Ecole Doctorale des Sciences Fondamentales

SUBJECT OF THE THESIS

Title of the thesis: Understanding Earth's late accretion and core formation using the noble metals.

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Project Summary:

Accretion and core formation are the most fundamental processes that have shaped the history and chemical evolution of Earth. Planetary growth occurred through accretion of primitive material over tens of millions of years, a uniquely extended period compared to the other terrestrial planets. The energy of impacts caused widespread melting, forming magma oceans, which allowed dense metal to separate to the core. Together, the nature of accreting material and core formation defined the composition of the silicate Earth, the oxidation state of the mantle and, ultimately, the chemical composition of Earth's continents and surface environment, including the presence and distribution of volatiles such as water. Yet many questions concerning the formation and evolution of the early Earth remain. These include the precise nature of accreting material, whether this changed during the course of accretion, and how certain elements became distributed between Earth's mantle and core as the planet grew.

The proposed work addresses these questions using a multi-disciplinary approach, combining experiments and natural samples, centred on the noble metals and their isotopes. On the basis of their siderophile (iron-loving) behaviour, noble metals should be quantitatively removed from the silicate Earth during core formation. Yet their mantle concentrations are too high for such a scenario. A long-standing theory reconciling this critical paradox invokes the late accretion of noble metal-rich material, after core formation had ceased. Late accretion has also been invoked to explain volatile element budgets on Earth, including water that may otherwise have been lost during accretionary impacts or may never have been present if Earth was accreted from 'dry' chondrites. The so-called 'late veneer' remains the simplest explanation for the noble metals, but is not without problems and various lines of evidence suggest that other processes may have been important. Thus, alternative hypotheses of reduced siderophile behaviour at core formation conditions and incomplete core formation both need to be fully explored; with potential implications for the conditions of core formation and the chemical evolution and oxidation state of the mantle.

This proposed research will address these questions through three distinct strands each using the noble metals, or highly siderophile elements (HSE: e.g. Os, Pt, Re, Au), and their stable and radiogenic isotopes as geochemical tracers. The principal goals are : a) To distinguish and quantify the roles of core-mantle equilibration and the earliest late accretion using noble metal-poor ancient mantle melts as a 'window' into the earliest mantle; b) To quantify the relative contributions of late accretion and equilibrium core-mantle partitioning to mantle noble metal budgets, through experimental determination of Pt stable isotope fractionation during core formation and new Pt and Os partitioning experiments; c) To reassess whether addition of primitive carbonaceous chondrite meteorites can account for Earth's noble metals and Os isotope composition and hence, crucially, its volatile budget.