What would you see on a journey to the centre of the Earth?

Crystals as big as cities and a sea of liquid metal are just some of the wonders you would see.

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If you could dig a tunnel right through the Earth you could theoretically free-fall to the centre of our planet in just eighteen minutes. You can't, of course: such a tunnel would have to tolerate temperatures as high as the surface of the Sun and pressures three and a half million times greater than those at the Earth's surface. No material yet developed could withstand those conditions. The deepest we have ever drilled is just over 12km. But just suppose you could build it, what would you find? Much of what we have learnt about the inside of our world, especially its innermost regions, we have discovered only recently. So, bold traveller, this is what you would encounter on your imaginary journey.

The Crust

It will take less than a minute to fall through the Earth's crust – its outermost hard shell made of the lighter rocks. The skin of our planet is only 35km thick and a mere 1 per cent of the Earth's mass. The crust is composed of two types. The continental crust is made of the lightest rock such as granite and it forms the continents that overlay denser rocks. The continents have the oldest rocks found on the surface of the Earth and the record holder is a greenish, finely grained rock 4.4 billion years old and found on the shore of Hudson Bay, Canada. These rocks solidified soon after the Moon was formed, and if you were there at that time you could have looked up from them and seen active volcanoes glowing on the Moon. Studies of the earliest rocks indicate that the early Earth was not hot and hellish for very long but cooled swiftly and had extensive oceans almost from the start. Everything mankind has ever built is made from metals and minerals mined from the crust with the exception of diamonds – they come to us from much deeper.

The so-called oceanic crust is much younger than the continents and is constantly being formed at mid-ocean ridges like that seen bisecting the Atlantic, from where it spreads as slabs of moving basalt. This is the driving force behind the movements of the continents. On the sea floor these slabs often gather sediments that can pile up in a thick layer. But its life at the Earth's surface is a relatively brief one, no more than 200 million years, for these rocks so recently solidified from the molten Earth below will soon rejoin it, bringing cold from the surface, sediments and great changes. Being heavier than continental crust, oceanic sea-floor slabs are pushed back into the Earth under the continents in a process called subduction.

The Mantle

Like you, the slab is heading through the crust into the mantle – the largest region of our planet, comprising about 82 per cent of its volume and 65 per cent of its mass. The mantle is where the archaeology of our planet is stored as well as newly recognised ancient structures and processes that may be necessary for life to exist on the surface. Indeed, scientists are beginning to realise that the conditions for life are created as much from below as they are by the Sun above.

As the slab descends it comes under extreme pressure and, being colder than the rock it is plunging into, it is brittle. Consequently it fractures and slips, causing the most powerful earthquakes we ever experience. Japan – the world's most earthquake-prone nation – sits above where the Pacific oceanic plate is subducting beneath the Asian continental crust. As the slab gets deeper the temperature and pressure increase to levels that it cannot withstand. It is heated so that the rock flows like plastic, meaning that below a few hundred km the earthquakes cease. Minerals containing water break down and release fluid. The water seeps out and rises and reaches the mantle rocks above it. There it causes the melting temperature of those rocks to lower, sometimes by as much as 400 degrees. This rock, now much less viscous, makes its way to the surface. That is why a hundred or so kilometres beyond a subduction zone there are arcs of new volcanoes.

The mantle – and this is generally true of the entire Earth – is mainly composed of four elements: oxygen, silicon, magnesium and iron. Their atoms link to form latticework structures that yield under pressure to form ever-closer arrangements. For many years only the mantle's upper section was considered interesting. Below that the increasing pressure and heat were supposed to have squeezed the rocks so mightily as to erase any structures. The result would be a uniform mass of rock reaching downwards until the dramatic boundary with the outer core is reached.

We now know that the mantle is a more active place than we had thought. Although it's made of solid rock, it does move slowly with material descending to and rising from its deepest layers. Some scientists believe there are plumes of rock making their way through the mantle heading for the surface and that every few hundred million years vast amounts of lava are disgorged at the surface causing mass extinctions.

Tuzo and Jason

By the sophisticated analysis of shock waves from earthquakes that bounce around in the interior, scientists have found four giant structures at the base of the mantle. There are two regions that seem to be relatively cool and sinking regions, one under the western edge of the Americas and the other under southern Eurasia. There are also two large and mysterious regions of higher than average density lying beneath Africa and the Pacific. The African region towers above the core–mantle boundary by well over a thousand km and the Pacific region is only a little lower. Together they cover half of the world. They have been given names, Tuzo and Jason, after the pioneering earth scientists W. Jason Morgan and Tuzo Wilson. They are truly giant structures, each 15,000 km across, and are considered by some scientists to be our planet's underground continents. Research suggests they are ancient and are likely to have formed 4.4 billion years ago when the Earth was young. Recent data indicate that the edges of Tuzo and Jason appear sharp and scientists speculate that they deflect material upwards, for what goes down to the lower mantle can come back up again billions of years later.

