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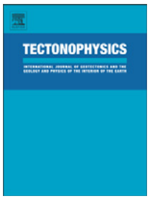

Review Article

Crustal structure of the Siberian craton and the West Siberian basin: An appraisal of existing seismic data

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ABSTRACT

We present a digital model SibCrust of the crustal structure of the Siberian craton (SC) and the West Siberian basin (WSB), based on all seismic profiles published since 1960 and sampled with a nominal interval of 50 km. Data quality is assessed and quantitatively assigned to each profile based on acquisition and interpretation method and completeness of crustal model. The database represents major improvement in coverage and resolution and includes depth to Moho, thickness and average P-wave velocity of five crustal layers (sediments, and upper, middle, lower, and lowermost crust) and Pn velocity. Maps and cross sections demonstrate strong crustal heterogeneity, which correlates weakly with tectono-thermal age and strongly with tectonic setting. Sedimentary thickness varies from 0–3 km in stable craton to 10–20 km in extended regions. Typical Moho depths are 44–48 km in Archean crust and up-to 54 km around the Anabar shield, 40–42 km in Proterozoic orogens, 35–38 km in extended cratonic crust, and 38–42 km in the West Siberian basin. Average crustal Vp velocity is similar for the SC and the WSB and shows a bimodal distribution with peaks at ca. 5.4 km/s in deep sedimentary basins and ~6.2–6.6 km/s in parts of the WSB and SC. Exceptionally high basement Vp velocities (6.8–7.0 km/s) at the northern border between the SC and the WSB indicate the presence of magmatic intrusions and are proposed to mark the source zone of the Siberian LIP. The cratonic crust generally consists of three layers and high-velocity lowermost crust (Vp ~ 7.4 km/s) is observed only locally. Pn velocities are generally ~8.2 km/s in the SC and WSB and abnormally high (8.6–8.9 km/s) around kimberlite fields. We discuss the origin of crustal heterogeneity and link it to regional crustal evolution.

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1. Introduction

Secular evolution of the crust and the mantle is closely related, and structural and compositional heterogeneity of the crust is essentially controlled by plate tectonics and mantle dynamics. Knowledge of the origin and evolution of the continental crust is compulsory for understanding of Earth evolution in general. Information on the crustal structure is further crucial for studies of the subcrustal lithosphere and the sublithospheric mantle, given that crustal structural heterogeneities effectively mask and distort mantle compositional anomalies as reflected, in particular, in seismic surface-wave tomography and gravity models. For this reason, it is essential to correct most geophysical data for the crustal effects prior to analysis for the mantle component of the anomalies.

Direct sampling of the deep crust has limited coverage, but provides key information on the composition and physical properties of crustal rocks. Laboratory-based information on the composition of the crust originates largely from crustal xenoliths brought to the surface by magmatic events (Downes, 1993; O'Reilly and Griffin, 1985; Rudnick and Fountain, 1995; Shatsky et al., 2005) and from several, although limited in number, slices of deep crust exposed by collision tectonics and impact events, such as the Kapuskasing terrane in Canada, the Vredeford impact crater in South Africa, the Ivrea zone in the Alps, and the Western Gneiss region in Norway. Given the limited spatial crustal sampling by xenoliths and the small number of tectonically exposed crustal sections, globally the structure of the continental crust is primarily known from geophysical data. These data are chiefly based on seismic studies (initially based on reflection and refraction profiles, supplemented more recently by receiver function (RF) studies and surface wave tomography), gravity modeling, and borehole data for the shallow crust.

The vast amount of seismic data collected worldwide in different tectonic settings, since the early crustal databases (Macelwane, 1951) has led to the recognition of specific crustal structures typical for various tectonic settings; a decade later they were systematically averaged and typical crustal cross-sections were derived (Closs and Behnke, 1963). Since then, this approach has become increasingly popular, in particular due to the growing demand for global seismic studies of the (first-order, at least) crustal structure even in regions without detailed geophysical data coverage. In such regions, some first-order constraints on large-scale structural properties of the crust (such as Moho depth) can be inferred from the tectonic evolution of a particular region. Such an approach is based on the widely adopted hypothesis that the structure of the continental crust is essentially controlled by its age and tectonic settings (Jarchow and Thompson, 1989; Mooney et al., 1998). However, significant deviations from generally accepted patterns are also very common (e.g. Artemieva et al., 2006; Clowes et al., 2002). In particular, recent high-resolution seismic studies of Precambrian cratons have demonstrated the presence of highly heterogeneous crustal structure even on small scale. For example, in the Kaapvaal craton of South Africa the depth to Moho varies from 35 km to 44 km over a distance of ca. 100 km and, due to strong compositional and structural heterogeneity of the crust, these variations are poorly correlated with variations in the Poisson's ratio (Nair et al., 2006; Youssof et al., 2013–this volume). Similar observations are reported in detailed seismic surveys from other tectonic settings.

Two widely used global crustal models, CRUST 5.1 and CRUST 2.0 (Bassin et al., 2000; Mooney et al., 1998) are largely based on seismic reflection–refraction data available by 1995 (Christensen and Mooney, 1995), complemented by other data sources on the thickness of sediments. These models are constrained by statistical averaging and tectonic regionalization of the available seismic models on regular grids used to fill-in the “white spots” where data are not available and, together with a significant number of regional databases of the crustal structure, they are important tools for modeling mantle velocity and density heterogeneities. Despite unquestionable advantages provided by global crustal models, they have limitations: (1) Spatial averaging over cells with dimensions of a few hundred kilometers smears lateral variations in the crustal structure and reduces the amplitude variation of seismic velocities and thicknesses of various crustal layers, as well as total crustal thickness. The situation is similar to a low-resolution topographic map of an orogen where high peaks and deep valleys are averaged into a smooth picture. (2) Spatial averaging may lead to artifacts in regions with strong crustal heterogeneity, in particular because data acquisition often targets at tectonically “exciting”, read anomalous, structures.

Given the above limitations, the accuracy and uncertainty of the two existing global crustal models cannot be assessed, even though they have been indirectly tested by global tomographic inversion (e.g. Mooney et al., 1998). For Siberia, the sparse sampling by teleseismic data prevents such a test, as it will be basically unconstrained by seismic data. The accuracy of the CRUST 2.0 model in each cell is estimated to be within 1.0 km for the sediment thickness and within 5 km for the crustal thickness (http://igppweb.ucsd.edu/~gabi/crust2.html). It is also clear that regional high resolution geophysical modeling requires high resolution regional crustal models. Additionally, such regional crustal databases would provide critical information for verifying the accuracy of global crustal models, updating the global statistics on the crustal structure that forms their basis, and potentially updating the global crustal models.

This study reports a new, independent compilation of the crustal structure of Siberia, SibCrust, based on all available seismic models for the region. The study area is limited to the area 60-132E and