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A partially molten mantle

Geeth Manthilake

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1 SEISMOLOGY

2 A partially molten mantle

3 Geeth Manthilake

4 Laboratoire Magmas et Volcans CNRS, IRD, OPGC, Université Clermont Auvergne, Clermont-
5 Ferrand, France

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7 *A global analysis of seismic waves has identified a widespread sharp velocity anomaly at the base of*
8 *the low seismic velocity zone that is consistent with partial melting, closing a decades-long debate*
9 *about the origin of this zone.*

10

11 The key to modern-day plate tectonics is thought to be the mechanically weak layer of rock
12 between the rigid lithosphere (comprising crust and the uppermost mantle) above and the more
13 ductile asthenosphere beneath. This layer has a low viscosity, which has a lubricating effect that is
14 considered essential for maintaining plate motion¹ (**Fig. 1**). It is known as the low-velocity zone as it
15 is characterized by low seismic wave velocities: seismic wave observations have revealed a sharp
16 decrease in velocity starting at a depth of around 80 km and then a gradual increase in velocity with
17 increasing depth. The lower boundary of the low-velocity zone is poorly constrained, dispersing
18 between 120 to 300 km depth in the upper mantle. This ambiguity regarding the base of the low-
19 velocity zone has made it difficult to determine its origin. Writing in *Nature Geoscience*, Hua and
20 colleagues² report a globally prevalent seismic anomaly at 150 km depth that they argue represents
21 the base of the low-velocity zone, which they use to explore the nature of this layer.

22 Despite its physical properties having such a profound effect on mantle dynamics, the nature
23 of the low-velocity zone has been the subject of a decades-long debate with opinions divided over its
24 origin^{3,4}. Partial melting has been considered the most plausible explanation because the behaviour
25 of seismic waves travelling through the layer closely resemble those obtained through laboratory
26 experiments³. However, the absence of a sharp increase in seismic velocity at the base of the low-
27 velocity zone has been one of the major arguments against the hypothesis that partial melting of the
28 mantle is responsible for the reduced seismic velocity and viscosity of this layer. Alternative
29 hypotheses based on the intrinsic mechanical properties of the mantle rocks have also been
30 proposed, the most widely accepted of which are the effects of temperature⁵ and water⁶ on the
31 elastic and plastic properties of mantle minerals.

32 Hua and colleagues² shed light on this fundamental question of the origin of the low-velocity
33 zone. By analysing scattered seismic waves, the authors have imaged for the first time a globally
34 distributed positive seismic velocity gradient in the upper mantle, at about 150 km depth. The sharp
35 nature of this seismic velocity anomaly indicates that partial melting can explain our observations of
36 the low-velocity zone and that it is not thermally controlled, as a sudden change of temperature is
37 not expected at these depths. Similarly, the presence of water in mineral phases such as olivine would
38 not produce such a sharp positive velocity jump at the base of the low-velocity zone. The authors also
39 investigated whether ductile deformation could be responsible for the observed velocity gradient by
40 looking at directional variation in seismic velocity in the upper mantle. Radial variation occurs where

41 mantle minerals exhibit a preferred crystallographic orientation due to strain, but this is not apparent
42 at the depth of the observed velocity gradient.

43 The study by Hua and colleagues² establishes the missing link that connects partial melting
44 to the origin of the low-velocity zone. It also establishes that this melting does not cause the low
45 viscosity of this layer, but it should be controlled by the gradual increase of temperature and pressure
46 with depth in the mantle. These new constraints shift the focus away from the debate on the origin
47 of the low-velocity zone and onto understanding partial melting at the lithosphere-asthenosphere
48 boundary. There has been much debate related to the composition of the melt (whether it is silicate⁷
49 or carbonatite⁸) and the melting mechanism, i.e., whether melting occurs because of the decrease of
50 water solubility in pyroxenes⁹, water saturation in the upwelling mantle¹⁰, or compression melting of
51 carbon-bearing assemblages⁸. With an improved understanding of the low-velocity zone, the focus
52 of future research can move to investigating the nature of these melts, especially the role of volatiles
53 in the melt genesis and melt extraction in the Earth's asthenosphere.

54 The low viscosity of the low-velocity zone is a prerequisite for plate motion, but the influence
55 of partial melting has been a topic of debate for decades. Hua and colleagues² demonstrate that
56 partial melting can explain our seismic observations of this layer and that future research should focus
57 on investigating the nature of these melts and their geodynamic significance.

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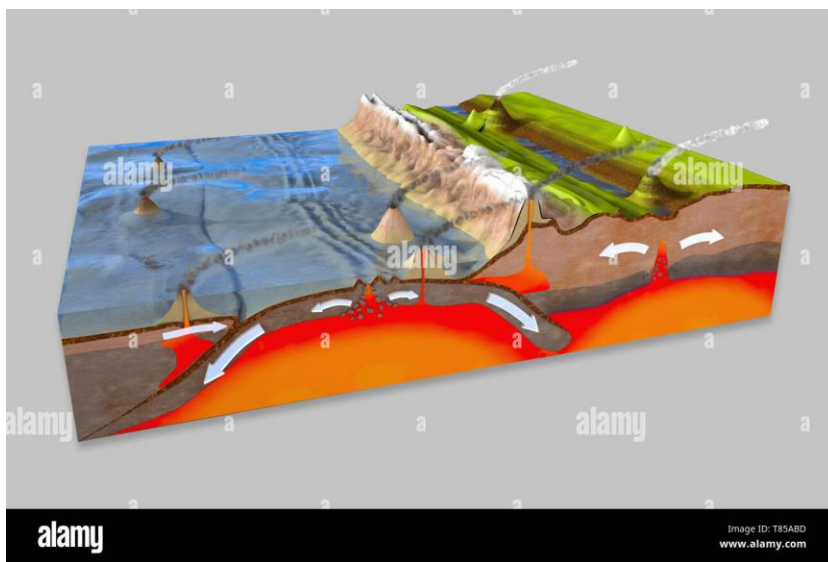
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60 **Fig. 1: Low-velocity zone facilitates plate motion**

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62 The low-velocity zone between the lithosphere and asthenosphere has a low viscosity that allows for
63 plate motion. Hua and colleagues² who are the first to image the base of this low-velocity zone,
64 confirming that it is due to partial melting of the upper asthenosphere.

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69 **Competing Interests**

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71 The author declares no competing interests.

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