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Mountain building in the Uralides: Insights from the crustal structure and composition

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Reflection and refraction seismic data show that the Uralide crust thickens eastward from ∼40 km to ∼ 52 km in the East European Craton (EEC) to between 50 to 55 km across the volcanic arcs, before thinning to between 40 to 45 km in the easternmost part of the orogen. In the Southern (URSEIS) and Middle (ESRU) Urals the EEC crust is imaged as sub-horizontal to east-dipping reflectivity that can be related to its Uralide and older orogenic events. The Magnitogorsk (URSEIS) - Tagil (ESRU) zone displays moderate to weak upper crustal reflectivity, but the middle and lower crustal reflectivity is diffuse in the case of the Magnitogorsk arc, but quite strong in Tagil. The Moho is not imaged beneath the Magnitogorsk zone, but is fairly sharp beneath the Tagil zone. East of the arc complexes, the upper and middle crust is imaged as clouds of diffuse reflectivity interspersed with, or cut by, sharp, predominantly west-dipping reflections that extend from the middle crust into the lower crust where it appears to merge with the Moho. In the ESRU data it is characterised by abundant lower crustal reflectivity.

The velocity structure of the Uralide crust is determined along the URSEIS transect. The upper crustal Vp reaches up to 6.3 kms^{-1}, and Vs reaches 3.9 kms^{-1}, with the higher values in the Magnitogorsk arc. In the middle and lower crust, Vp ranges from 6.5 to 6.8 kms^{-1}, reaching 7.1 kms^{-1} above the Moho in the central and eastern part. Vs ranges from 3.7 to 3.9 kms^{-1}, increasing to between 3.9 to 4.0 kms^{-1} at the Moho. The Moho is marked by an increase in Vp to $>$ 8.0 kms^{-1} and Vs $>$ 4.6 kms^{-1}.

The Uralide heat flow density is characterised by a minimum along the central part of the orogen, with values as low as 10 mW m^{-2}, reaching up to 60 mW m^{-2} on either side. The short wavelength of the HFD anomaly suggests a shallow origin for the minimum. This implies more ultramafic material at depth beneath the volcanic arcs than below the EEC crust. Alternatively, the HFD minimum is due to propagation of ground surface temperature changes to depth as a result of palaeoclimatic changes. Modelling assuming the first alternative suggests that the Uralides thermal structure is characterised by relatively flat geotherms, with a Moho temperature of around 600 ºC.

Petrophysical modelling along the URSEIS transect shows clear differences between the composition of the old continental crustal nucleus of the EEC and the newly added crust of the accreted arc terranes to the east. The crust of the EEC is more felsic than that of the Magnitogorsk and East Uralian zones, and the latter two have a lowermost crust whose characteristics indicate mafic garnet granulite and/or the presence of hornblendite. The composition of the arc terranes is basaltic. The physical properties data suggest that eclogite is not present in the lower crust, or present in such small amounts that it is below the resolution of the data set.

The overall reflection seismic pattern of the Uralide crust is bivergent, perhaps representing the original collision-related crustal architecture. With the exception of possible minor extensional features in the eastern part of the ESRU section, there is little evidence in the reflection seismic fabric for large-scale extensional collapse of the Uralides. The URSEIS and ESRU sections indicate that crustal thickness and Moho topography change somewhat between the Southern and Middle Urals, although the crustal root can be seen to extend along the western volcanic axis of the orogen. Petrophysical modelling of the Uralide crust along the URSEIS transect indicate that the root zone is made up of mafic garnet granulite and not eclogite. The Uralide Orogen records a long and complex subduction/accretion history prior to the continent-continent collision that gave it its final bivergent architecture. The complex late-orogenic history, which involved extensive wrench faulting accompanied by widespread melt generation and granitoid emplacement in the interior of the orogen likely significantly overprinted and/or reworked much of the subduction- and accretion-related tectonic fabric, giving this zone its varied and complex reflection seismic character.