GEOPHYSICAL CONSEQUENCES OF PHANEROZOIC AND ARCHEAN CRUSTAL EVOLUTTON: EVIDENCE FROM CRUSTAL CROSS-SECTIONS; David M. Fountain, Dept. of Geology and Geophysics, Program for Crustal Studies, Univ. of Wyoming, Laramie, WY 82071

Geophysical properties of continental crust depend on the nature of crustal evolution. This is well illustrated by examination of two crustal cross-sections (1), the combined Ivrea-Verbano zone (IVZ) and Strona-Ceneri zone (SCZ) of northern Italy and the Pikwitonei granulite belt (PGB) and Cross Lake subprovince (CLS) of Manitoba. These two cross-sections are of particular interest because the IVZ and SCZ developed during Phanerozoic time whereas the PGB-CLS is an example of Archean crustal evolution. Consequently, each cross-section is geologically distinctive and, thus, exhibits very different geophysical properties such as density, seismic velocity, heat production, and magnetism.

Perhaps the best known cross-section of the crust is the IVZ-SCZ of northern Italy (Figure 1). Deeper crustal levels are represented by the granulite and upper amphibolite facies ultramafic, mafic and pelitic rocks of the IVZ that experienced peak metamorphic conditions of 9-11 kb and 700°-820°C during Caledonian time (2,3). Isotopic data indicate that these high-grade rocks resided at lower to middle crustal levels until Jurassic time. Amphibolite and greenschist facies pelitic schists and gneisses, intruded by post-metamorphic granitic plutons, dominate higher crustal levels exposed in the SCZ. Peak metamorphism in the SCZ was also Caledonian (2). The IVZ and SCZ are separated by a vertical mylonite zone, the Pogallo line, which Hodges and Fountain (4) interpret as a Jurassic low-angle normal fault rotated into its present position during Alpine deformation. The Pogallo line is but one manifestation of the rift event that created the Tethys Ocean.

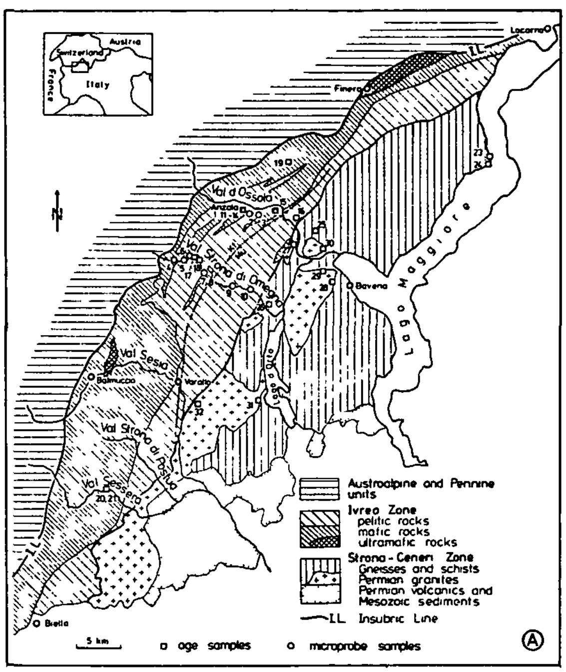

Figure 1. Sketch map of IVZ and SCZ from Hunziker and Zingg (2).

The early history of the IVZ and SCZ is somewhat enigmatic but was dominated by deposition of a thick pelitic package of sediments between 480 and 700 Ma (2). Deep burial and amphibolite facies metamorphism preceded intrusion of mafic and ultramafic magmas and peak metamorphism during Caledonian time (2). Schmid (5) speculated that granulite facies pelitic gneisses were de-granitized during this event. Post-metamorphic intrusion of granites suggests Andean margin conditions prevailed later in the Paleozoic. Rifting, normal faulting and formation of a Tethyan trailing margin modified this Paleozoic crustal block during early Mesozoic time.

Geophysical properties of the IVZ and SCZ are a consequence of its Phanerozoic evolution. Seismic velocities (6) for mafic and ultramafic rocks are expectedly high (7.2-8.4 km/sec). Pelitic granulites also have high velocities (7.0-7.6 km/sec) because of high garnet and sillimanite content. Deep crustal levels are characterized by high P-wave velocities. In contrast, schists, gneisses and granites of the SCZ have P-wave velocities around 6.4-6.5 km/sec, causing a marked seismic distinction between the lower crust and higher levels. Investigations by Wasilewski and Fountain (7) indicate that magnetite is the magnetic phase in the granulites and that susceptibilities are high in mafic granulites and very low in higher level rocks of the SCZ. The deep crust represented by the IVZ, therefore, is also magnetically distinct and could cause long-wavelength magnetic anomalies if it resided in areas of normal geothermal gradients. Published heat production data (8) indicate that heat production is low in mafic granulites (0.8 HGU), moderately high in upper amphibolite pelitic gneisses and SCZ lithologies (5-6 HGU) and high for post-metamorphic granites (7 HGU). No data is available for pelitic granulites. These data suggest that there may be a significant stepwise decrease in heat production at deep crustal levels although analysis of high-grade pelitic rocks is necessary to confirm this.

