Press Releases

May 29, 2009
Japan Agency for Marine-Earth Science and Technology

First Evidence for Slab Tearing Associated with Slab Stagnation in the Mantle Transition Zone

1. Outline

Masayuki Obayashi and his colleagues from the Deep Earth Structure Research Team at the Institute for Research on Earth Evolution, the Japan Agency for Marine-Earth Science and Technology (JAMSTEC: Yasuhiro Kato, President), reported for the first time that oceanic plates subducting from the Japan and Izu-Bonin Trenches were torn apart at depths of more than 300 kilometers beneath the junction of these trenches (see Figure 1 for the tectonic setting). Possible mechanisms of the tearing were also presented.

Tectonic plates are known to rupture or tear apart in shallower depths; but the mechanical properties of deep slabs, the plates subducting into the mantle, have been poorly understood. The finding of the slab tearing and consequence slab gap in the mantle transition zone, therefore, has provided a landmark breakthrough in understanding behavior of subducted slabs, which implies that tectonic plates could retain their mechanical properties even under high temperature and pressure conditions in the Earth's deep interior.

The report has been published online in the May 29 issue of the U.S. journal Science.

Title	:	Tearing of Stagnant Slab
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2. Background

Dr. Obayashi and his colleagues have reported in their previous studies that subducted slabs tend to deflect near-horizontally in the upper and lower mantle transition zone at a depth range of 400 to 1000 kilometer (*1) (Fig.2). These slabs are called "stagnant slabs." The slabs subducted from the Japan and Izu-Bonin trenches, east of Japan, tend typically to flatten near the boundary of the upper and lower mantles at a depth of 660 kilometers. The process of the slab stagnation and its subsequent descent into the lower mantle is a key to better understand the history of plate motion; however, little has been understood on the mechanical properties of the stagnant slab.

3. Methods

In order to better understand the state of stagnant slabs and the surrounding mantle, they focused on the mantle transition zone under southwest Japan and analyzed seismic waves, using data from several seismic networks. These include ocean-bottom seismic observation systems; the Broadband Seismograph Network deployed in the central to western Pacific regions; as well as dense seismograph networks in Japan.

4. Results

The high resolution images of seismic tomography (*2) for the western Pacific region showed a clear gap in fast P-wave speed anomalies (*3) associated with slabs, around the junction of the Japan and Izu-Bonin trenches (Fig. 3B - arrow (a), and Fig. 4). The gap was observed in the Kinki area (central southwest Japan) below a depth of about 300 km and persists westward and downward to a depth of about 700 km beneath the Yellow Sea. The gap corresponds with the absence of deep-focus earthquakes that would occur in subducting slabs, implying tears in the slabs.

The Japan Trench and Izu-Bonin Trench meet off east of Japan, with a junction being shaped like a "dogleg" (Fig. 1). When the slabs subducted from these two trenches bend to the horizontal, their horizontal parts have to be either separated by making a gap (Fig. 3A) or deformed by flowing. The findings from this study clarified mechanical characteristics of the stagnant slab by showing evidence that stagnant slabs do not flow in the transition zone but rupture like surface plates. In addition, focal mechanisms of the events near the tip of the slab gap at a depth of 350 km, are different from down-dip compression mechanisms for neighboring events. Instead, they have lateral-tension axes parallel to the strike of the slab (Fig. 3B – arrow (b)), suggesting the ongoing slab tear.

5. Future perspective

The behavior of Earth's surface layers has been explained by the movements of hard and brittle lithospheric plates. The properties of the slabs descending deep down the mantle, on the other hand, have been poorly constrained by observation. The finding of the slab tearing associated with slab stagnation is expected to bring about great progress in understanding the mechanical properties and behavior of the subducted slabs, which in turn will unravel the history of plate motion and evolution of Earth.

***1. Mantle transition zone**

The mantle transition zone is a region of abrupt increases in seismic wave speed, at depths ranging from 400 to 1000 km. In a narrower definition, it refers to an area between the discontinuities of seismic velocity at depths of 410 and 660 km.

