THE DEEP STRUCTURE OF PRECAMBRIAN SHIELDS: INSIGHTS FROM MULTIDISCIPLINARY STUDIES

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Major geoscience initiatives such as Lithoprobe in Canada and Europrobe have provided a wealth of new information concerning the formation and stabilisation of the continental crust in the Precambrian. These projects have been spearheaded by the acquisition of seismic reflection and broad-band refraction data, but have also been complemented by extensive geochronolgical data bases and regional mapping. In addition to providing a better understanding of the structure of the continental lithosphere, these studies provide important constraints for problems related to the origin of the crust, such as an origin from plume-products, or island arc-related accretionary complexes, the role of subduction and obduction in collision processes, the rates of crust accretion and extent of crust preservation.

Images of deep crust to mantle sutures in the Baltic Shield (Babel working group, 1991), and from Mesoproterozoic crust dipping below the Slave Province in Canada (Cook et al., 1999), when coupled with the geochronological and tectonic models provide convincing evidence for a Wilson cycle and associate plate tectonics as being the main driving force for crustal accretion in the Proterozoic. This evidence can be reasonably well extrapolated back to the Neoarchean accretion of the Southern Superior Province (Calvert and Ludden, 1999), and, in general plate-tectonic regimes broadly analagous to those of the Paleozoic are applicable for at least the last 3 Ga of Earth's evolution. Furthermore, there is no reason to discount the extent of continental crust as having changed through this period.

The third dimension provided by these studies leads to a substantially different view of the volume of crust in relation to the that implied from plan view. In a general sense, for certain periods on Earth's history crust may have been preferentially preserved; this is possibly the case for the Neoarchaean , and may relate to the widespread stabilisation of a thick lithosphere root to continental crust at this time. These cratons provided a stable backstop for Proterozoic collisional orogens in which the juvenile crust was largely destroyed. For example the Grenville Province of Canada comprises as much as 80% Mesoproterozoic crust in plan view, but seismic interpretations indicate that at least 50% and maybe as much as 80% of the Grenville Province has an Archaean age – either as buried cratonic rocks or as Archaean crust reworked in the Grenvillian Orogeny. In plan-view the PC shields are not representative of crustal age and composition.

Juvenile magmatic products are added to the crust throughout its history. The Baltic shield and in particular the Kola Peninsula provide evidence for plume-related additions to the lithosphere on an near continuous basis during the Paleoproterozoic. In the time interval 2.5 to 2.0 Ga, the whole eastern Baltic shield, including Kola, Karelia, eastern Finland, was an arena of extensive plume-related basic magmatism. This process was manifest in the formation of large Cu-, Ni-, Co-, Cr-, PGE-bearing, layered intrusions and dyke swarms emplaced over an area of 600 by 900 Km. These intraplate magmatic events changed through time, from E-Nd of about –2 in the Neoarchaean to E-Nd of +2 in the Mesoproterozoic (Mitrofanov and Buyanova, 1999). The Paleoproterozoic magmatic underplating, related to plume tectonics, led to the formation of rift-systems (Mitrofanov, 1995) and widespread intraplating of basic material in the lower continental crust (Mitrofanov et al, 1998). This process was accompanied by obduction and prograde-metamorphism and the formation of the Lapland granulite belt, which overthrust the Archaean TTG basement (Buyanova et al., 1995). The plume thermal events were coupled with ductile shearing processes, high-grade metamorphism, isotope re-equilibration and significant transformation of the lower- mid-crust.

Similarly the Superior and Slave cratons were subject to plume-related magmatism, although the surface evidence for these events is largely in the form of dyke swarms, with the plumes reworking the craton margins. Nonetheless, widespread high velocity layers in the lower crust and ages of xenoliths from the lower-crust (eg. Moser and Heaman, 1997) may attest to widespread Paleoproterozoic intraplating of the Archaean crust of the Canadian Shield. This intense widespread plume-related activity may reflect the first major continental breakup following Neoarchaean continental assembly.

Earth Scientists are coming to terms with mapping of the crust and lithosphere at depth. Understanding the relative ages of thermal events and seismic structure in the deep crust, and the resolution to which we can integrate data remain a significant challenge. International collaboration on studies of key geological targets in the deep crust and upper mantle should be the way of the future.

References

Babel Working Group (1991) Evidence for Early Proterozoic plate tectonics from seismic reflection profiles in the baltic Shield, Nature, 348, 34-38

Buyanova, A.F. Glaznev, V.W., Mitrofanov, F.P. and Raevsky A.B., 1995. Three dimensional modelling of the Lapland Granulite Belt and adjacent structures of the Baltic Shield from Geophysical data. Nor. Geol. Unders., Special Publication, 7, 167-178.

Calvert, A.J., and Ludden, J.N. 1999. Archean continental assembly in the southeastern Superior province of Canada. Tectonics, 18: 412-429.

Calvert, A.J., Sawyer, E.W., Davis, W.J., and Ludden, J.N. 1995. Archaean subduction inferred from seismic images of a mantle suture in the Superior Province. Nature, 375: 670-674.

Moser, D.E; and Heaman, L.M (1997) Proterozoic zircon growth in Archaean lower crustal xenoliths, southern Superior craton – a consequence of matachewan ocean opening. Contrib. Mineral. Petrol., 128, 164-175.

Mitrofanov, F.P. 1995 Geology of the Kola Peninsula (Baltic Shield)., Apatity, 145p.

Mitrofanov, F.P. and Buyanova, T.B., 1999. Duration and timing of ore-bearing Paleoproterozoic intrusions of Kola province. Mineral Deposits : Processes to Processing, Stanley et al. (eds), Balkenia, Rotterdam, 1275-1278.

Mitrofanov, F.P., Sharov, W.V., Zagorodny, V.G., Glaznev, V.N., 1998. Crustal structure of the Baltic sShield along the Pechenga-Kostomuksha-Lovisa Geotraverse. Internat. Geol . Rev., 40, 990-997.