SAMPLE

Worlds Beyond Earth: Earth's Interior

The Hidden Layers of Our World

Aira Astralis

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This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

Everything this book describes sits where no one has ever been and nothing built by human hands has ever gone. The deepest hole ever drilled, the Kola borehole in the Russian far north, bottoms out at a little over twelve kilometres, a scratch on the skin of a planet nearly 6,371 kilometres from surface to centre. Everything below that scratch is known the way an object behind a closed door is known: by knocking, by listening, by measuring what seeps out through the cracks. What the knocking has revealed is a planet of layers, each with its own chemistry, its own behaviour, and its own history, stacked inside one another like the nested weights of a pendulum clock.

The broad architecture can be stated in a sentence. Above lies a thin silicate crust; beneath it a mantle of dense rock, solid but slowly flowing, nearly 2,900 kilometres thick; then a liquid shell of molten iron and nickel about 2,260 kilometres deep; and at the very centre a ball of solid iron, crystallised under pressure no surface laboratory can fully reproduce, roughly the size of the Moon's diameter and hotter than the surface of the Sun. That statement, for all its simplicity, took two centuries to earn. Every number in it was pried out of the planet indirectly: from the travel times of earthquake waves, from the pull of gravity, from the strength and wanderings of the magnetic field, from rocks vomited up from depths no drill can reach, and from crystals squeezed in diamond anvils until they confessed the behaviour of iron at the pressures of the core.

One habit of method runs through all of it and deserves a word at the start. Geophysicists build models, the planet corrects them, and the corrections are where the discoveries live. The story of the interior is therefore not a story of expeditions downward but of instruments upward: better seismographs, better gravimeters, better satellites, better ways of listening. The chapters that follow walk through the layers from the outside in, then through the tools that made them visible, the heat and magnetism that make them move, and the honest catalogue of what remains unknown. It ends where the science itself is heading, with neutrinos, simulations, and the patient hope of hearing the centre of the Earth more clearly than any generation before.

Chapter 01: The Discovery of Earth's Interior

The first measurement that pointed inward was a measurement of weight. In 1798 Henry Cavendish, working with a torsion balance in a garden shed, measured the gravitational attraction between lead balls and from it calculated the density of the Earth: about five and a half times the density of water. The rocks at the surface average less than three. The arithmetic was ruthless. Most of the planet's bulk had to be made of something far heavier than anything exposed at the surface, and the only candidates abundant enough were the metals, iron chief among them. Long before anyone could see inside, the interior had already been weighed and found metallic.

The proof that the heavy shell had a name and a boundary came from earthquakes. In 1906 the Irish geologist Richard Dixon Oldham, studying the records of a great earthquake in Assam, noticed that the waves which travel slowest and shake the ground sideways, the S waves, were being blocked by something deep in the planet. Solids carry those waves; liquids swallow them. Somewhere below was a vast body of fluid. In 1909 Andrija Mohorovicic, examining a Croatian earthquake, found that a second class of waves, the fast compressional P waves, jumped in speed at a shallow boundary, marking the line where crust gives way to mantle. In 1914 Beno Gutenberg fixed the roof of the liquid shell at about 2,900 kilometres down. The deepest of the layers had found its ceiling.

The innermost discovery belonged to a lone seismologist working with other people's data. In 1936 Inge Lehmann, reading the arrival times of waves that should not have been where they were, concluded that the liquid core held a solid heart, that waves were bouncing off something at the centre of the Earth. She announced it in a paper whose title asked the question plainly, and the answer has stood for ninety years: the inner core exists, a solid seed inside the liquid metal, about 1,220 kilometres in radius. With Lehmann's observation the layered planet was complete from crust to centre, and every surprise since has been a refinement rather than a revolution of the architecture she and her predecessors laid down.

How the iron came to be at the centre at all is a story from the planet's childhood. Earth formed about 4.6 billion years ago by the accretion of smaller bodies, and the young planet was hot from the collisions and from the decay of short-lived radioactive isotopes. Heat softened the interior until much of it flowed, and in that softened state the dense materials sank toward the centre while lighter silicates floated upward, a sorting geologists call planetary differentiation and wryly name the iron catastrophe. It was not a single afternoon's event but a drawn-out settling, and it left the planet zoned like the

output of a gigantic centrifuge: metal at the bottom, light rock at the top, and the whole history of geology since has been the working out of consequences of that one great sorting.

A stage worth adding to the drama is the seismograph itself, because none of the discoveries would have arrived without it. John Milne, working in Japan in the 1890s and then in England, developed a compact instrument sensitive enough to record distant earthquakes and helped organise the first global network of stations, so that by the early twentieth century every large shock anywhere was being caught by instruments on several continents. Oldham's core paper was built on exactly such distant records; so was Mohorovicic's boundary; so was Lehmann's inner core. The science of the interior was, from the first, a network science, and its heroes were as much the station keepers as the theoreticians who read their drum records by lamplight.

There is also a road-not-taken worth honouring. Emil Wiechert, the German geophysicist who built improved seismographs and promoted the global network, proposed as early as 1897 that the Earth must have a heavy metal core inside a stony shell, reasoning from the planet's mean density. He was proved right by the very instruments he championed, though the liquid nature of his metal core came as a surprise he did not expect. After the core was confirmed, Harold Jeffreys and Keith Bullen compiled, in the 1930s, the first precise tables of how long seismic waves take to cross the planet along every possible path, tables that generations of analysts refined and that still underlie the naming of the interior's regions; Bullen lettered the layers A through G, from crust to centre, a nomenclature that survives in the notation of models today. Lehmann, fittingly, gave her reflected wave its own name in that alphabet, and the discovery it announced has borne her name ever since.

One more instrument closed the twentieth century's account. The Chilean earthquake of May 1960, the largest ever instrumentally recorded, set the whole planet ringing in its free oscillations, and the frequencies of those tones, measured against the predictions of the layered models, matched: the interior's structure, built entirely from short-period body waves, was confirmed at wavelengths the size of the planet itself. The same decades converted the seismograph from a mechanical pendulum scratching a smoked drum into a broadband digital sensor recording ground motions from nanometres to metres across, so that a single station today does the work a network once did, and the study of the interior became quantitative in a way its founders would not recognise. From Oldham's hand-logged arrival times to a million-channel archive, the discovery layer of this science has never been the layers themselves; it has been the improvement of the hearing.

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ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.