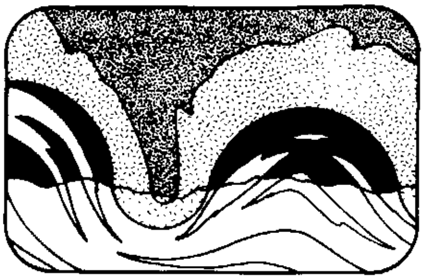

The Superior Geotraverse Project

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Summary

The Superior Geotraverse Project is a cooperative geological and geophysical research program being carried out by the Precambrian Research Group of the University of Toronto, assisted by scientists from other universities. The purpose of the project is to study the origin of the Archean crust north of Lake Superior in a 300 mile long, N-S corridor which crosses three volcanic-plutonic belts (Uchi, Wabigoon and Shebandowan) and two metasedimentary-gneiss belts (English River and Quetico).

Six different models for the origin of the Archean crust are under consideration: no decision between competing models will be possible until further work is done. One possible model, however, is that the crust developed in three stages: 1) development of Archean "oceanic" crust, 2) development of Archean "island arc" crust as a result of subduction, 3) accumulation of greywackes in foreland basins.

Introduction

A prominent and challenging feature of Canadian Archean crust is the striped pattern of alternating volcanic-plutonic belts and metasedimentary-gneiss belts. Volcanic belts contain the well-known, abundantly mineralized, and thereby economically attractive, greenstone assemblages together with granitic plutons ranging to batholithic dimensions, whereas intervening metasedimentary-gneiss belts comprise assorted metasediments with derived schist, gneiss, migmatite and granitic plutons. Of all parts of the Canadian Shield this striped pattern is best displayed in Archean crust of western Superior Province specifically in the Lake Nipigon – Lake of the Woods region wherein three major east-trending volcanic-plutonic belts and two intervening metasedimentary-gneiss belts form the basis for tectonic subdivision into subprovinces.

The striped pattern of Archean crust raises fundamental problems of the origin, early development and subsequent elevation to present continental stature of sialic crust in the early development stages of planet Earth. What is the origin of this sialic crust? Does the striped pattern reflect accretionary growth of successive tectonic belts upon primitive sialic cratons or rather the product of folding and faulting of an original volcanic-sedimentary layer-cake crust? What were the primary tectonic relations of the now intricately juxtaposed volcanic and sedimentary rocks? What is the source of the granitic components, the single most important element of the Canadian and other world shields? Did plate tectonics or evolutionary analogue play a significant part in the development of Archean crust? By what processes did the crust evolve from its indicated Archean thin-crustal state to present thick-crustal state (35-40 km)? What are the structural configurations and compositions of deeper crustal levels and their relationship to underlying mantle? Answer to these and allied questions have broad implications to crustal studies here and abroad. Clearly successful assault upon these problems requires sustained multi-disciplinary field-based research.

In response to this need the Precambrian Research Group was formed in 1969 at the University of Toronto. Broadly based in geological and geophysical sciences this group constitutes a powerful team supported by comprehensive laboratory and

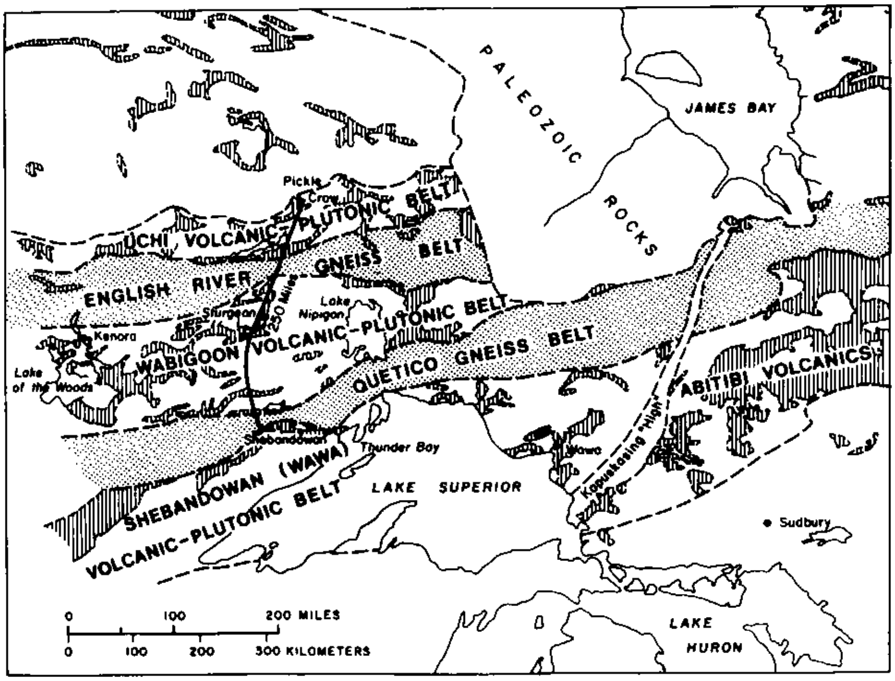

Figure 1
Regional map showing location of Geotraverse corridor in relation to the five east-trending supracrustal belts of western Superior Province. Vertically patterned rocks are volcanics; stippled patterns are metasediments, schist, paragneiss and migmatite; clear areas are underlain by granitic rocks.

technical facilities. In line with the principal purpose of the group namely to undertake crustal studies of a fundamental nature the present focus of this group, augmented by scientists from sister universities, is the Superior Geotraverse Project.

The project focuses upon the study of Archean crust in a 300 mile long, north-south corridor which crosses the regional grain dominated by the presence of the abovementioned five, east-trending, alternating belts. The three volcanic-rich belts are, from north to south, Uchi, Wabigoon and Shebandowan (Wawa) (Fig. 1). The two intervening migmatite belts are, again from north to south, English River and Quetico. Each type of belt contains distinctive lithic associations with characteristic gravity, seismic and magnetic patterns.

