The University of Oxford Department of Earth Sciences

EARTHSCIENCES

UNIVERSITY OF OXFORD

Modelling tectonic regimes on rocky planets

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Key Words	**Plate tectonics, convection, subduction, planetary interiors, mineralogy**

Overview

The Earth currently exhibits a '*mobile lid*' geodynamic regime – plate tectonics – that is characterized by the horizontal motion of lithospheric plates across the surface of the Earth at rates significantly faster than flow in the underlying asthenospheric mantle (e.g. Palin and Santosh, 2021). This motion is facilitated by production of oceanic lithosphere at mid-oceanic ridge spreading centers, and its destruction via subduction at convergent plate margins. Plate tectonics, however, is an unusual and unexpected geodynamic state for a silicate planet (O'Neill et al., 2007). No other rocky bodies in our solar system (or beyond) show reliable evidence of ever having exhibited such a mobile lid regime (Stern, 2016), and it is accepted by most geoscientists that the early Earth (pre-c. 3 Ga) instead exhibited a '*stagnant lid'* geodynamic regime (Palin et al, 2020), where lithospheric plates moved very slowly, if at all.

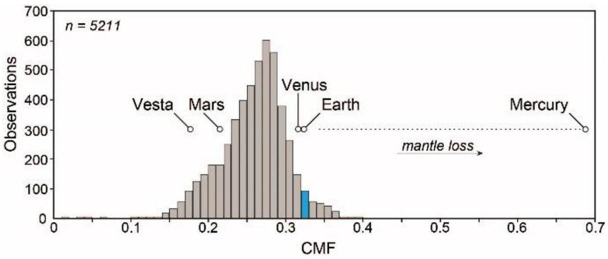

Figure: Histogram of planetary core-mass fraction (CMF) interpreted using data from the Hypatia catalogue (from Dyck et al., 2021), compared to values for major rocky bodies in our solar system.

As the densification of oceanic crust in subduction zones provides the necessary slab pull force to drive and maintain plate tectonics (Forsyth and Uyeda, 1975), the mineralogy of a planet's crust is of critical importance for deciphering its potential to develop a mobile lid regime. The petrology, composition, thickness, and structure of newly formed lithosphere at the Earth's surface are in turn directly affected by the composition of the underlying mantle and pressure–temperature conditions at which partial melting occurs (Roman and Arndt, 2020). For example, variations from terrestrial core-mass fractions in other rocky bodies of equivalent size promote the dilution or concentration of iron into a silicate mantle, which affects its fertility during adiabatic decompression (Fig. 1; Dyck et al., 2021).

This proposed research will apply innovative combinations of cutting-edge analytical techniques – ground-truthed with petrological analyses of real-world samples, as needed – to interrogate variable space and define the planetary characteristics that promote or inhibit development of a plate tectonic regime. Such work is expected to have far-reaching implications within the geoscience and planetary geology communities, and may inform associated cross-disciplinary studies that seek to determine the conditions on Earth-like planets that are conducive to harboring complex life.

Methodology

The student will develop holistic models at a range of scales (e.g. terrane, crustal, lithospheric, and planetary) that focus on interplay between geochemistry, geophysics, and igneous and metamorphic petrology. Depending on student interest, fieldwork to collect samples of terrestrial mantle xenoliths may also be conducted. Given the large datasets that will be utilised (e.g. the Hypatia Catalog; Hinkel et al., 2014; Putirka and Rarick, 2019), supervised and unsupervised machine learning techniques will be applied as and when needed. A student working on this project may thus expect to gain experience with the following tools and techniques:

- Optical microscopy
- Scanning-electron microscopy (SEM)
- Electron probe micro-analysis (EPMA)

- Supervised and unsupervised machine learning
- Petrological modelling (e.g. software such as THERMOCALC and Perple_X)

The student will be supervised by a team with significant expertise in these fields, based both at the University of Oxford, UK, and the University of British Columbia, Canada.

Timeline

Year 1: Doctoral training courses, literature review, potential sample acquisition and characterisation, and laboratory training.

Years 2 and 3: Petrological and geodynamical modelling. Data compilation and interpretation. Presentation of results at domestic and international conferences.

Year 4: Data integration, thesis completion, write papers for submission and publication in scientific journals.

Training & Skills

The successful student will join the Hard Rock research group at the University of Oxford, UK, which has a long-standing history of research excellence in metamorphism, magmatism, and changes in tectonic styles through time. They will also have the opportunity to integrate with faculty at external institutions and industry partners at annual career fairs.

The student will be trained how to conduct geochemical, petrological, and geodynamic modelling, with elements of supervised and unsupervised machine learning. The student will also be mentored on how to prepare scientific results for presentation at international conferences and how to write papers for publication in high-profile, international journals.

References & Further Reading

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Further Information

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