Tomographic and gravimetric signatures of the fault system associated with the 2016 Kumamoto earthquake (M7.3), Japan

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A series of shallow large earthquakes with the M_J7.3 mainshock (April 15, 2016) struck the Kumamoto area of Kyushu, Japan. The mainshock was a slip along the Futagawa Fault, a segment of the EW-running Oita-Kumamoto Tectonic Line. By this tectonic line the Beppu-Shimabara Graben is bounded sharply on the south, where NS-extensional crustal deformation is now taking place and earthquakes (including the 2016 aftershocks) are largely NS-dipping normal faulting. We conducted a seismic tomographic study for the crustal Vp and Vs anomalies using arrival time data from the Hi-Net stations in Kyushu. The most outstanding tomographic feature in this region is a belt of low Vp and Vs anomalies at depths of the upper crust geographically coinciding with the Beppu-Shimabara Graben (Fig.1). This belt is characterized by such an approximate equality that dVs/Vs ≈dVp/Vp (<0) in marked contrast to the relation in other regions or at greater depths where dVs/Vs < dVp/Vp (<0). This observation can be interpreted in terms of water-saturated, oblate-spheroid pores created by the extensional deformation of the upper crust in the Beppu-Shimabara Graben. The approximate equality between dVs/Vs and dVp/Vp holds if the aspect ratio α of pore geometry is either ~0.04 (flat pore) or ~1 (spherical pore). Once α is specified, the water volume fraction and hence density anomaly $d\rho / \rho$ (<0) can be calculated from the observed dVp/Vp or dVs/Vs. We calculate Bouguer anomalies from the density anomaly distribution so obtained. The Bouguer map calculated for spherical pores shows a remarkable negative anomaly belt in agreement with the Beppu-Shimabara Graben signature on the observed Bouguer map (Fig.2). The agreement is very poor if pores are flat. This result demonstrates a unique role of gravity data when it is combined with seismic P and S wave data. The Oita-Kumamoto Tectonic Line, including the Futagawa Fault, is a bimaterial boundary, to the north of which the material is slower in both Vp and Vs and less dense. The rupture process of the 2016 Kumamoto earthquake was likely to be affected by this bimaterial nature of the fault.

Keywords: 2016 Kumamoto earthquake, Fluid intrusion, Multiple parameter imaging

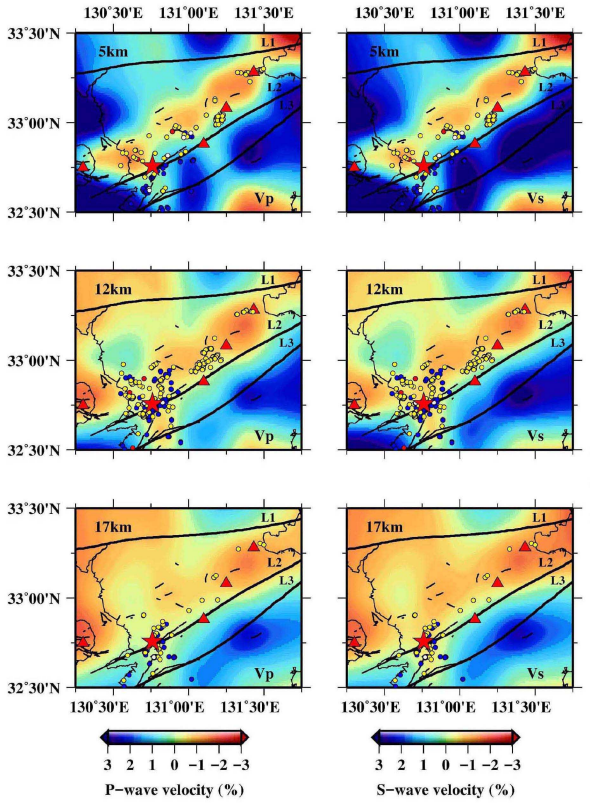

Figure 1: Vp and Vs anomalies at three depths of the upper crust

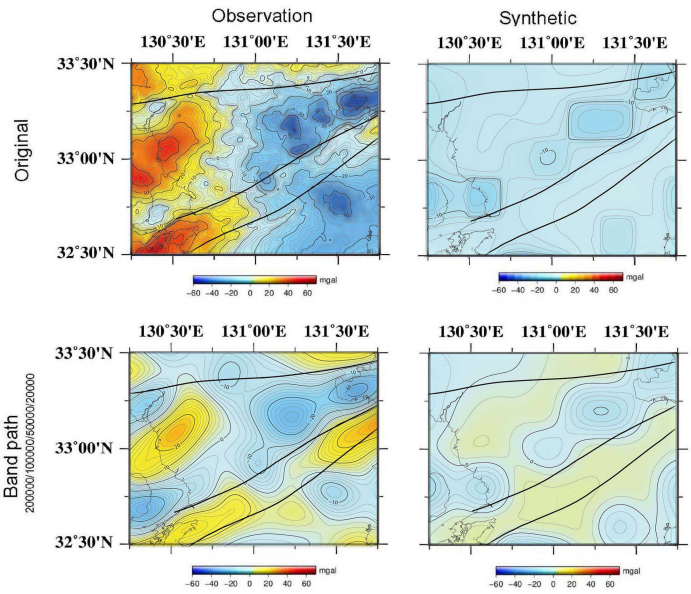

Figure 2: Observed and synthetic Bouguer anomaly maps. Synthetic maps are shown for a case of water-saturated spherical pores. Top: unfiltered maps. Bottom: bandpass-filtered maps.