How may we most reasonably interpret this distinctive segment of Precambrian crust? In our view, careful and sustained probing of this critical corridor is required to win significant answers. To this end, during the 1973 field season, mainly in continuation of previous work, 20 separate projects headed by staff members and graduate students were engaged in independent, yet integrated field studies along and adjacent to the corridor. The studies cover the principal fields of gravity, seismology, magnetics, paleomagnetics, structure, metamorphism, petrology and metallogenesis. Of the 26 scientists nine are primarily concerned with measurement of physical properties, six with petrogenesis including granites, volcanics and metamorphism, four with structure, three with metallogeny, two with sedimentation and two with geochronology. The period of individual involvement in the Geotraverse projects varies from one to three years with some studies (e.g., structure, granites), comparatively well advanced and others (e.g., geochronology, magnetotellurics) only recently on-stream.

Participating scientists with respective affiliation (other than University of Toronto) and subject emphasis are as follows, in alphabetical order: A. Bau – structure; D. Beggs – volcanism; R. T. Bell (Brock University) – sedimentation; J. B. Currie – structure; D. J. Dunlop – paleomagnetics; J. J. Fawcett – metamorphism; R. M. Farquhar – geochronology; J. M. Franklin (Lakehead University) – metallogenesis; A. M. Goodwin (coordinator) – granites, volcanism; N. B. W. Harris – granites, geochronology (in cooperation with T. E. Krogh, Carnegie Institution); M. M. Kehlenbeck (Lakehead University) – petrogenesis, structure; B. Jones – gravity; D. MacKidd – magnetics; A. J. Naldrett – sulphur abundance; S. Nwachukwu (University of Nigeria) – paleomagnetics; W. M. Schwerdtner – structure, granites; S. D. Scott – metallogenesis; R. Shegelski – sedimentation; Z. Szewczyk – gravity; C. Talbot (University of Dundee, Scotland) – granites, structure; D. W. Strangway and A. Koziar – magnetotellurics; G. F. West – seismic, gravity, magnetics. In addition, T. F. Pearce (Queen's University) is studying quench textures in Archean volcanic rocks in the Pickle Lake area. The Ontario Division of Mines has on-going geological and geophysical programs of great relevance to the Geotraverse Project.

The Geotraverse Project is supported by the Department of Energy, Mines and Resources in the form of individual research grants.

Models

At an early state in the Geotraverse Project the decision was taken to relate the studies to a number of possible models of Archean crust. Six models, described below, were selected. As data accumulate from year to year the models are reviewed to assess current relevance. With full allowance for modifications of existing models and introduction of new ones it is anticipated that the most appropriate model will eventually emerge. Thus an ongoing review of models is the chosen method of synthesis and evaluation. At this stage no model preference is intended or implied.

The six models are: 1) layer-cake crust, faulted and/or folded; 2) lateral accretion; 3) simple crustal spreading; 4) convergent plates, simple or complex (migrating subduction zone); 5) full convection system with double arcs; and 6) inter-arc and back-arc basins.

1) *Layer-cake crust.* A simple two-layer accumulation of sediments overlain by volcanics is the simplest model to explain alternating belts as a result of a) simple keystone faulting and/or b) folding. Either style of deformation could provide alternating belts.

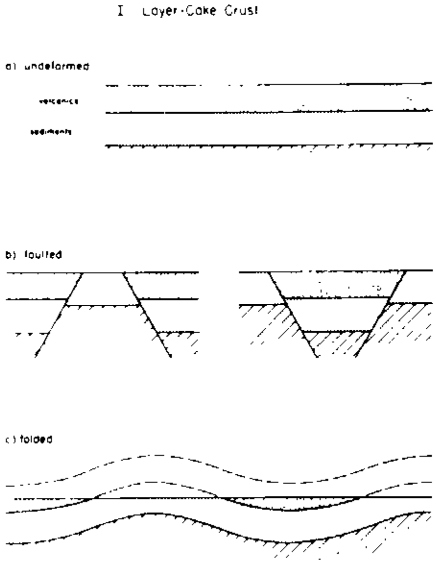

Figure 2
Model I. Layer-cake crust. A simple or repeated succession of sediments and volcanics which by faulting and/or folding, yield the striped belt pattern.

2) *Lateral accretion.* This model allows for development of an Archean geosynclinal belt including volcanic arc and sedimentary basins as illustrated, at the margin of a pre-existing sialic craton. Successive welding of geosynclinal belts might have produced the striped belt pattern.

3) *Simple crustal spreading.* Extension of sialic crust to form an intracratonic trough or geosyncline in which developed a volcanic arc and sedimentary basins which, when deformed, could produce the striped pattern of indicated relative ages.