***2. Seismic tomography**

Seismic tomography is a methodology to obtain three-dimensional images of velocity structure inside the Earth, using arrival times of seismic waves and waveforms.

***3. Fast speed anomalies**

A region with higher velocities than the average at a given depth. A slab cooled on the Earth's surface exhibits fast speed anomalies.

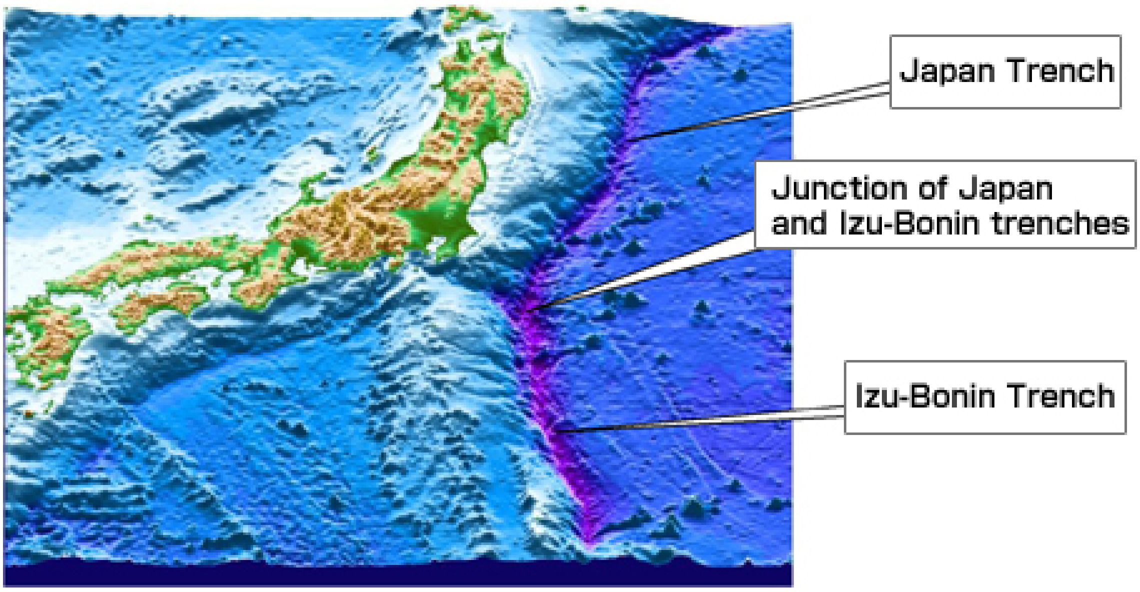

Figure 1: Bathymetric Chart around Japan. The Izu-Bonin Trench connects at its north end to the Japan Trench, forming a junction of a sharp right-hand bend.