Deep levels of Archean crust are exposed in the Pikwitonei granulite belt of Manitoba (Figure 2). About 80% of the PGB gneisses are silicic granulites (enderbites and charnockites) that surround much less abundant, discontinuous layers of granulite facies paragneisses, iron formation, and mafic and ultramafic rocks (9) that are similar to nearby lower grade greenstone belt lithologies. The CLS, representing shallower crustal levels, lies to the southeast of the PGB and consists of several greenstone belts surrounded by granites and granitic gneisses. Metamorphic grade in these belts tends to decrease to the southeast.

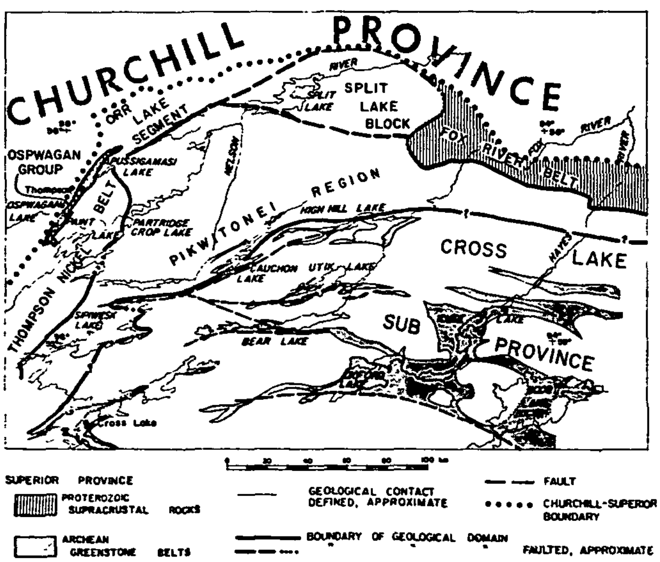

Figure 2. Sketch map of geological domains of northwestern Superior Province from Weber and Scoates (9).

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Geologic investigations in the PGB and CLS (9, 10) suggest that there is no fundamental difference between the two terrains other than variation of metamorphic grade and differences in volumetric abundances of certain supracrustal lithologies. Mapping by Hubregtse (10) in the Cross Lake area demonstrated that low-grade greenstone belts can be traced across the orthopyroxene isograd into the PGB, suggesting that the PGB and CLS share a common history. Isotopic data (11) suggest an approximate 2.8 Ga age of metamorphism for PGB enderbites. Ages of metaplutonic rocks of CLS are between 2.7-3.0 Ga (11).

The bimodal compositional nature of rocks of the PGB and CLS produce a distinctive geophysical character. Enderbites and granitic rocks surrounding supracrustal belts have similar mineralogy, low densities (mean density = 2.68 g/cm^3) and thus, low seismic velocities (estimated at approximately 6.5 km/sec). This is in contrast to high densities (2.8-3.1 g/cm^3) and seismic velocities (estimated at approximately 6.8-7.2 km/sec) for the supracrustal belts. Overall, this crustal section is dominated by a low P-wave velocity matrix that surrounds discontinuous, high velocity layers, thus there is little seismic distinction between the upper, middle and lower crust. Work in progress (Shive and Williams) indicates that magnetite is also the magnetic phase in PGB enderbites but susceptibilities are much less than IVZ granulites, suggesting that lower crustal magnetic patterns will differ substantially for the two crustal cross-sections. Work on heat production is also in progress. Preliminary data indicate no significant difference in K_2O content between PGB enderbites and CLS granitic rocks suggesitng there may be no major change in heat production across the amphibolite-granulite facies boundary.

The IVZ and SCZ represent Phanerozoic crust in which mafic and ultramafic magmas were added to deeper portions of a modestly metamorphosed pelitic package of sediments. Physical properties of mafic, ultramafic and de-granitized pelitic rocks are distinctively different than upper level granites and pelitic schists and gneisses resulting in a geophysically zoned crust. This zonation is enhanced by the Pogallo line, a Jurassic low-angle normal fault. In contrast, the granite-greenstone belt mode of evolution of the PGB and CLS created a crustal cross-section with little geophysical distinction between various crustal levels although significant lithologic heterogeneity exists. In the future, geophysical techniques may have the resolution necessary to detect differences such as these thus permitting routine analysis of crustal evolution through use of geophysical surveys.

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