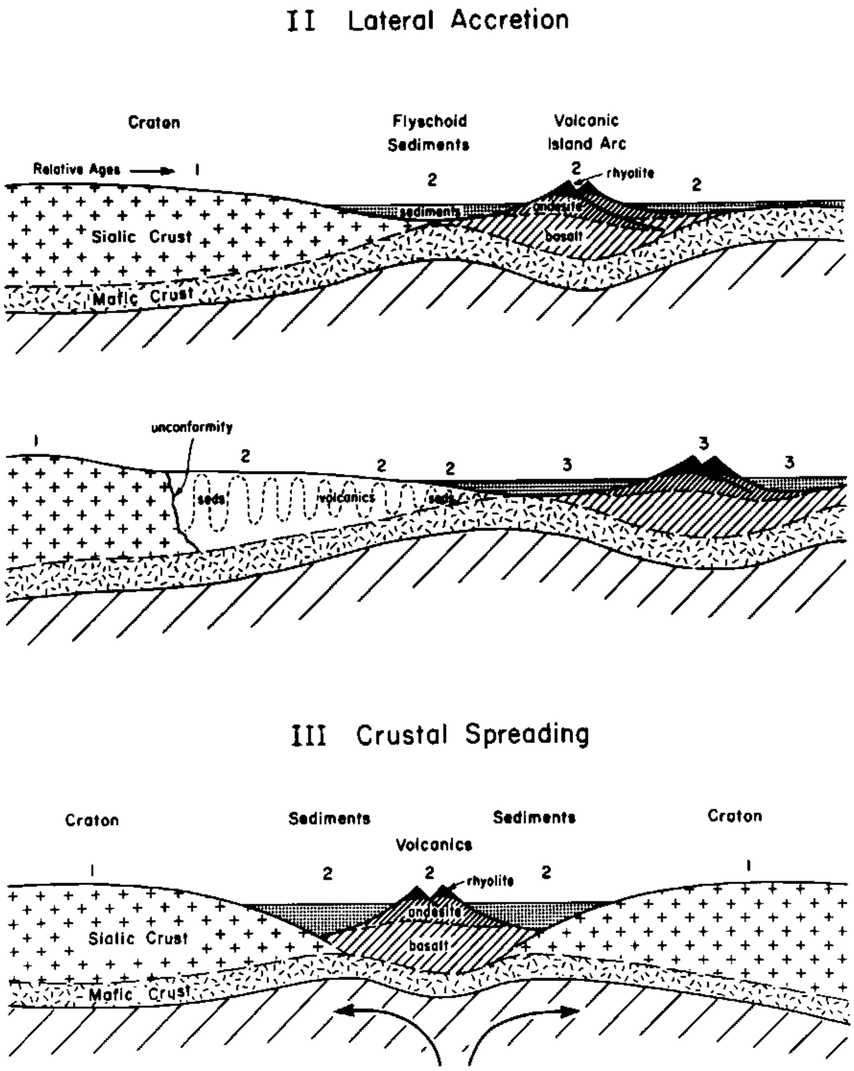

Figure 3

Model II. Lateral accretion involving sialic craton, off-shore volcanic arc and sedimentary basins.

Model III. Simple spreading of sialic craton with subsequent development of intercratonic volcanic arc and adjoining sedimentary basins.

4) *Convergent plates.* Assuming the plate tectonic model, an Archean volcanic belt would represent an island arc situated above a subduction zone at converging sialic-oceanic plate boundaries. Migration of the subduction zone to the ocean side would result in development of successive parallel volcanic arcs to produce the striped pattern illustrated in Figure 4.

5) *Full convection system.* Assuming the presence of comparatively small Archean plates and the operation of local, small-scale convection systems, a double arc system with volcanic belts and sedimentary basins might develop as illustrated. Subsequent deformation would compress the lithic elements to produce the existing striped belt pattern (Fig. 5).

6) *Inter-arc and back-arc basin modification (not illustrated).* Allowance is made for the accumulation of great thicknesses of sediments from nearby sialic highlands in foreland basins. The sediments proceed through a classical geosynclinal history of orogeny (Andean-type) to produce migmatities plus anatectic derivatives. The main source of the sediments is sialic craton. More or less volcanic detritus is included depending on the proximity of the basin to off-shore island arcs. In the case of inter-arc basins the main sedimentary component would be volcanic derived.

Geological Relations

The principal geological relations in the Geotraverse area are briefly summarized below.

Volcanic-Plutonic Belts. The Uchi-Wabigoon and Shebandowan (Wawa) belts have in common a close association of volcanic, sedimentary and plutonic elements. The principal volcanic components comprise lava flows and pyroclastics of the basalt-andesite-dacite-rhyolite association commonly arranged in mafic to felsic cycles or sequences. They are intercalated, especially in upper parts, with greywacke, argillite, tuff, conglomerate and banded iron formation. Granitoid plutons or diapirs are common. Mafic and ultramafic sills, dykes and small irregular plutons are widely though sparsely distributed. The volcanic-plutonic belts vary considerably in width to a maximum of 120 miles. Lithic proportions in the 5,960 square mile Lake of the Woods – Wabigoon region of the Wabigoon belt immediately west of the Geotraverse corridor are as follows: granitic plutons – 50.6 per cent, volcanic rocks – 40.1 per cent, and sediments – 7.7 per cent.

The abundances of principal volcanic classes in the well-studied Lake of the Woods – Wabigoon area immediately west of the Geotraverse corridor is as follows: basalt – 62.3 per cent, andesite – 25.8 per cent, and felsics (dacite + rhyolite) – 11.9 per cent.

The main felsic volcanic concentrations representing principal felsic volcanic centres of the region are at Lake of the Woods, Sturgeon Lake and Savant Lake in the Wabigoon belt and at Red Lake and Uchi Lake in the Uchi belt. Smaller felsic concentrations are present at Shebandowan Lake to the south and at Pickle Lake and Lake of the Woods to the north.

The volcaniclastic sediments, mainly tuffs, agglomerates and greywacke are generally andesitic or

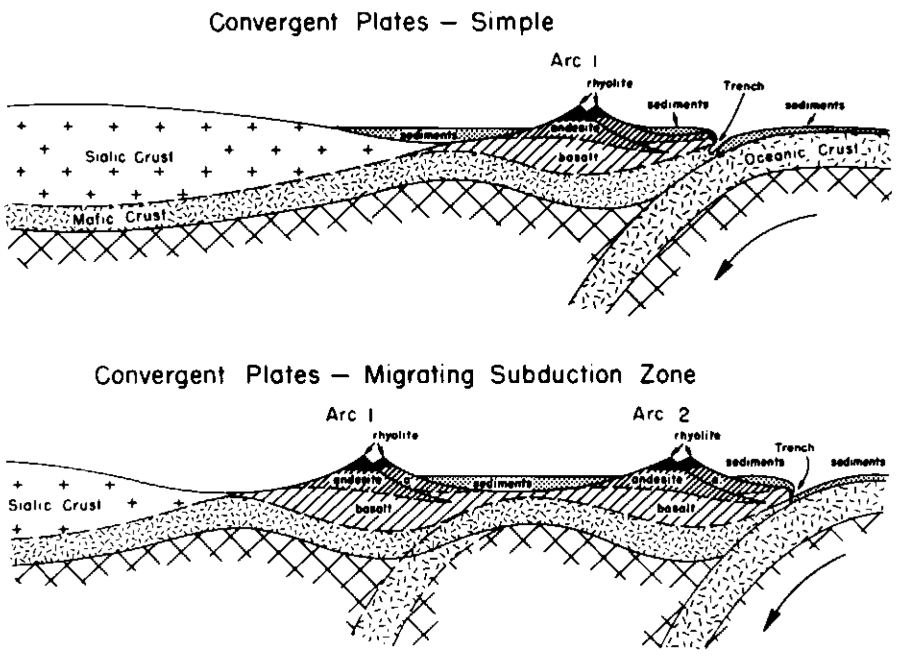

Figure 4
Model IV. Convergent plates – simple. Craton-oceanic plate interface involving subduction of oceanic crust and development of volcanic arc, trench and accompanying sedimentary basins.

