in porosity and permeability occurred in a very narrow zone at the leading edge of the visible alteration front.