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The Earth's Inner Core: a Black Box

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The Earth's inner core continues to provoke interest and interaction among various disciplines within the deep Earth scientific community for many reasons, including the following:

i) The phase diagram of iron and its alloys at high pressures and temperatures is still in a state of investigation, and several crystalographic phases of iron and/or their aggregates have been proposed to be stable at inner core conditions. Seismological datasets have increased in size, but there is a serious trade-off between isotropic and anisotropic velocity structure. This is further exacerbated by the non-uniqueness of the inverse problem in which travel time data are modeled by volumetric changes in isotropic/anisotropic structure. These datasets are nevertheless invaluable, and their further growth through receiver installations in remote regions will further constrain this problem.

ii) Radial and lateral variations in inner core structure have been intensively studied and confirmed, both in terms of velocity and attenuation. Studying the latter is complicated since another trade-off exists – that between the viscoelastic and scattering origin of attenuation. There is an ongoing debate about the existence of the innermost inner core and the geodynamical mechanism responsible for the seismologically observed east-west dichotomy in isotropic velocity. The growing travel time and waveform datasets, both from individual stations and arrays, hold the key to solving these problems.

iii) The growth mechanism of the inner core is in dispute; its age is still unknown, and it is not completely understood how its growing front crystallizes. The seismological datasets are arguably less potent in providing direct answers to this question. Nonetheless, there is some potential in studying the texture present in the outermost inner core, the velocity gradient at the bottom of the outer core, and the nature of the inner core boundary using waveform simulations and the coda of the seismic phases that interact with the inner core boundary.

iv) Recent studies have revealed complex structures in the lowermost mantle and outermost inner core that impose complex boundary conditions on the geodynamo. It is possible that the lowermost mantle structure is "mapped" onto the surface of the inner core through convection patterns in the outer core. There is much potential to make further progress on this topic due to the improving quality and increasing number of data and the continual advancements in mathematical geophysics, which can now provide uncertainty maps in addition to tomograms.

v) The rotational dynamics of the inner core is still not well understood despite recent progress. While this topic is difficult to address seismologically due to the lack of the north-south ray-paths, the emergence of novel approaches to inverse problems and new seismological classes of data, such as interferometry datasets, is promising.