Convergent plates – complex. Successive migration of the subduction zone to the ocean side results in development of successive parallel volcanic and sedimentary belts.

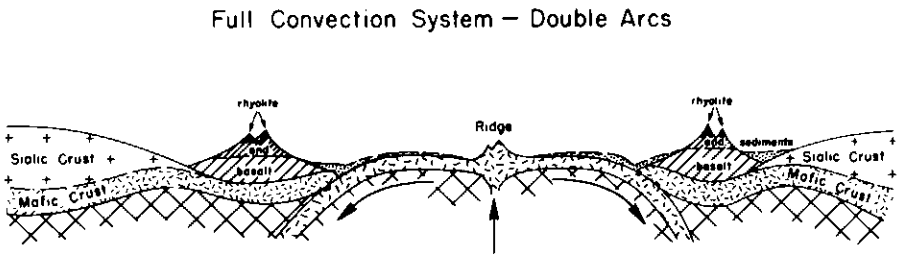

Figure 5
Model V. Full convection system – double arcs. Within the concept of numerous, small, thin, comparatively supple crustal plates in Archean time (termed miniaturized soft-plate tectonics) a double volcanic arc-trench system might have developed as illustrated resulting in parallel, alternating volcanic and sedimentary belts.

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felsitic. In some places the distinction between tuff and greywacke is made with difficulty. The sediments are typically intercalated with volcanic rocks and distributed peripheral to and between the major internal granite plutons. Principal accumulations occur south of Shebandowan Lake, in the Lake of the Woods – Sioux Lookout area, at Sturgeon Lake and Savant Lake and in the Red Lake, Uchi and Lake St. Joseph areas.

Banded iron-formation including oxide, carbonate, and sulphide facies, is widespread. Principal concentrations occur near Shebandowan Lake, in the southern belt, at Steeprock Lake, Scotch Lake, Bending Lake, Sioux Lookout, Sturgeon Lake and Savant Lake in the Wabigoon belt, and at Red Lake, Uchi-Woman Lake, Lake St. Joseph and Pickle Lake in the Uchi belt.

Granitic plutons which are widespread within the volcanic-plutonic belts typically form large elliptical masses commonly elongated in the regional grain around which flow the supracrustal assemblages. Included are prekinematic epizonal stocks, sills and dykes related to volcanism (syn-volcanic); large mesozonal stocks and batholiths of variable age relationships; and late epizonal stocks, dykes and sheets. The larger plutons range in composition from gabbro to granite but trondhjemite, granodiorite and quartz monzonite predominate by far.

Metasedimentary-Gneiss Belts. The English River and Quetico belts range from 10 to 60 miles wide with extreme pinching near Savant Lake and Shebandowan. The belts are laterally continuous across western Superior Province. The most abundant sedimentary facies is the greywacke-slate turbidite sequence comprising cyclic or rhythmic alternation of greywacke with conspicuous upward grading in the sandy beds. Greywackes are matrix-rich and contain much feldspar, mainly or wholly albitic plagioclase, and angular quartz. Rock particles are also present but are not easily distinguished from the matrix.

Conglomerates are less widespread yet locally very thick, 2,500 feet or more, and persistent along strike being traceable 30 miles or more. All contain abundant pebbles of mafic volcanics, common felsic volcanic rocks, and nearly always some acid plutonic rocks, granodiorite or quartz diorite.

Recognizable greywacke and conglomerate assemblages are largely confined to the margins of the English River and Quetico belts. Within the interior of both belts a vastly greater body of schists, paragneiss and migmatite are present. The relations of these paragneisses, commonly riven with tongues of granite and pegmatite, to the other Archean supracrustal rocks has been the subject of spirited controversy for many years and represents a major challenge of the Geotraverse Project.

A salient contrast of the two major types of belts is the apparent paucity of large granitic plutons in the metasedimentary-gneiss belts compared to their great size and abundance in the volcanic-plutonic belts.

Major unresolved problems concern the relative ages and source of sialic material in the metasedimentary-gneiss belts.

Metamorphism. All the volcanic and sedimentary rocks have been metamorphosed to some extent, the grade ranging from low greenschist facies to granulite facies. The facies series range from low to moderately high pressure reflecting regional variation in geothermal gradient during metamorphism. Intermediate to low-intermediate pressure facies series predominate. Low pressure series that formed in high geothermal gradients are restricted as known to contact metamorphic aureoles.

In general, the volcanic-plutonic belts are of common low metamorphic grade whereas the metasedimentary-gneiss belts are of higher, commonly intermediate grade. This metamorphic contrast, within the context of the major east-trending belts, poses fundamental problems of relative ages and tectonic settings.

Ages. Limited data is available on absolute ages of rocks in western Superior Province. To summarize, 23 U-Pb and/or Rb-Sr isochron dates are presently available – 20 ages from granitic material, two from volcanics and one from metasediments. All dates older than 2.9 b.y. (2.9-3.5 b.y.) are restricted to 1) the Berens Block (north of Uchi Belt) and 2) Minnesota River Valley to the south of the belt system. Within the belt system proper plutonic rocks date mainly from age 2.65-2.90 b.y. generally synchronous with the age of the volcanism. Younger dates (2.55-2.45 b.y.) are fairly common and probably represent metamorphic ages. In addition about 100 K-Ar and Rb-Sr (mineral) ages in the range 2.3-2.7 b.y. probably reflect metamorphism. No dates are available from the Quetico Belt.