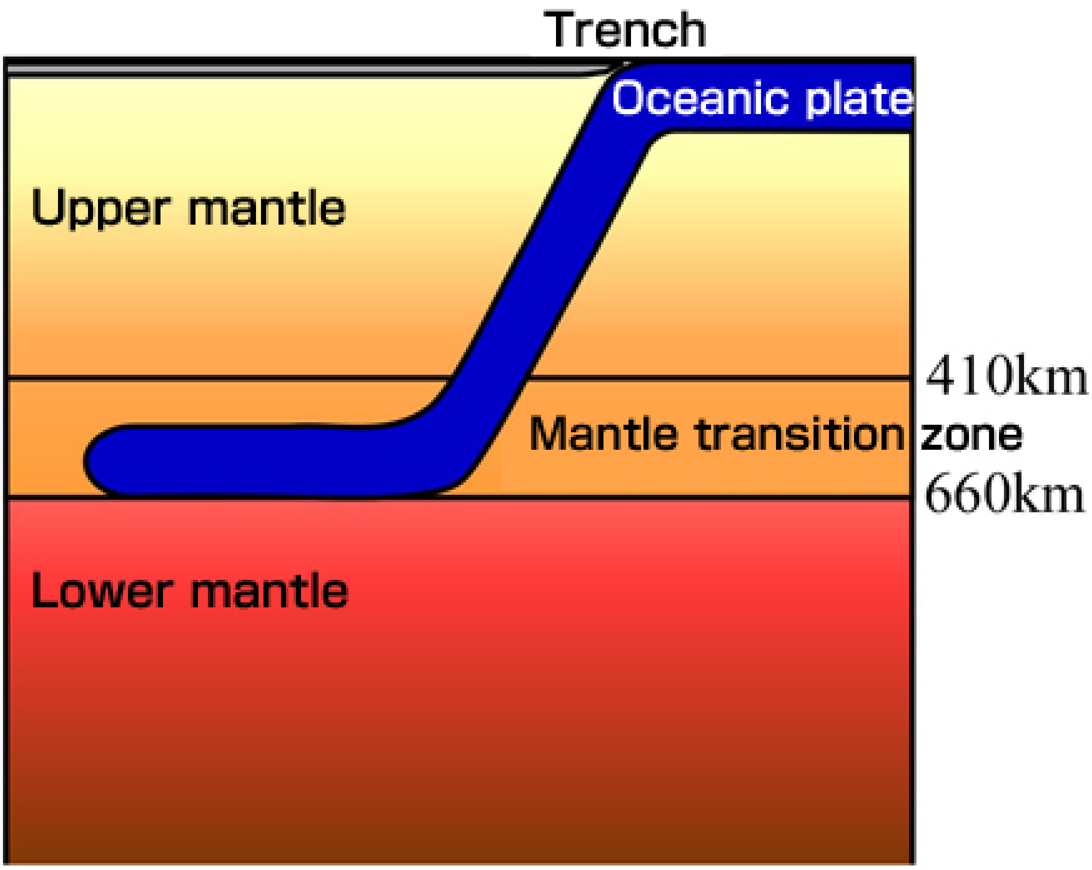

Figure 2: Slabs Subducted from the Japan and Izu-Bonin trenches bend to the horizontal in the mantle transition zone.

