GEOPHYSICAL CHARACTERISTICS AND CRUSTAL STRUCTURE OF GREENSTONE TERRANES, CANADIAN SHIELD;

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A knowledge of the deep structure and geometry of greenstone belts is fundamental to tectonic models of Archean evolution. In the Canadian Shield long linear granite-greenstone terranes of generally low metamorphic grade alternate with temporally-equivalent metasedimentary belts of higher grade. The focus of geophysical investigations of these terranes has been to examine geometries and contact relationships within individual terranes, and to look at the broader and deeper aspects of structure and inter-terrane relationships.

Major greenstone belts are characterized by positive gravity anomalies in the range 15-30 mGal that primarily reflect the relatively high density mafic and ultramafic metavolcanic components (1). These anomalies are sometimes interrupted by negative anomalies caused by felsic plutons and are poorly developed where high metamorphic grade basement is present and/or boundaries are gently-dipping. Modelling reveals that many greenstone belts are more or less basin-shaped, some having deep keels, and that their steep surface boundaries extend to depth. Model depths of polycyclic greenstones are 2-8 km and non-polycyclic are 3-12 km (1). The generally smaller depths of the former have been attributed to granitic intrusion decreasing vertical extent by stoping, or to listric normal faulting or thrusting (1). Models indicate abrupt changes in depth of up to ~10 km between supracrustals of the Wawa greenstone and Quetico metasedimentary terranes and point to a major faulted contact (2). Granitic intrusions at and within boundaries of greenstones are associated with prominent negative gravity anomalies. Modelling indicates that they have depths ranging from 2-16 km with depths in the middle of the range being characteristic (3,4). Generally, the contacts of the granites are modelled as steeply dipping. Some granites extend several kilometres deeper than adjacent greenstones but in other cases greenstones are interpreted to underlie the granite. For example, interpretation of a combined gravity-seismic study of the Aulneau batholith of the Wabigoon subprovince suggests that it is floored by up to 10 km of greenstones (3). Gravity studies in Wabigoon subprovince have contributed to classifying granites into epizonal sheets and deep diapiric batholiths intruded in two separate periods (4).

Regionally, greenstone belts generally correspond to magnetic lows and associated granites to magnetic highs (5,6). Magnetization studies (6) indicate values that are generally < 0.05 A/m for greenstones and > 0.05 A/m for granites. Linear positive anomalies within the English River gneiss belt have drawn attention to pyroxene amphibolite gneisses, probably derived from metavolcanics (7). Their occurrence is significant in that they are in an area where volcanism is thought not to have been important. Aeromagnetic shaded relief maps have been used to assist in mapping surface geology in the Abitibi greenstone belt (8). Various features correlate with diorite-gabbro and peridotite-serpentinite intrusions, diabase dykes, major faults, iron formations and zones of contact metamorphism around granitic intrusions. The magnetic signature

of the Abitibi belt, however, is not noticeably different from that of the bordering terranes. Modelling has been limited. Interpretation of a 300 km N-S profile across the Abitibi belt (8) indicates that the greenstones extend to a maximum depth of 13.6 km in the south, with an average depth of ~9 km compared to 6 km in the north. This agrees with seismic refraction results that suggest the bottom of the belt dips southward increasing in depth from 6 to 14 km (9). Surface magnetic units over granites of the Wabigoon belt have been modelled as extending to the intermediate discontinuity (16-19 km) with an increase in magnetization occurring at a few kilometres depth (6). Magnetization is low or absent below the discontinuity.

Seismic reflection studies within the Aulneau batholith and adjacent greenstones (10,11) have mapped a near-vertical contact between granite and greenstone to a depth of several kilometres (confirmed by later gravity studies) and a vertical fault zone. Although there are no detectable velocity differences between the greenstones and granites, the impedance contrast is sufficient to produce recognizable reflections from the near-vertical contact. The lower surface of the batholith, as interpreted from gravity, did not produce reflections, perhaps due to its undulatory nature (12). There is also a poor correlation between the average depth of the Yellowknife greenstone belt as determined from seismic (~10 km) and gravity (~3 km) studies (13,14). In contrast, the seismic refraction survey (9) across the Abitibi belt yielded a geometry for the bottom of the belt similar to that based on magnetic interpretation (8). The seismic investigations in the vicinity of the Aulneau batholith (10,11) also detected several deep horizontal or near-horizontal reflectors. The most prominent reflectors are at intermediate depths of about 19 and 22 km and the Moho at 38 km. The three reflectors appear to be continuous beneath the granite and greenstones suggesting that complex structure, which typifies the upper crust, is absent at depth. A similar picture of the Wabigoon crust has been found by long-range refraction - wide angle reflection experiments (15,16), but in the Quetico metasedimentary belt to the south no sharp boundaries are found within or at the base of the crust which is about 40-42 km thick (16). In the English River gneiss belt to the north seismic refraction studies indicate thinner crust with an average thickness of 34 km (17). The average depth of the intermediate discontinuity remains about the same (~18 km). In detail, the Moho is upwarped by roughly 8 km in the northern part of the belt, whereas the intermediate discontinuity exhibits a complementary downwarp with an amplitude of 10 km. Re-examination of the orginal data (12) indicates that the axis of this proposed warping lies close to the northern margin of the gneiss belt where it coincides with a sedimentary basin.

Magnetotelluric investigations have been carried out in the western Wabigoon belt (18). A 3.9 km thick near-surface resistive zone under the metavolcanics is considerably less resistive (21,300 Ω-m) than one 7.4 km thick under the granitic gneiss (3,280,000 Ω-m). It suggests that crust underlying metavolcanic rocks is partially fractured and contains saline fluids and/or that the metavolcanics extend throughout the resistive zone. Heat flow studies reported from several Precambrian shields indicate that the average heat flow in greenstones is roughly 10% lower than in crystalline terranes (19). Heat generation data from the Churchill and Superior provinces of the Canadian Shield indicate that

greenstones are approximately 7 km thick.

A general <u>conclusion</u> is that greenstone belts are not rooted in deep crustal structures. Geophysical techniques consistently indicate that greenstones are restricted to the uppermost 10 km or so of crust and are underlain by geophysically normal crust. Gravity models suggest that granitic elements are similarly restricted, although magnetic modelling suggests possible downward extension to the intermediate discontinuity around ~18 km. Seismic evidence demonstrates that steeply-dipping structure, which can be associated with the belts in the upper crust, is not present in the lower crust. Horizontal intermediate discontinuities mapped under adjacent greenstone and granitic components are not noticeably disrupted in the boundary zone. Geophysical evidence points to the presence of discontinuities between greenstone-granite and adjacent metasedimentary terranes. Measured stratigraphic thicknesses of greenstone belts are often twice or more the vertical thicknesses determined from gravity modelling. Explanations advanced for the discrepancy include stratigraphy repeated by thrust faulting and/or listric normal faulting (1), mechanisms which are consistent with certain aspects of conceptual models of greenstone development. Where repetition is not a factor the gravity evidence points to removal of the root zones of greenstone belts. For one region, this has been attributed to magmatic stoping during resurgent caldera activity (20).

Geophysical studies in the Canadian Shield have provided some insights into the tectonic setting of greenstone belts. Much work, however, remains to be done, particularly in the use of geophysics in evolutionary models of greenstone development. Future needs include detailed, integrated studies, the introduction of relatively new methods such as Vibroseis seismic reflection, greater use of magnetotellurics and the application of other electromagnetic methods such as very low frequency (VLF) surveys.

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