The Kapuskasing uplift: a deep crust natural laboratory

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Interpretation of deep seismic features is largely unconstrained without knowledge of physical properties and structural history. For that reason, the Kapuskasing uplift[1] of central Canada was an early target of Lithoprobe[2], aimed at calibrating seismic reflectivity in a terrane formed at depths >30 km. Previous work had shown sheet-like tonalitic and mafic (garnet-clinopyroxene-hornblende-plagioclase migmatites; 8-12kb, 700-850°C[3,4]) gneisses interlayered on scales of 100-1000m, with modeled acoustic velocity contrasts[5] mimicking lower crustal reflectors. Structural features suggested passive rotation of sub-horizontal layers to 30° dips along a brittle, southeast-verging thrust fault[6].

Seismic refraction and reflection surveys were conducted as part of the Kapuskasing Lithoprobe transect. Refraction data showed a shallow velocity anomaly associated with the deep-crustal material, as well as crust as thick as 55 km in contrast to ca. 40 km regional values[7]. Reflection surveys confirmed velocities as high as 7.4 km.s^{-1} for some near-surface units and mapped a reflective package from near the surface to background levels at >20 km depths (Fig. 1)[8,9]. The crustal root defined by high refraction velocities is expressed as a zone of short, scattered reflectors on reflection profiles. Taken together, these features suggest an intracratonic shortening model (ca. 1.9 Ga) wherein brittle thrusting and erosion in the upper crust was balanced by ductile flow into a lower crustal root (Fig. 1).

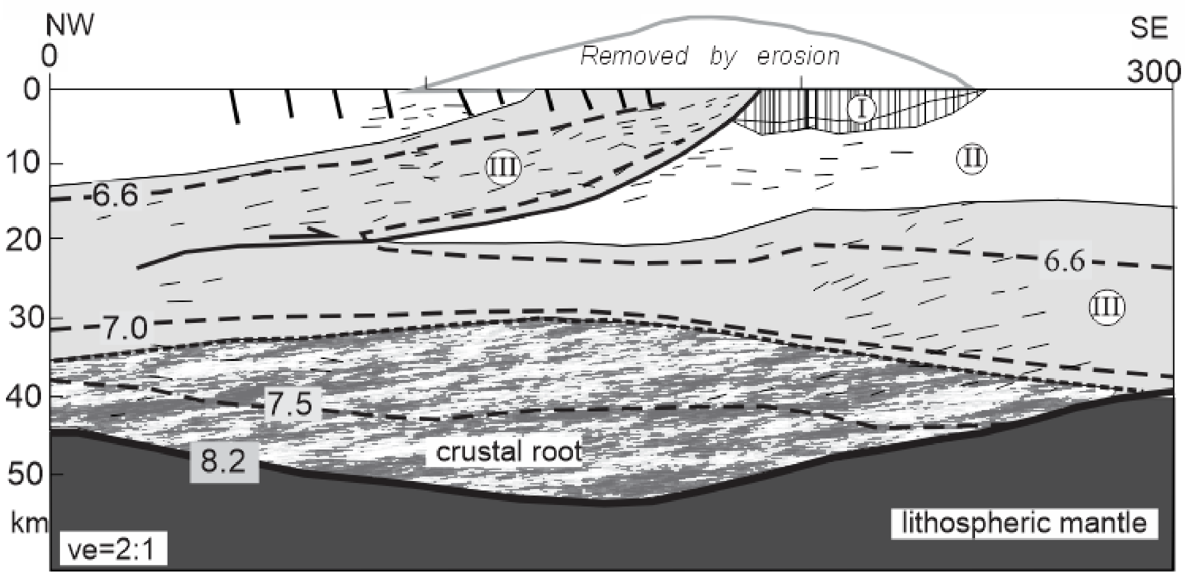

Figure 1. Composite northwest-southeast profile across the Kapuskasing uplift structure, combining interpretative geological cross section, seismic reflection and refraction (velocity contours in km/s) results. The section shows Archean crustal levels I: greenstone-granite; II: tonalite gneiss; and III: layered mafic and felsic granulites, and 15-km thick crustal root beneath the Kapuskasing uplift, produced during a ca. 1.9 Ga intracratonic shortening event.

The structural-petrogenetic history of the Archean crust prior to uplift is constrained by detailed work at both shallow and deep paleo-levels. The history of supracrustal rocks of the Abitibi belt involved submarine deposition of volcanic and sedimentary rocks (2750-2696 Ma), followed by polyphase deformation, syn-orogenic sedimentation, alkaline magmatism and gold mineralization (2690-2670 Ma)[10]. Protolith ages of Kapuskasing gneisses resemble those of volcanic units (2765-2700 Ma)[11] but peak metamorphism, as recorded by zircon U-Pb ages, occurred later, between ca. 2660 and 2580 Ma[11,12,13].

These ages correspond to a period of ductile extensional deformation in the deep-crustal section, responsible for reorientation of structures into sub-horizontal orientations and prominent east-west stretching lineations formed during orogen-parallel flow[14]. Lower temperature isotopic systems (U-Pb titanite, Ar-Ar hornblende, Rb-Sr biotite) yield significantly younger ages (2.5-1.9 Ga), suggesting protracted slow cooling and continued deep-crustal residence until ca. 1.9 Ga[15]. The uplift event has been modeled as a far-field deformation effect of orogenic activity at the margin of the craton[16].

Additional insight into the structure and dynamic evolution of continental interiors continues to be extracted from the Kapuskasing deep crustal laboratory. Work is underway to model ancient and current thermal regimes[17], as well as to document processes of diffusion, dissolution and precipitation in zircon [18,19]. Unexpectedly, a gold deposit was discovered in the Kapuskasing uplift in 2011[20,21], calling into question the long-held hypothesis that metals migrate away from high-temperature metamorphic terranes and thereby opening new exploration frontiers in deeply eroded settings.

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