Earth's inner core is melting... and freezing

18 May 2011

The inner core of the Earth is simultaneously melting and freezing due to circulation of heat in the overlying rocky mantle, according to new research from the University of Leeds, UC San Diego and the Indian Institute of Technology.

The findings, published tomorrow in *Nature*, could help us understand how the inner core formed and how the outer core acts as a 'geodynamo', which generates the planet's magnetic field.

"The origins of Earth's magnetic field remain a mystery to scientists," said study co-author Dr Jon Mound from the University of Leeds. "We can't go and collect samples from the centre of the Earth, so we have to rely on surface measurements and computer models to tell us what's happening in the core."

"Our new model provides a fairly simple explanation to some of the measurements that have puzzled scientists for years. It suggests that the whole dynamics of the Earth's core are in some way linked to plate tectonics, which isn't at all obvious from surface observations.

"If our model is verified it's a big step towards understanding how the inner core formed, which in turn helps us understand how the core generates the Earth's magnetic field."

The Earth's inner core is a ball of solid iron about the size of our moon. This ball is surrounded by a highly dynamic outer core of a liquid iron-nickel alloy (and some other, lighter elements), a highly viscous mantle and a solid crust that forms the surface where we live.

Over billions of years, the Earth has cooled from the inside out causing the molten iron core to partly freeze and solidify. The inner core has subsequently been growing at the rate of around 1mm a year as iron crystals freeze and form a solid mass.

The heat given off as the core cools flows from the core to the mantle to the Earth's crust through a process known as convection. Like a pan of water boiling on a stove, convection currents move warm mantle to the surface and send cool mantle back to the core. This escaping heat powers the geodynamo and coupled with the spinning of the Earth generates the magnetic field.

Scientists have recently begun to realise that the inner core may be melting as well as freezing, but there has been much debate about how this is possible when overall the deep Earth is cooling. Now the research team believes they have solved the mystery.

Using a computer model of convection in the outer core, together with seismology data, they show that heat flow at the core-mantle boundary varies depending on the structure of the overlying mantle. In some regions, this variation is large enough to force heat from the mantle back into the core, causing localised melting.

The model shows that beneath the seismically active regions around the Pacific 'Ring of Fire', where tectonic plates are undergoing subduction, the cold remnants of oceanic plates at the bottom of the mantle draw a lot of heat from the core. This

extra mantle cooling generates down-streams of cold material that cross the outer core and freeze onto the inner core.

Conversely, in two large regions under Africa and the Pacific where the lowermost mantle is hotter than average, less heat flows out from the core. The outer core below these regions can become warm enough that it will start melting back the solid inner core.

Co-author Dr Binod Sreenivasan from the Indian Institute of Technology said: "If Earth's inner core is melting in places, it can make the dynamics near the inner core-outer core boundary more complex than previously thought.

"On the one hand, we have blobs of light material being constantly released from the boundary where pure iron crystallizes. On the other hand, melting would produce a layer of dense liquid above the boundary. Therefore, the blobs of light elements will rise through this layer before they stir the overlying outer core.

"Interestingly, not all dynamo models produce heat going into the inner core. So the possibility of inner core melting can also place a powerful constraint on the regime in which the Earth's dynamo operates."

Co-author Dr Sebastian Rost from the University of Leeds added: "The standard view has been that the inner core is freezing all over and growing out progressively, but it appears that there are regions where the core is actually melting. The net flow of heat from core to mantle ensures that there's still overall freezing of outer core material and it's still growing over time, but by no means is this a uniform process.

"Our model allows us to explain some seismic measurements which have shown that there is a dense layer of liquid surrounding the inner core. The localised melting theory could also explain other seismic observations, for example why seismic waves from earthquakes travel faster through some parts of the core than others."

Provided by University of Leeds

APA citation: Earth's inner core is melting... and freezing (2011, May 18) retrieved 14 October 2019 from https://phys.org/news/2011-05-earth-core.html

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