European Mineralogical Conference
Vol. 1, EMC2012-297, 2012
European Mineralogical Conference 2012

Mantle and core formation - a view from ultramafic meteorites

H. Downes
Birkbeck College, Dept. of Geology, London WC1E 7HX, United Kingdom (H.DOWNES@UCL.AC.UK, 0044-171-3)

Studies of the petrology and composition of Earth's upper mantle depend heavily on observations made on ultramafic xenoliths brought to the planet's surface by volcanic activity. Xenoliths entrained in young volcanoes provide a snapshot of the present-day mantle, whereas those from older eruptions can also reveal part of the history of the lithospheric mantle. However there is no easy way to investigate the very early history of the Earth's mantle because the dynamic processes that have affected our planet have erased all evidence of the Hadean mantle. Ultramafic meteorites are in effect mantle xenoliths from asteroidal bodies and therefore can provide an insight into Hadean terrestrial planetary formation.

The most abundant group of ultramafic meteorites is the ureilite group, which have many commonalities with Earth's mantle. They are composed of olivine and pyroxene, together with carbon polymorphs, sulphides and metals. Although, due to wide differences in oxygen isotope compositions, ureilites cannot be directly related to Earth, nevertheless both Earth and the ureilite parent asteroid share some common characteristics. Studies of ureilite meteorites show that their parent body underwent differentiation into a mantle and core. However, unlike Earth and other terrestrial planets, the parent body never reached a "magma ocean stage". Instead it experienced a catastrophic impact disruption and gravitational re-accretion that essentially fossilized the remaining "rubble-pile" body at an early stage of planetary differentiation. Evidence for the Hadean mantle may be absent from the Earth, but information from ureilites give us a valuable view of processes on the early Earth.

Although evidence for the existence of a solidified basaltic crust on the ureilite parent body is very limited, nevertheless there is significant data indicating extraction of silicate partial melts from the parent body. Ureilite mantle rocks lack Ca- and Al-bearing phases, suggesting that partial melting had removed them from the parent body. Thus they are the extraterrestrial equivalent of harzburgites. Furthermore, all of the silicate phases within the restitic mantle are LREE-depleted. Possibly most of the basaltic melt was removed from the parent body by fire-fountaining into space at velocities greater than the escape-velocity of the asteroid. A few rare ureilites are pyroxene-rich, suggesting some retention of this melt within the mantle.

Within ureilites we find numerous examples of solidified globules of iron-nickel silicides and Si-bearing metals, which may represent the compositions of core-forming liquids in a reduced environment on early terrestrial planetary bodies. Core formation may have been in progress when the parent asteroid was disrupted. Naturally-occurring iron silicides are reported from Earth, including from mantle peridotites, suggesting that parts of the Earth's mantle are strongly reduced. Finally, the ureilite parent asteroid retains some record of a late-stage bombardment by chondritic material. Meteorites derived from the fall of former asteroid 2008TC3 indicate that parts of the ureilite parent body contain up to 30% chondrite clasts. This may be the equivalent of the "Late Veneer" of the Earth.