Towards self-consistent modelling of the Martian dichotomy: Coupled models of simultaneous core and crust formation

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The crustal dichotomy, a large difference in elevation and crustal thickness between the southern highlands and the northern lowlands, is the oldest geological feature on Mars. It was formed more than 4.1 Ga ago owing to either exogenic or endogenic processes. Based on the geochemical analysis of SNC meteorites it was suggested that a primordial crust with up to 45 km thickness can be formed already during the Martian core formation. The final accretion stage of terrestrial planets is based on stochastically distributed impacts. Therefore we suggest that the sinking of iron diapirs, delivered by late pre-differentiated impactors, might have induced shear heating-related temperature anomalies in the mantle, which fostered the formation of early Martian crust. In this study, we examine parameter sets that will likely cause an onset of hemispherical low-degree mantle convection directly after, and coupled to, an already asymmetrical core formation. To test this hypothesis we use a numerical model, where we self-consistently couple the formation of the Martian iron core to the onset of mantle convection and crust formation. We perform 2D spherical simulations using the code I2ELVIS applying the 'spherical-Cartesian' methodology. It combines finite differences on a fully staggered rectangular Eulerian grid and Lagrangian marker-in-cell technique for solving momentum, continuity and temperature equations as well as Poisson equation for gravity potential in a self-gravitating planetary body. In this model, the planet is surrounded by a low viscosity, massless fluid to simulate a free surface. Previous studies showed that the convection patterns in the Martian mantle are highly dependent on its effective viscosity structure. Therefore we apply a temperature, stress- and phase-dependent viscoplastic rheology inside a Mars-sized planet and include radioactive-, shear- and adiabatic heating. To self-consistently simulate the mineralogical phase changes expected inside a Mars-sized body, we employ the thermodynamical Perple_X database. First results indicate that both the presence of one large impactor core and viscosity layering due to phase-dependent rheology might induce low-degree convection already during core formation.

Controls on Mo isotope fractionations in modern anoxic marine sediments – A key to paleoredox research

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To evaluate past ocean redox conditions it is necessary to understand redox sensitive element and isotope cycling in modern sedimentary environments. Mo isotopes in particular have great potential as a paleoredox indicator, particularly in terms of quantifying the spatial extent of different redox conditions [1, 2]. This arises due to differing isotopic fractionations associated with oxic and anoxic deposition. Fe and Mn (oxyhydr)oxides, Fe-sulphides, and organic mater have all been proposed to exert an influence on Mo isotope fractionations during diagenesis [1, 3, 4]. However, the controlling factors on Mo cycling and isotopic fractionations under distinct redox conditions remain poorly understood.

For this purpose we took shallow cores of sediments experiencing various redox conditions from seas around Denmark. The redox chemistry ranges from sulphidic to Fe-rich to Mn-rich sediments and pore-waters. We analysed Mo, Mn, Fe and S concentrations in dissolved and solid phases. Solid phase Fe was chemically separated into different Fe-bearing species [5]. Fe speciation varies at different sites as well as with depth, while dissolved Fe(II) in pore-water profiles indicates release and uptake of sediment Fe. Mo isotope composition also varies systematically in relation to the precise redox conditions.

These data will be discussed together with S isotope compositions and organic carbon contents to evaluate what drives Mo abundance and isotope cycling in different redox settings, specifically to compare Mo isotope behavior in sediments deposited beneath oxic versus anoxic water columns. The findings add to our understanding of Mo isotope fractionations under differing diagenetic conditions and their relation to the interpretation of Mo isotope data for ancient sediments.

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