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Illuminating craton architecture using deep-probing electromagnetic studies

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Electromagnetic (EM) studies on cratons have provided a wealth of information related to the vertical and lateral variation in electrical conductivity. Those changes can be interpreted in terms of variations in physical parameters (primarily, but not exclusively, temperature and water content) and the architectures of the cratons. We will examine two cratons in detail – the Slave Craton of Canada and the Kaapvaal Craton of South Africa – for the unique contributions and insight that deep EM studies have provided.

The Slave Craton in NW Canada is particularly interesting, as an imaged high conducting zone within the middle of the lithospheric mantle, the Central Slave Mantle Conductor (CSMC), correlates spatially (both in lateral extend and in depth extent) with a known ultra-depleted harzburgitic layer and also with the surface emergence of Eocene-aged kimberlite pipes. The conductor has far too high an electrical conductivity to be explained by “wet” NAMs, predominantly olivine and orthopyroxene, and exotic (and untestable) candidates such as graphite and/or carbon on grain boundaries must be appealed to. Support for this interpretation comes from the maximum depth extent of the CSMC being above the graphite-diamond stability field. To the north, south, east and west of the CSMC, no strong conductor is found within the lithospheric column, and generally the conductivities imaged can be explained by thermal and water content variation, the latter albeit with the most conducting pathways being along fine-grained olivines or pyroxenes. The lithosphere-asthenosphere boundary is imaged at shallower levels beneath the central part of the craton compared to the southern part. The three-dimensional geometry of the CSMC, coupled with the timing of extrusives, infer craton formation through slab stacking.

The Kaapvaal Craton exhibits generally low conductivities than can be explained by thermal and proton diffusion effects, although also requiring most conducting pathways along fine-grained minerals. A highly anomalous region is that affected by Bushveld plutonism, where high conductivities are found that cannot be explained solely by thermal and water effects. Otherwise, for the Kaapvaal Craton, as for much of Southern Africa, there is a linear relationship that can be defined between seismic shear wave velocity, as determined through surface wave studies, and electrical conductivity, attesting to the dominance of thermal effects for the two. Electrical anisotropy observed in Southern Africa is depth-dependent, with lithospheric anisotropy exhibiting lateral variation consistent with domain definitions, whereas asthenospheric anisotropy is generally parallel to plate flow.

For both cratons there is evidence of a spatial relationship between electrical conductivity variations and kimberlitic diamond occurrences. This relationship will be examined.