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Mohorovichich discontinuity: handredth anniversary of the discovery

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Mohorovichich discontinuity (Moho) is a basic boundary at any geophysical studies of the Earth's crust. Strong changes of the seismic velocities and density is characteristic for the boundary. At deep seismic studies (DSS) high amplitude wide angle reflections and converted waves are recorded from this boundary. Several specific features of the Moho-generated waves are observed: (1) the multiphase form of wide-angle reflections; (2) significant amplitudes of precritical reflections which may be explained by interlayers of anomalously high velocities (8.6- 8.9 km/s) observed in anisotropic mantle rocks; (3) low amplitudes of vertical reflections: the Moho is most frequently poorly defined in the CDP fields; (4) the CDP data often present the Moho as a boundary between the reflective lower crust and the transparent upper mantle, and, in contrary, the migration of the wide-angle reflections show the Moho as a top of a heterogeneous uppermost mantle.

All these data make it perfectly clear that Moho waves are generated not at a simple sharp boundary, but in complexly built heterogeneous zone. The boundary can be also associated with a change in the heterogeneity scale: the fine stratification (high-frequency reflectivity) of the crust changes for a larger-scale (low-frequency) stratification. This makes the boundary transparent for the CDP method and layered for the DSS waves.

Two Moho models can be proposed for interpreting this phenomenon. In terms of the first model, this boundary is marked by a transition from small-scale crustal heterogeneities with sharp boundaries to layer-scale heterogeneities surrounded by transition zones. Another model is represented by a gradient zone with anisotropic inter-layers in which the horizontal velocity is higher than the vertical one. In terms of this model, if a wave strikes the anisotropic layer at a right angle (vertical reflections), it does not respond to a change in velocity and does not produce a reflection. An incidence at the critical angle gives rise to a refracted wave traveling along the layer at a higher velocity and producing intense wide-angle reflections.

Such models were substantiated from the standpoint of mechanics. The crustal material becomes ductile under the P-T conditions at Moho depths. The material in this state becomes nearly impervious to fluids; as a result, deep fluids can concentrate under such layers. Laboratory studies showed that even a small percentage of fluids in mantle rocks can dramatically change their rheological properties, so that they can flow at relatively low temperatures. The velocity anisotropy can be accounted for by the flow of the mantle material resulting in a preferred orientation of highly anisotropic olivine crystals. This provides a reasonable interpretation of high thicknesses of anisotropic layers: material flow is easier in thick layers.

This Moho origin is consistent with structural properties of this boundary. Usually beneath the orogenic belt the Moho depth increases and beneath the deep sedimentary basins it decreases. But in the old platform regions, this boundary is nearly horizontal beneath ancient fold belt where mountain roots undoubtedly existed earlier. It is flat beneath the basin fulfilled by the dense sediments. So the isostatic equilibrium is observed, as a rule, precisely at the M boundary. This equilibrium is easy to explain with the Moho as a weak zone where the material can flow.

The other DSS data confirm the Moho mobility during the geological history. For instance, in the Dnieper-Donets paleorift two types of crustal structure were determined. The first one is characteristic of the grabens: below the subsiding basement, the M boundary rises and the average velocity in the crust increases, since the upper layer with 6.0-6.3 km/s velocities wedges out. In the Donbass deep depression, fulfilled by metamorphic sediments forming the Central Anticline, the M boundary splits into two horizons, one of which rises beneath the depression, while the other goes down. Both boundaries may be considered as the Moho or a “double Moho”: the upper one forms the uplift which is typical for most sedimentary basins and the lower one forms the Central Donbass Anticline "roots" which are typical for mountains. The double Moho formation may be explained by changes in the crustal temperature regime. When the crustal temperature increased after sediment accumulation, the depth level of such a boundary formation went upwards and the Moho moved up too. When the crust cooled after sediment metamorphism this level went down and the new Moho appeared at the normal depth for the old platforms.

The double Moho is observed in other regions too, not only beneath the sedimentary basin with tectonic inversion. A regional change of the Moho depths is observed in Europe: beneath the East Europe they are 45-55 km, in West Europe – only 30-35 km. But beneath the west-european crust at depth of 40 km a clear subhorizontal boundary is often observed, it also may be the old Moho.