

Textures of sub-continental mantle peridotite rocks

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Based on his PHD thesis at Birkbeck College, the speaker intended to look at the questions of what, where and why and how do we know about the internal structure of the earth and mantle.

The Russian super-deep borehole on the Kola Peninsula is 12.26km deep, so does not come near penetrating the mantle. Our knowledge of the earth's structure is based on the interpretation of astronomical and seismic data together with compositional constraints from the study of meteorites.

The upper mantle and lower part of the lithosphere are characterised by high velocity and efficient propagation of seismic waves and is rich in olivine. It is inaccessible but geological processes do bring up some random samples, the largest number as mantle xenoliths in violent alkali/silica-unsaturated volcanic eruptions, along with occasional abducted plate margins and kimberlite composite eruptions of deep origin. Random samples are not ideal but they do provide an indication to confirm the postulated effects of pressure on mineral composition, eg the transformation of olivine + plagioclase to orthopyroxene + clinopyroxene + spinel and of spinel + orthopyroxene to olivine + garnet. Mantle xenoliths occur in many places and typically in remnants of the Hercynian orogeny in the Armorican massif, the Massif Central and the Rhenian and Bohemian massifs.

Whitten and Brooks (1972) define texture as the relationship between grains of minerals forming a rock. There are 3 major groups, the grain size and size distribution, grain shape and shape distribution and the contact relationships of the grains. The characteristics are manifest in both 2 and 3 dimensions. For most rocks we see exposed surfaces on thin sections and it may be difficult to determine the grain size as most geological materials do not have a single diameter.

In the Massif Central, Tertiary and Quaternary volcanic regions provide an abundant source of spinel peridotite xenoliths for study. For their first degrees, the speaker and his late wife mapped the valley of the River Eysse, a tributary of the Ardèche and then the Rhone, over 3 summers. Most of the valley has steep-sided granitic rocks, with the Echonne Plateau supported by 4 volcanic necks and a lava sequence, which has been worked for construction material at Molines Quarry, with occasional mantle xenoliths.

The textures of mantle peridotite rocks have been the subject of detailed qualitative description but this is subjective and interpretation is possibly questionable. A quantitative method has been established using optical scanning, skeletonisation and computerised measurement of individual grain section areas. The technique involves hand-drawing a skeleton outline of grains and using a pixel-counting programme to produce summary measurements. It has been applied to 102 spinel peridotite xenoliths from intra-plate continental volcanic regions, 33 kimberlite-hosted garnet peridotite and spinel peridotite xenoliths, 5 tectonically emplaced ultramafic bodies and 7 ureilite meteorites. The greatest number was from the Massif Central with another important area being the Rhenian massif in western Germany in the Central European volcanic province.

The analyses show that a plot of mean grain size against standard deviation produces a straight line with greater scatter for garnet peridotites compared to spinel peridotites. Protogranular, porphyrogranular and equigranular rocks form distinct groups on the same linear trend. Qualitative estimates of grain size tend to be greater than the quantitative measurements. Coarser-grained xenoliths need over 300 measurements for a statistically reliable estimate of mean grain size. Some samples have layering of finer- and coarser-grained material. Orthogonal sections of some xenoliths have similar mean and standard deviation but others show a greater spread.

The markedly skewed distribution indicates that each stage of crystallisation is affected by the previous stage (the Law of Proportionate Effect) as opposed to industrial models of crystallisation in an infinite medium. Logarithmic plots of area against perimeter of fractals and xenoliths follow the same line.

2 samples have been subjected to electric discharge disaggregation and study of the grains under the scanning electron microscope shows non-concave features. X-ray computer tomography of some samples, initially as fragments and then as cylinders, enables mineral components to be identified at low x-ray energy.

In summary, the independent quantitative assessment technique developed for texture indicates that crystallisation was not in separate mineral stages but a continuum of peridotite evolution and that individual grains have non-concave features.