

A standard model of the lithosphere-asthenosphere system: Significance of recent observations in the old Pacific

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In a classic model of the lithosphere-asthenosphere system (before ca. 1990), most of the anomalous properties of the asthenosphere (low velocities, high electrical conductivity, low viscosity) are assumed to come from the presence of a small amount of melt. However, during the last ca. 10-15 years, progresses in several areas of Earth science suggested that this classic model will require some modification. Petrological studies on the peridotites (upper mantle rocks) showed that melting in the upper mantle occurs through two stages: in the first stage in the deep portion of the upper mantle, melting occurs due to the presence of water (and other impurities). This type of melting occurs when the geotherm exceeds the solidus of an impure system, at ca. 70-150km. The amount of melt thus produced is determined by the amount of impurities (such as water), and is estimated to be less than ca. 0.2%. When the geotherm exceeds the dry solidus (at ca. 60-70 km), then a larger amount of melting will occur (ca. 10%) to produce the oceanic crust. In this model, the shallow part (less than 60 km) of lithosphere is made of a residual of this later stage melting and is composed of almost completely depleted (dry) materials. The asthenosphere is made of a material that has undergone only a small degree of partial melting (less than ca. 0.2%) so that the asthenosphere is made of materials with a modest amount of impurities such as water (ca. 0.01wt% of water) with a small amount of melt. Because the amount of melt in the asthenosphere is small, in this model, most of geophysical properties (electrical conductivity, viscosity) are not much affected by the presence of melt. Therefore the contrast in physical properties between the lithosphere and the asthenosphere is considered to be due partly to the large difference in temperature and water content. In this talk, I will discuss some implications of recent observations in the old Pacific on the plausible models of the lithosphere-asthenosphere system. Among others, I will discuss geophysical anomalies in the central Pacific and the recently reported petit spots in the western Pacific. In the central Pacific asthenosphere (ca. 100-200 km depth), a broad region around the Hawaii, has unusually strong V_{SH}/V_{SV} anomaly associated with weak azimuthal anisotropy (also low electrical conductivity and high viscosity). These anomalies are difficult explain by a standard model where these regions are anomalously hot. Based on the knowledge of petrology and on the recent results in the laboratory, I propose that these anomalies can be attributed to deep upper melting associated with the Hawaii plume and resultant depletion of water in the ascending materials. The presence of petit spots suggests a presence of wide-spread melting in the old Pacific asthenosphere that is consistent with the standard model of the asthenosphere. When the stress state of the lower lithosphere is modified by bending, melt could be accumulated to regions with relatively tensional stress that could trigger the unstable penetration of small amount of melt. Possible roles of such petit spots to modify the physical properties of the lithosphere will be discussed including thermal and chemical effects.