

Earth's composition: origin, evolution and energy budget

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Abstract

One in every two atoms in the Earth, Mars, and the Moon is oxygen; it is the third most abundant element in the solar system. The oxygen isotopic compositions of the terrestrial planets are different from those of the Sun and demonstrate that these planets are not direct compositional analogs of the solar photosphere. Likewise, the Sun's O/Fe, Fe/Mg and Mg/Si values are distinct from those of inner solar system chondrites and terrestrial planets. These four elements (O, Fe, Mg, Si) make up 90% to 94% by mass (and atomic %) of the rocky planets and their abundances are determined uniquely using geophysical, geochemical and cosmochemical constraints.

The rocky planets grew rapidly (<10 million years) from large populations of planetesimals, most of which were differentiated, having a core and a mantle, before being accreted. Planetary growth in the early stages of protoplanetary disk evolution was rapid and was only partially recorded by the meteoritic record. The noncarbonaceous meteorites (NC) provide insights into the early history of the inner solar system and are used to construct a framework for how the rocky planets were assembled. NC chondrites have chondrule ages of two to three million years after t_{CIP} (the age of calcium-aluminum inclusions, CAI), documenting that chondrites are middle- to late-stage products of solar system evolution.

The composition of the Earth, its current form of mantle convection, and the amount of radiogenic power that drives its engine remain controversial topics. Earth's dynamics are driven by primordial and radiogenic heat sources. Measurement of the Earth's geoneutrino flux defines its radiogenic power and restricts its bulk composition. Using the latest data from the KamLAND and Borexino geoneutrino experiments affirms that the Earth has ≤ 20 TW of radiogenic power and sets the proportions of refractory lithophile elements in the bulk silicate Earth at 2.5 to 2.7 times that in CI chondrites. The bulk Earth and the bulk Mars are enriched in refractory elements about 1.9 times that of the CI chondrites. Earth is more volatile-depleted and less oxidized than Mars.

Keywords: BSE (bulk silicate Earth), pyrolite, heat production, geoneutrino ¹

1. Introduction

Earth and other rocky planets have undergone a unique physical, chemical, and isotopic evolution compared to the gas giants that are sourced in the outer solar system. It is not clear whether our solar system history is typical and therefore directly applicable to

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This paper is dedicated to my mentor, colleague, and good friend, Shen-su Sun.

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