# Direct phylogenetic and isotopic evidence for multiple groups of archaea involved in the anaerobic oxidation of methane.

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The biological oxidation of methane by anaerobic microorganisms is a significant sink for methane in the marine environment. Although there is convincing biogeochemical evidence for anaerobic oxidation of methane (AOM) by methanotrophic archaea and sulfate-reducing bacteria, the identity of these uncultured microorganisms is only now being described. In this study, we examined the diversity archaeal and bacterial assemblages involved in AOM using directly coupled isotopic and phylogenetic analyses at the level of single cells. The combined application of fluorescent *in situ* hybridization and secondary ion mass spectrometry (FISH-SIMS) identified two phylogenetically distinct groups of archaea (ANME-1 and ANME-2) from marine methane seeps that were extremely depleted in carbon-13 (-83 ‰) and appear to be capable of directly oxidizing methane. These archaeal groups were observed to exist as monospecies aggregates or single cells as well as in physical association with bacteria including, but not limited to, members of the sulfate-reducing *Desulfosarcina*. The results from this work illustrate the complexity of the microbial communities and possible mechanisms involved in AOM. FISH-SIMS is an effective approach for understanding the dynamic microbial interactions within diverse methane-associated communities and may provide a useful culture-independent tool for deciphering the metabolic function of other environmentally significant microorganisms *in situ*.

# Lunar constraints on core formation: a new model with many implications

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The widely accepted iron-cores-by-percolation model is invalidated in two ways. The mantle has preserved, at least since 3.8Ga, a nearly chondritic Ni:Co (~20) despite Ni's tenfold higher liquid Fe/silicate partition coefficient. Although the coefficients do even up at mid-mantle pressure, most melting and segregation would have been at low pressure. Secondly, its essential corollary, the provision of a siderophile- and water-rich 'late veneer' after core completion (dated at ~4.45Ga by the ending of mantle Pb depletion, if attributed to Fe percolation), is denied by the Moon, which never underwent a late veneer (Taylor & Esat 1996), and was in Earth orbit by 4.50Ga (Lee & Halliday 1998).

The new core genesis model must work at least all the way from Mercury to Jupiter's Io, Ganymede and watery-surfaced Europa. In the presence of a dense and high-opacity radiatively cooled nebular disc the growing protoplanets would have acquired an accretion-rate controlled temperature and internal convection, largely independent of orbit radius. Erupted magmatic FeO was reduced to Fe by the nebular atmosphere and 'subducted'. The dense Fe-loading of the downwelling limb ensured its deep penetration, with the Fe dropping off at the bottom, thus accelerating convection and core formation. Transfer to the core of mantle chalcophiles and siderophiles took place across the CMB but was delayed by the expulsion of silicate dross from the core. The CMB was sealed at ~4.45Ga by the build-up of subducted primitive crust to start forming D", leaving a time-window for transfer, evident in the Hf-W data for Earth and Mars (Lee & Halliday). This function of D" denies that mantle plumes can start at the CMB. Planetary core formation was terminated (= 'age of the Earth') by nebula departure (4561Ma?), with comets and the Great Planets incorporating some of the potentially ~1000 Earth-ocean volumes of total reaction water expelled with it. The model makes C and S the preferred core dilutants. Entry of U and Th is possible. Much water entered the early-Earth mantle, as seen in komatiites (e.g. -Nb anomalies), ensuring their high-melting magmagenesis without a need for plumes.

Such early acquisition of the Moon, its distinct siderophile composition and the dynamics of the Earth-Moon system suggest tidal-drag capture by a hot low-viscosity Earth, rather than by impact. The predominance of prograde satellites in the Solar System implies a tidal mechanism for their capture too (Counselman, 1973, *Ap.J.*), the retrograde ones (bar Triton) having 'wound in' to coalescence. So most non-gas planetary growth was completed in nebula-present conditions. Thus their growth would have been much faster than by impact alone because nebular-atmospheric drag, combined with their accretion-generated partially melted state, provided a much bigger (tidal) capture cross-section for planetesimals.

The extent to which asteroids possess cores is put in doubt. Small bodies would cease convecting and resurfacing themselves very soon after nebular departure, leaving iron and lavas on their surface as sources of iron and eucrite meteorites.