Geophysical Relations

The main pre-existing geophysical data for the Geotraverse area is the Federal-Provincial aeromagnetic survey and the Earth Physics Branch (EMR) regional gravity mapping. Now underway as part of the product are a number of detailed gravity surveys and interpretation studies of the aeromagnetics (both in conjunction with sample studies), and a program of crustal scale seismic refraction-reflection measurements.

Figures 6 and 7 show the Bouguer gravity and the regional magnetic anomaly maps of the Geotraverse and vicinity. The local magnetics are unfortunately much too detailed to be reproduced here.

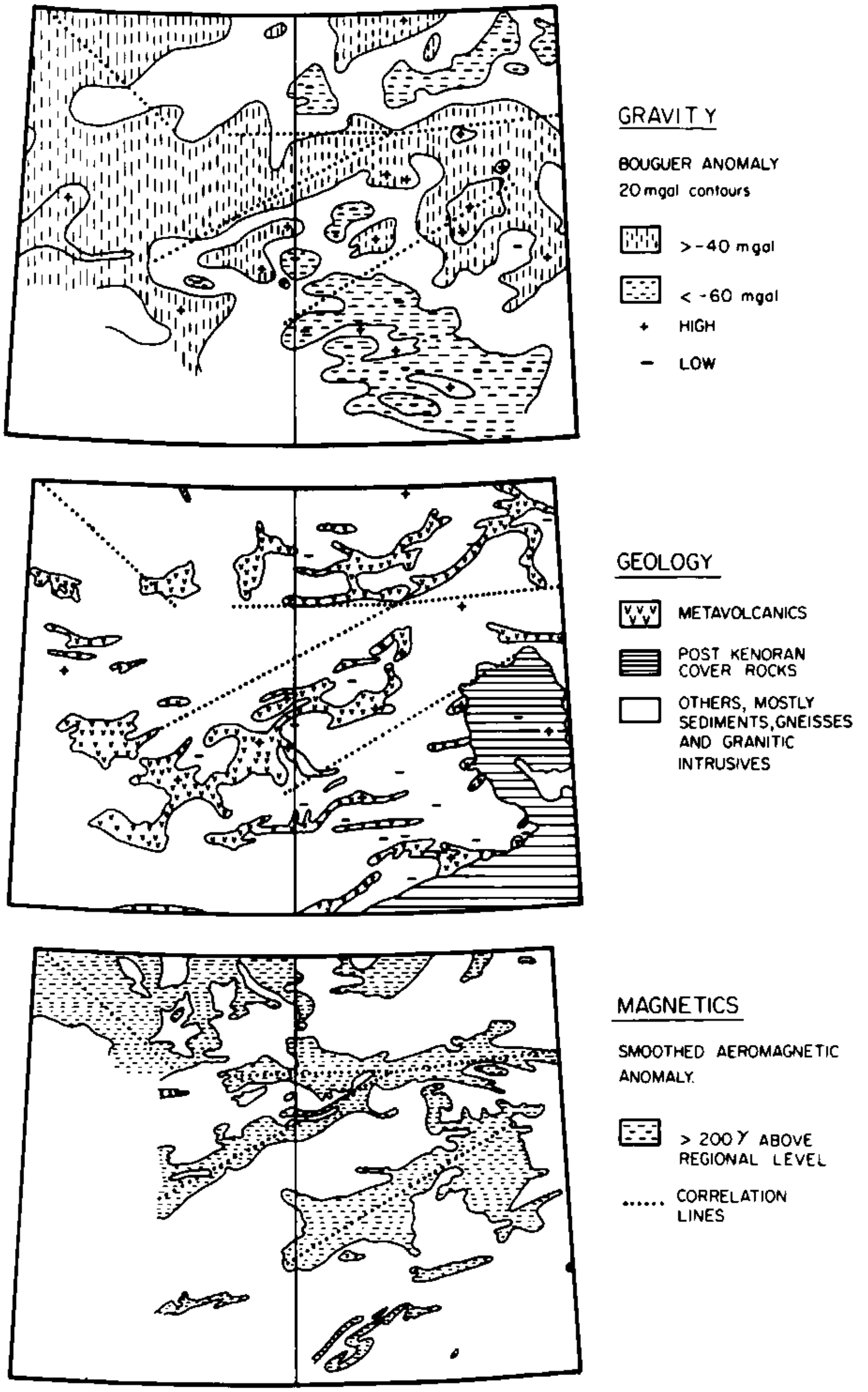

Figure 6
Regional geology, gravity and magnetics in the vicinity of the Geotraverse corridor. To aid in the correlation of the three maps, a series of dotted reference lines have been superimposed. (Prepared from G.S.C. maps 1250A, 1255A and Bouguer Anomaly Map of Canada, Department of Energy, Mines and Resources, with minor modifications).

The general features of the gravity and magnetic surveys are the following:

1. The base level (median) of the gravity survey is approximately −50

mgals. However, there is a general drop of 10 to 15 mgals as the U.S. border is approached. Immediately south of the border, there is a large gravity positive over the dense Duluth gabbro and Keweenawan volcanics. In all likelihood, the negative is a halo caused by the thickened crust necessary to support the heavy load indicated by the gravity positive. The crustal thickening has been confirmed by seismic surveys. To the east of the Geotraverse, in the region covered by the Nipigon plate, the gravity base level seems to be 5 to 10 mgals higher than in the Geotraverse.

2. Local gravity highs of 10 to 40 mgals above base level occur over the greenstone units. The station spacing on the regional map is too sparse to see a really close correlation, but the local surveys find an excellent correspondence. This is to be expected, as the mean density of the greenstone units is around 2.85 g/cm^3 which is 0.15 to 0.25 g/cm^3 greater than in the granitoid rocks.

3. There are a number of prominent elliptical gravity lows of 10 to 20 mgals below base level which correspond with what appear to be diapiric granitoid intrusives.

4. A sustained regional high of 10 to 20 mgals above base runs along the English River gneissic belt. The Quetico belt is, however, at background or below.