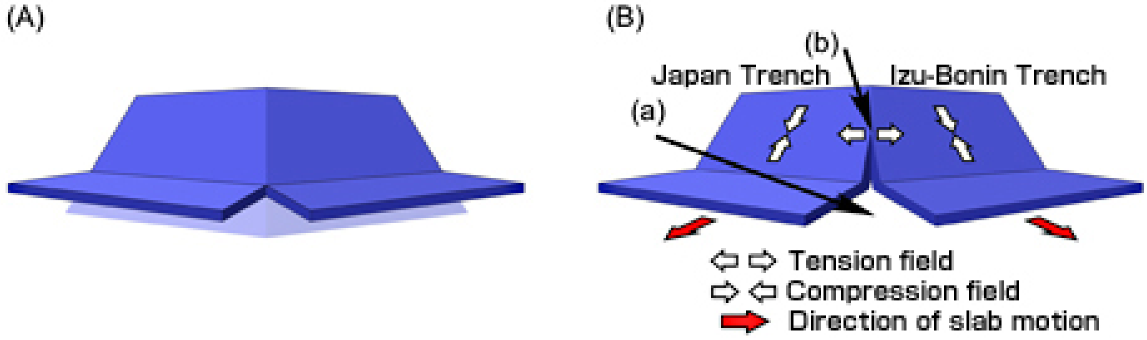

Figure 3: Schematic illustration of slab tearing

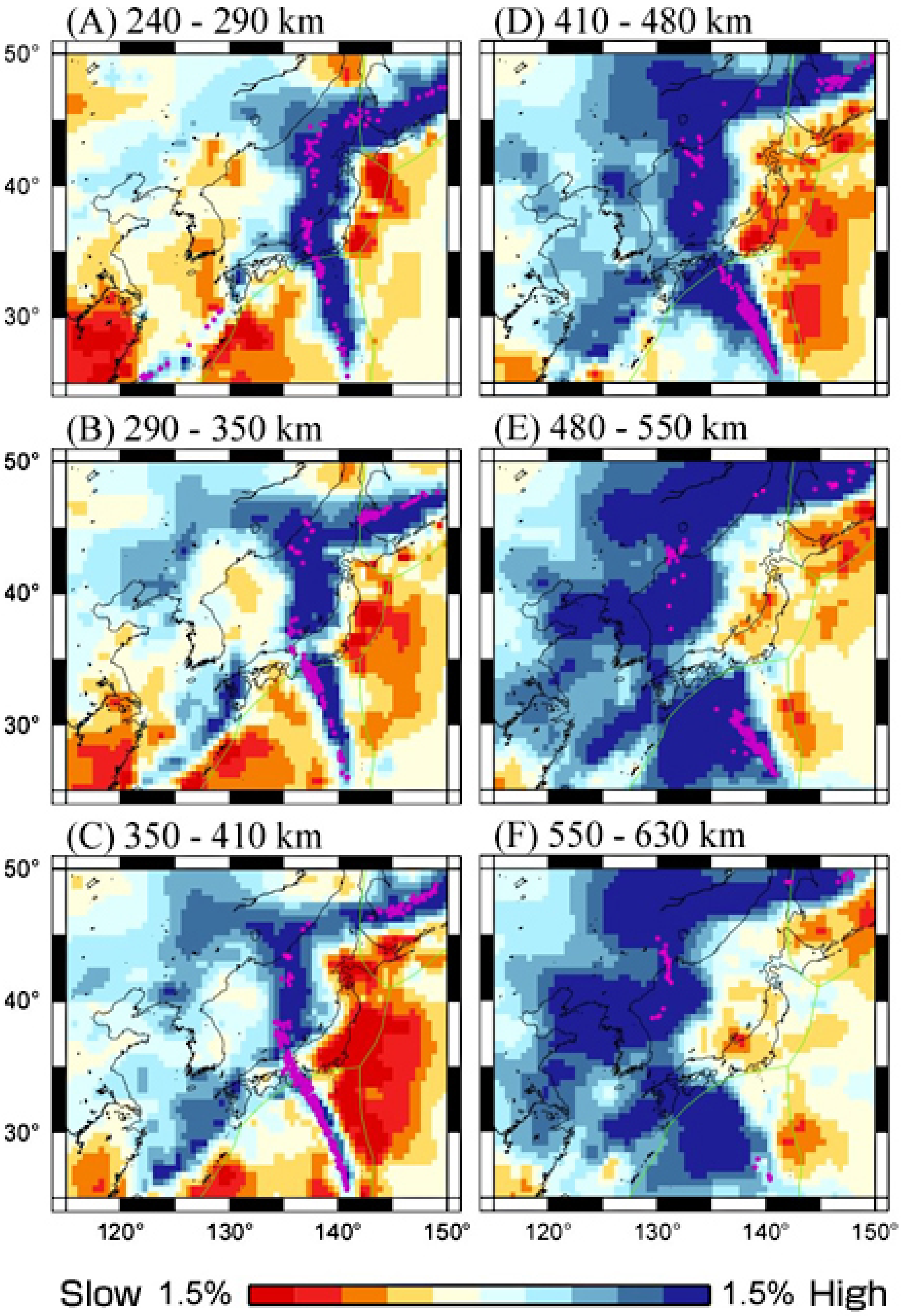

Figure 4:P-wave speed anomalies around Japan. Blue colors denote high speed anomalies and red colors denote low speed anomalies. Oceanic plates cooled on the Earth's surface exhibit anomalous high P-wave velocity in the mantle. The dots indicate earthquake focuses. The black arrow indicates the slab tear found in this study.

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