Exoplanet Mineralogy, And Related Issues of Bulk Earth And Solar Compositions

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We survey the Hypatia Catalogue and use terrestrial mantle mineral compositions and mass balance to calculate possible exoplanet mantle mineralogies. Our estimates make use of those stars where each of Si, Al, Fe, Mg, Ca, Na, and K are reported. Like prior studies we find that Earth is Fe-rich and that most exoplanets will have slightly smaller metallic cores, with exoplanet core radii that range from +5% to -21% relative to Earth. We also find that exoplanets with bulk silicate mantles (BSMs) of >50% SiO_2 (20% of our database) may have mantles dominated by orthopyroxene (Opx) at shallow depths, and majorite garnet in their transition zones. Experimental deformation studies are not clear about the role of Opx in affecting plate tectonics, but high Maj in Si-rich exoplanet transition zones may limit whole mantle convection.

A fundamental assumption of our method is that planetary compositions mimic the stars they orbit. But our tests reveal a problem: either Earth is hiding a Si-rich reservoir, formed from non-Solar like compositions, or has lost a Si-rich component (i.e., the Moon). Our tests compare depleted upper (MORB-source) mantle, and some new estimates of the putatively deep-seated source of mantle plumes. If plumes tap the lower mantle, leaving nothing un-hidden, then Bulk Silicate Earth (BSE) appears tightly constrained, and more Si-poor than most chondrites or the Solar atmosphere. Moreover, there is not near enough Si in Earth's core to compensate for the contrast. Barring hidden reservoirs, at least two other options can explain BSE. First, the Earth could be made mostly of certain, CV3-like, or chondrule-rich materials; in this case, Earth would fall near the end of a chondrite Si-Mg compositional spectrum, rather than in the middle. Another possibility is to add back Earth's Moon, which apparently was formed by a Mars-sized impactor (whose components are putatively integrated into the current Earth and Moon). But the mass of the Moon is too small to explain contrasts in Si, and would in any case drive the Bulk Earth even further from the Sun with respect to Ca and Al. This lends plausibility to a chondrule-rich Earth, or a Si-rich reservoir in Earth that is untapped by modern volcanoes.