Liquid Metal

On your journey to the heart of our planet you will reach the base of the lower mantle in about eight minutes. You you must then prepare for the biggest shock of your journey. Nowhere in or on our planet is there such a dramatic change of scenery as the one you are about to experience. Suddenly, at a depth of 2,890 km, you burst through the rocky part of the Earth into a sea of liquid metal five thousand degrees hot. This is the outer core, occupying about 10 per cent of the Earth's volume and 27 per cent of its mass. That's about the size of the planet Mars.

Imagine if our capsule could pause just above the boundary in the white-hot rock of the lower mantle, and then move perhaps just a few tens of metres into the liquid metal of the outer core. It would be like diving into an ocean from a slightly curving wall of rock. You have left behind the rocky regions of our planet and now, for the next 2,000 km, you are a submariner in a sunless sea of slow-motion currents, storms and cyclones of liquid metal riven with magnetic and electrical fields.

If you donned super-protective gloves you could run your hands through it like water. Its influence extends further than the Earth itself, for out of its motions emerges our great protector – the Earth's magnetic field. Without our magnetic protection life on the surface would not be possible, for it shields us from harmful particles from the Sun and deep space. Mars lacks such a defence and has lost most of its atmosphere. Consequently no life can exist on its exposed surface.

Every once in a while something happens to the currents in the outer core. They seem to become chaotic and no longer generate as strong a magnetic field. On the surface the magnetic strength declines to about ten per cent of what it was.
Over thousands of years it increases as the outer core recovers from the disturbance. But

the magnetic poles have reversed: north becomes south and vice versa. It has happened many times in the past and life has survived. There is no indication it is happening now, though some day it will be something humanity will live through.

The Crystal Core

After eight more minutes of descent you reach the greatest mystery of our planet: a super-dense ball of solid iron and nickel as hot as the surface of the Sun. It is only solid because of the pressure of over a million times that of the surface. This is the crystal core, only about half a per cent of our planet's volume, a little smaller than the Moon, but nearly 2 per cent of our planet's mass, and one of the strangest objects ever encountered by science.

Imagine the volume of water in all of the world's oceans and multiply it by five and you have the volume of the inner core of the Earth. It is difficult to gather information about the inner core. It presents a small target for seismologists. Few seismic waves reach it, let alone make it back to the surface to reveal what they have travelled through. New techniques are being developed to pick out the faint and elusive waves that traverse the inner core. With the right processing it's possible to identify the faint echoes from the inner core, and the more we analyse them the stranger it becomes.

This iron-clad world is floating within a metal sea and is not obviously tied to anything above. There are indications that it rotates at a slightly different rate from the rest of the Earth, and is also offset from the very centre of the Earth by many kilometres.

Some believe that the boundary between the inner and the outer core is undulating and mushy, with the iron crystals growing dendritically; reaching out like giant iron trees with a kind of iron mush between them. Others believe the topmost few hundred kilometres of the inner core consist of small crystals of iron, but inside the inner core they may merge, losing their individual identity as they become giant crystals aligned with the Earth's overall magnetic field.

These crystals are marvels, unseen wonders of the solar system. If you could sail past them they might remind you of a geological structure similar to the basalt columns of the Giant's Causeway in County Antrim, Northern Ireland, though thousands of times longer and wider. Single iron crystals the width of a city, stretching the distance from London to Birmingham!

But the biggest mystery is that the inner core is a newcomer. The latest calculations indicate it only appeared between 500 and 1,000 million years ago, having grown steadily from a single crystal of iron. It continues to grow at half a millimetre a year and in a billion years it may even switch off the Earth's magnetic field.

We will never reach the centre of the Earth. The conditions are so harsh – six thousand degrees Centigrade and a pressure of three and a half million atmospheres – that no probe will ever get there. Perhaps it will always be an enigma. A scientist involved in inner-core research told me, "Everything is getting increasingly complex as we get more data. We are seeing more and more complexity, and the more we do the less we understand."

David Whitehouse's book, Journey to the Centre of the Earth, is published by Weidenfeld & Nicolson

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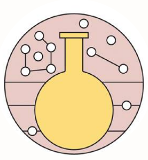

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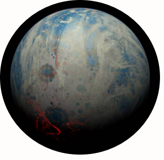

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