5. The volcanic-plutonic subprovinces differ from the metasedimentary-gneiss subprovinces, not so much in gravity level as in character. The former are characterized by numerous highs and lows, while the latter lack much gravity relief.

6. The magnetic mapping delineates a wide variety of geological features. The following formations are, in general, magnetic (i.e., anomaly causing, volume susceptibility $>10^{-3}$ cgs emu): magnetite iron formations; mafic and ultramafic intrusions and flows which are irregular in shape; plug-like, near vertical intrusives, many of which are alkaline in character and which are most magnetic near their contacts; some gneisses, particularly in the north and in the English River belt; most diabase dykes and the Nipigon and Logan sills.

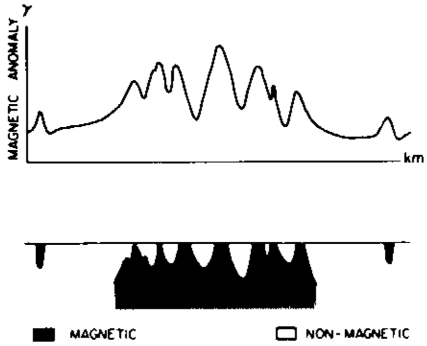

Figure 7
A schematic explanation for the regional magnetic anomalies. The contact between generally non-magnetic and generally magnetic regions is envisaged as a metamorphic front.

The following are generally non-magnetic: mafic and silicic metavolcanics; sediments other than iron-formations; granitic intrusions, particularly those which correspond with gravity lows.

Minor magnetizations capable of producing weak anomalies are found in many of the more gneissic parts of the volcanic-plutonic subprovinces. However, it must be stressed that even though the list of anomaly causing formations is quite long, on a volumetric basis only a very small fraction of surface rocks are anomaly causing.

7. The correspondence of magnetics with mapped geology is good in most parts of the Geotraverse, the correspondence improving with the detail of the mapping. It is best in the south half where relatively few gneissic rocks are very magnetic. To the north, particularly in the English River subprovince and again north of 51.5° N, there are extensive "fields" of anomalies. These correlated chiefly with gneissic and migmatitic terrains, but in some cases with areas mapped as metasediments. Systematic trend patterns which obviously are closely related to geological structures are visible in some of the fields. In some cases, bands of sinuous subparallel anomalies can be followed clearly for tens of kilometers. The petrological significance of these or other anomalies in the "fields" is not yet known.

8. The magnetic anomaly trend pattern is a useful indicator of faults. The most vivid example in the Geotraverse is the Miniss Lake (Manitou-Dinorwick) Fault which cuts across the English River belt at an angle of N 40° E. Other NE and a few NW faults, some inferred and others confirmed, are to be seen. The magnetics also define the position of major east west trending lineaments that occur along the north side of the Quetico and English River belts.

9. Three regional magnetic highs cross the Geotraverse. They strike at N 60° E, the same direction as the belt structure. All are coincident with fields of local magnetic anomalies, although the local anomaly intensities are much higher for the two northern regional anomalies than for the southern one. The middle one of the three coincides with the English River gneiss subprovince. There is no similar magnetic expression of the Quetico subprovince. The two northern anomalies both coincide with broad gravity highs.

Quantitative interpretations of the gravity anomalies over continuous greenstone units both in the Geotraverse and elsewhere usually indicate that the density contrasts seen at the surface between the volcanics and the granitic material extend more or less vertically to depths of 6 to 12 km.

Discussion

The following discussion is based upon present data level specifically incorporating material presented at the January, 1974 Geotraverse Workshop. Although to be viewed as only one frame in a currently changing picture it does provide a useful perspective of present direction.

The discussion proceeds in 4 stages: Structural Patterns, Sedimentary Patterns, Belt Patterns and Metamorphism and Igneous Rocks and Development of Continental Crust. Much of the relevant data is contained in extended abstracts of papers presented at the 1974 Geotraverse Workshop and available in most cases from individual authors on request.

Structural Patterns. An interim conclusion reached from consideration of the structural data derived so far mainly from the southern half is that a long-standing stress pattern expressed in north-south horizontal compression together with some east-west extension affected the Geotraverse corridor. Whether this horizontal compression is related in time and space to the vertical emplacement of the main diapiric granites is under investigation.

The main lithologic trends in the region are N 60-70 E upon which are superimposed major and minor structures as summarized below. The main groups are oriented respectively at N 30 E (left lateral) and N 40 W (right lateral) with common bisectrix at approximately N 5 W, and east-west extension.

Major Structures. (1) E-W lineaments, e.g., Quetico lineament – ductile faulting representing zone of attenuation; slight movement; right lateral. (2) N 30 E fractures and pre-existing folded structures; e.g., Steep Rock fold structure. The fractures are probably left lateral, e.g., Manitou-Dinorwick fault and Atikokan fault with vertical component. They have a consistent orientation. The N 30 E group of fractures and previous folds merge or feather into the E-W lineaments. (3) NW-trending fractures, e.g., Crayfish Creek fault. Not well-developed in the corridor. More variable orientation than N 30 E fractures. The sense of motion is right lateral.

Minor Structures. N 30-40 W. Offsets are dominantly right lateral. Mainly minor faults with offsets recorded by veins and layering and movement recorded by slip striae.

The original or true trend of the major E-W lineaments e.g., Quetico lineament which actually measures 100° bearing on the ground, is probably more nearly 90° bearing or even 70-80°. But where it has crossed abundant close-spaced right lateral NW fracture zones the net trend is 90-100°.

Diapiric Granites. Available evidence favours vertical movement or diapirism, perhaps involving dilation of supracrustal blocks with forceful emplacement along vertical discontinuities and vertical uplift even including a mushrooming effect as a principal method of granite emplacement. Such vertical motion is in agreement with the prevailing vertical to high angle isoclinal, doubly buckled fold patterns in the volcanic belts which are the preferred home of the granite diapirs. This contrasts with the apparently open fold patterns in the migmatite-metasedimentary belts which, in this regard, appear to contain comparatively few and small granite diapirs.

