Comparisons of Slave and Superior electric lithosphere

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Active or ancient tectonomagmatic processes operating within the crust and upper mantle may introduce electrical charge carriers into an insulating sub-continental lithosphere mantle (SCLM). Long period magnetotellurics (MT), a deep-probing, natural-source electromagnetic geophysical method, offers a complementary technique to seismics for obtaining in-situ physical property information about the SCLM. Carbon-based conductors are an attractive explanation for the conductive features observed in the Slave and Superior lithospheres above the graphite-diamond stability field (~150 km depth). Given our understanding of the conductivity of olivine from laboratory studies, features in our models of the Slave and Superior SCLM are too conductive, by orders of magnitude, for an olivine-dominant mantle without the addition of an interconnected minor conducting phase. Grain boundary carbon or graphite is the most likely minor conductive phase in the SCLM (Duba & Shankland 1982).

Spatially correlated with the surface Eocene aged kimberlite field, the Central Slave Mantle Conductor (CSMC) also correlates in depth with a geochemically-imaged ultra-depleted harzburgitic region (Griffin et al. 1999). The CSMC at 80-100 km depth has a minimum thickness of 20 km, and an internal isotropic (1-D) conductivity of the order of 0.03 S/m or greater. The elongated axis of the conductor is roughly east-west, consistent with a subdivision of the Slave based on shear wave splitting observations (Bank et al. 2000) and with G10 garnet populations (Grütter et al. 1999). This orientation is suggestive of emplacement as a consequence of the 2620 Ma subduction of an exotic Archean craton to the southeast rather than as a result of the north-south suturing of the eastern arc (?) terrane with the western Central Slave Basement Complex (CSBC) at 2690 Ma (Bleeker et al. 1999a, b). Off the conductor, the Slave's SCLM appears to be resistive and electrically isotropic. This is particularly the case beneath the Anton complex, the southwestern exposure of the CSBC, and the LAB is thought to be at depths in excess of 200 km.

The conductive features in the Superior Province 3-D model at approximately 40 km depth are aligned sub-parallel to the major zones of syn- and post-2.7 Ga transpression and may be related to other syn- and late-orogenic processes; perhaps the most pervasive of which is magmatism. A possible link between the MT data and Superior magmatism can be demonstrated with simple melting relationships. The pyrolite solidus (Green & Falloon 1998) is depressed in the case of fluid present melting and, provided the oxygen fugacity is within approximately two log units of the iron-wüstite (IW) buffer, graphite, garnet and amphibole can be major phases present in the residual. Fugacity values within a few log units of the IW buffer have recently been demonstrated for large regions of the Kaapvaal craton (Woodland 2001) and at a depth range of approximately 80 to 100 km based on equilibrium pressure and temperature estimates. The residual phases near the IW buffer have notable geophysical properties and are possible sources of spatially correlated geophysical and geochemical anomalies preserved at depths of 50-100 km or more within a cratonic root. In the Superior Province, the graphite in the residual from syn to post-tectonic partial melting may have been deposited along the (weak) fault zones and may therefore be the source of the link we observe between the EM data and major zones of transpression.

Reduction and geochemical depletion are coupled processes as $Fe3+$ is generally incompatible during partial melting. MT may therefore offer a view of regions where ancient C-H fluid-present partial melting occurred under reducing or depleted conditions. This view can be tested with xenolith information and deep seismic data as the partial melt model predicts that conductivity can be associated with major garnet in the residual. This interpretation also provides a new tool for geoscientists correlating the geochemical stratigraphy with the electrical stratigraphy. The regional conductivity structure coupled with the linkage to geochemical stratigraphy will provide an enhanced 3-D image of the lithosphere. Our goal is an increase in our understanding of the genesis of the Slave and Superior Provinces related to major magmatic and deformational events through better maps of the deep interior of the cratons

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References

Bleeker, W., Ketchum, J.W.F., Jackson, V.A. & Villeneuve, M.E., 1999a, The Central Slave Basement Complex, Part I: Its structural topology and autochthonous cover. Canadian Journal of Earth Sciences, 36, 1083-1109.

Bleeker, W., Ketchum J.W.F. & Davis, W.J., 1999b, The Central Slave Basement Complex, Part II: Age and tectonic significance of high-strain zones along the basement-cover contact. Canadian Journal of Earth Sciences, 36, 1111-1130.

Duba, A.G. & Shankland, T.J., 1982, Free carbon and electrical conductivity in the Earth's mantle, Geophysical Research Letters, 9, 1171-1174.

Green, D.H. & Falloon T.J. 1998: Pyrolite: A Ringwood concept and its current expression, in *The Earth's mantle: Composition, Structure, and Evolution*, Ian Jackson (ed), 311-380, Cambridge University Press.

Griffin, W.L., Doyle, B.J., Ryan, C.G., Pearson, N.J., O'Reilly, S.Y., Davies, R., Kivi, K., van Achterbergh, E., & Natapov, L.M., 1999, Layered mantle lithosphere in the Lac de Gras area, Slave craton: composition, structure and origin: Journal of Petrology, 40, 705-727.

Grütter, H.S., Apter, D.B., & Kong, J., 1999, Crust-mantle coupling; evidence from mantle-derived xenocrystic garnets, in *Proceedings of the 7th international Kimberlite conference, J.B. Dawson Volume 1*, Gurney, J.J., et al., eds, 307-313, Red Roof Design, Cape Town.

Woodland, A. 2001, Ferric-ferrous iron in mantle minerals from South African and Lesotho xenoliths: Changing oxygen fugacity with depth. Abstract. EUG XI, Strasbourg, France, April 2001.