The prevailing vertical movement of granite diapirism may be compatible with a long-standing stress pattern involving N-S compression and E-W extension, on condition that the horizontal compression and vertical diapirism were generally synchronous. A synchronous relationship finds some support in the common shape of the granite diapirs which are elliptical in the N 70-90 E direction of extension. The apparent prevailing unaltered state, or low to moderate level of metamorphism of some granite diapirs suggests, however, that emplacement of these bodies was late-tectonic or post-tectonic. The confinement or preferred concentration of granite diapirs in the volcanic-plutonic belts and, as known, their comparative paucity in the migmatite-metasedimentary belts suggests that the granites and the volcanics had a common source such as the Archean mantle, and had closely related histories of development. Isotopic, trace, and rare earth element investigations, so important in this context, are now underway.

On the regional scale of the southwestern Canadian Shield the 5 east-trending supracrustal belts crossing the Geotraverse corridor occupy an "intercratonic" position between old Archean crust identified: 1) east of Lake Winnipeg (3000-3300 m.y.) on the north, and 2) in the Minnesota River Valley (3550 m.y.) in the south. Furthermore, preliminary U-Pb dating of zircons by Krogh and others indicates that the three volcanic belts under consideration lie in the 2750-2900 m.y. period and have a consistent pattern of younger ages to the south.

One possible interpretation would ascribe the long-standing stress pattern of north-south horizontal compression and vertical diapirism to persistent closing of the two above-mentioned old Archean cratons. In this connection the oft-mentioned resemblance of Archean volcanic assemblages to those of modern island arcs plus the presence in some Superior Province volcanic belts, e.g., Abitibi, of oceanic-type peridotite-bearing volcanic crust suggest that this N-S horizontal closing of the two Archean cratons involved consumption of Archean oceanic crust and development of Archean island arcs and continental-type crust as at modern convergent plate boundaries. The exact nature of the presumed plates and the styles of motion, both horizontal and vertical are speculative. Paleomagnetic data are potentially significant in this connection.

Sedimentary Patterns. Two main sedimentary types have been defined in the corridor: 1) volcanogenic sediments forming integral parts of the volcanic belts are of predominant volcanic composition and include chemical sediments (banded iron-formation); and 2) greywackes of the migmatite belts, of indicated cratonic or quartzo-feldspathic crystalline source.

Volcanogenic sediments including iron-formation as at Savant Lake are related to specific volcanic centres as well as, on a regional scale, to the development of large tectonic basins. Being sensitive indicators of local environment of deposition the iron-formation and other exhalative sediments are particularly useful in reconstructing paleobathymetry an approach now being pursued in the Sturgeon-Savant Lake region of the Wabigoon volcanic-plutonic belt.

Available data demonstrate that the migmatite-generating greywacke and derived schists of the English River and Quetico belts are more reasonably ascribed to a cratonic rather than a volcanic source. However, this does not deny the possibility of local volcanic rocks and derived sediments within the migmatite belts. But the main mass of greywacke, as petrologically and chemically known, had an indicated "cratonic" source in pre-existing sialic crust.

In this regard, the two old "cratons" of early Archean crust specified above lying respectively north and south of the corridor, each possibly involved in both horizontal motion (closure) and vertical (epeirogenic) uplift, are natural contenders as provenance. Implicit to this interpretation is the presence of old crust (grey granite gneiss) in the Geotraverse region.

In this context, the concept of the back-arc basin situated at the "continent"-side of the volcanic arc by providing for influx of craton-derived detritus is more attractive than the inter-arc basin of exclusive volcanic provenance as the source and environment of accumulation of English River and Quetico greywacke. Considered further, the concept of foreland basins developed upon, and filled by erosion of, nearby uplifted sialic crust is particularly appealing.

Belt Patterns and Metamorphism. The striped pattern of alternating volcanic belts and metasedimentary-migmatite belts which is such a striking feature of western Superior Province, has, as previously described, a metamorphic expression in that greenschist facies prevails in the volcanic-plutonic belts and amphibolite facies in the metasedimentary-gneiss belts.

At first glance, the analogy with modern island arcs, specifically the paired belts of the Pacific-type orogeny as described by Matsuda and Uyeda, is attractive. According to this concept the Archean volcanic-plutonic belt would represent the volcanic front and adjoining part of the inner belt of a modern island arc, and the Archean metasedimentary-migmatite belt would represent the outer sedimentary pluton-free belt on the ocean-side of the modern arc. However, this analogy is considered to be untenable because: 1) there is no evidence of low temperature – high pressure metamorphic assemblages or equivalents in the Archean metasedimentary-migmatite belts; on the contrary, the migmatite-associated sediments of the English River and Quetico belts are consistently higher grade than in adjoining volcanic belts; 2) the apparently open fold patterns of the Archean migmatite belts are not in keeping with the intense crumpling to be expected in the trench-subduction environment of the outer belt; and 3) chemical evidence points to a sialic cratonic source of sediments in the English River and Quetico belts rather than a volcanic source as would prevail in the outer belt of an island arc.

A back-arc or foreland environment in proximity to epeirogenically rising cratonic crust is considered to be more consistent with available data.

Accumulating data on metamorphic relations in the Geotraverse corridor indicate that the simple generalization of relative grades of metamorphism in volcanic (greenschist facies) and migmatite (amphibolite facies) belts respectively is unwarranted. Belt boundaries as presently defined do not agree in detail with changes in metamorphic grade. There is evidence of metamorphic regression. Available data indicate a more complicated metamorphic history than hitherto realized with exceptionally high thermal gradients in Archean time.

Igneous Rocks and Development of Sialic Crust. A three-stage process of development of Archean sialic crust is proposed using plate tectonics as an interim and not unattractive model. The three stages in grossly simplified form, each involving processes of igneous fractionation and differentiation, are as follows (see accompanying A-F-M diagrams, Fig. 8): 1) development of Archean "oceanic" crust from a sub-crustal or mantle source. Differentiation may have proceeded in a similar manner to that giving rise to oceanic crust at modern spreading ridges. Archean "oceanic" crust may have had the composition represented by point P in the A-F-M diagram (Fig. 8).
2) development of Archean "island arc" crust as a result of "subduction" or analogous predecessor motion of previously formed Archean oceanic crust in proximity to sialic cratons with synchronous or near-synchronous emplacement of large granite diapirs. The average composition of typical Archean "island arc" crust may have been represented by point K in A-F-M diagram. 3) accumulation in foreland basins of great thicknesses of greywacke derived mainly from weathering of nearby cratons. The sediments proceeded through a classical geosynclinal history of orogeny (Andean-type) to produce large quantities of migmatite with a broad range of neosomatic derivatives including high silica-potash end members. As specified, the main source of the sediments was old craton. It is not known whether the basement of the foreland basins was entirely sialic or involved some extentional opening with development of local oceanic crust in the manner of modern back-arc basins. The average composition of the resulting Archean granitic crust is represented by points C.S. and E.R. in A-F-M diagram (Fig. 9) and the main range of granitic components by the Quetico trend from point 3 to point 5.

MS received, June 21, 1974.

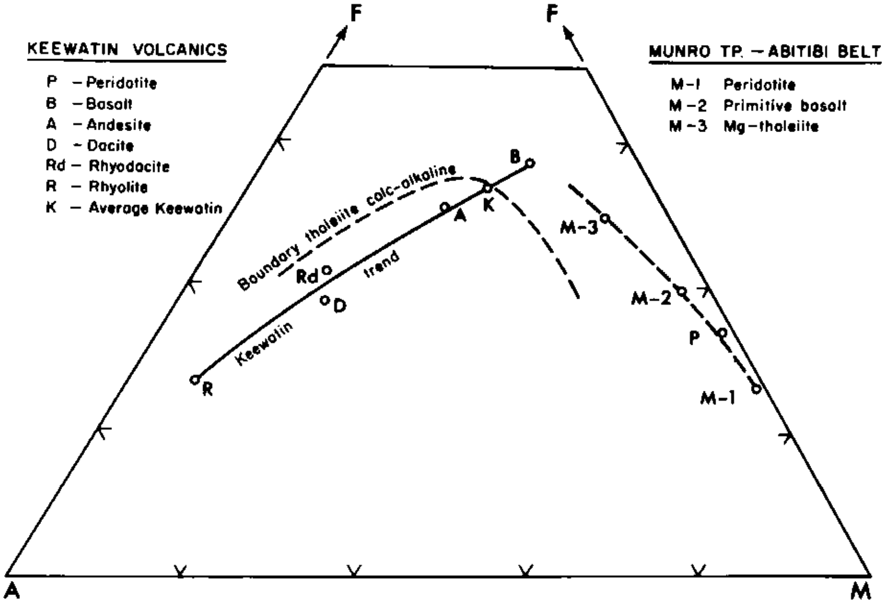

Figure 8
A-F-M diagram (A=alkalies, F=total Fe as FeO, M=MgO) illustrating relative compositions of Keewatin (Lake of the Woods region) and Munro Twp (Abitibi Belt) peridotites, possible representatives of Archean "oceanic" crust, plus differentiation trend towards Archean volcanic island arc asemblage of average composition K. The full differentiation trend of typical Archean island arc assemblage is illustrated by the line B-A-R based on mean composition of Keewatin volcanic classes. The combined compositional trend is from primitive tholeiites of presumed Archean oceanic environment to calc-alkaline island arc environment situated at Archean sialic craton-oceanic interfaces.

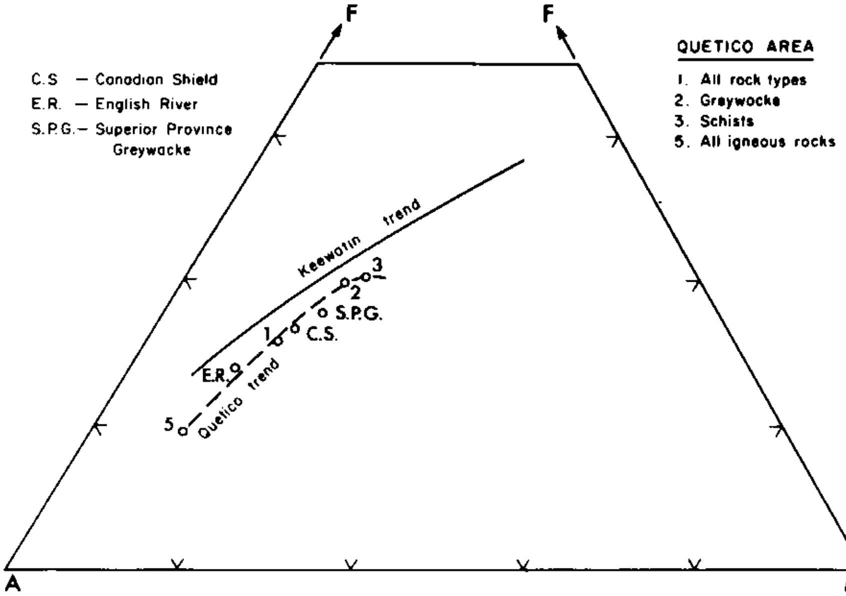

Figure 9
A-F-M diagram as in Figure 8. The Keewatin trend is taken from Figure 8. The Quetico trend is that of metasediments (2), derived schist (3), migmatites (1) and neosome granites (5) in the Quetico Belt. Also shown is the plot of average Canadian Shield (C.S.), average English River gneisses (E.R.), and average Superior Province greywacke (S.P.G.). The corresponding compositional trend for the Fitchie Lake area of the English River gneiss belt is essentially parallel to the Quetico trend. Thus, English River and Quetico sediments, schists, gneisses and derived granitic rocks lie on the alkali-rich side of typical Archean volcanic rocks. These data support the contention that typical Archean greywacke is derived from the weathering of pre-existing sialic cratons rather than volcanic rocks and that the various components of the gneiss belts are mainly of sedimentary derivation.