Geoscience Canada

Towards a Mobilist Tectonic Model for Part of the Archean of Northwestern Ontario

C. E. Blackburn

Volume 7, Number 2, June 1980

URI: https://id.erudit.org/iderudit/geocan7_2art03

See table of contents

Publisher(s)

The Geological Association of Canada

ISSN

0315-0941 (print)
1911-4850 (digital)

Explore this journal

Cite this article

Blackburn, C. E. (1980). Towards a Mobilist Tectonic Model for Part of the Archean of Northwestern Ontario. *Geoscience Canada*, 7(2), 64–72.

Article abstract

Models that have been proposed forevolution of the Archean crust can beconsidered as either fixist, involvingprocesses acting in place such as riftingand diapirism, or mobilist. involving horiz-ontal processes such as lithospheric platemovements, of which rifting and diapirismare adjuncts.

Consideration of regional geology of aportion of Superior Province suggests thatsupracrustal sequences can be tracedacross subprovince boundaries, but thatthe boundaries have been subsequentlymodified by considerable faulting bothdip-slip and strike-slip. Within the Wabi-goon Subprovince lowermost supracrus-tal sequences are everywhere of thicktholeiitic mafic volcanics that show noevidence of being ensialic.

Granite diapirism accounts for muchbut not all deformation of supracrustalsequences. Crustal shortening independ-ent of diapirism is indicated by the style ofthrust faulting. Geochronology supportsthe concept that batholithic invasion wascoeval with calc-al kali ne voieanism, andpaleomagnetism confirmsthat cratoniza-tion was complete by about 2.6 Ga ago.

Fixist models do not fully explain theseobservations, whereas a mobilist model,because of its broader nature, can accom-modatethem all.

Towards a Mobilist Tectonic Model for Part of the Archean of Northwestern Ontario

C. E. Blackburn
Ontario Geological Survey
Ministry of Natural Resources
77 Grenville Street
Toronto, Ontario M5S 1B3

Summary
Models that have been proposed for evolution of the Archean crust can be considered as either fixist, involving processes acting in place such as rifting and diapirism, or mobilist, involving horizontal processes such as lithospheric plate movements, of which rifting and diapirism are adjuncts.

Consideration of regional geology of a portion of Superior Province suggests that supracrustal sequences can be traced across subprovince boundaries, but that the boundaries have been subsequently modified by considerable faulting, both dip-slip and strike-slip. Within the Wabigoon Subprovince lowermost supracrustal sequences are everywhere of thick tholeiitic mafic volcanics that show no evidence of being ensialic.

Granite diapirism accounts for much but not all deformation of supracrustal sequences. Crustal shortening independent of diapirism is indicated by the style of thrust faulting. Geochronology supports the concept that batholithic invasion was coeval with calc-alkaline volcanism, and paleomagnetism confirms that cratonization was complete by about 2.6 Ga ago.

Fixist models do not fully explain these observations, whereas a mobilist model, because of its broader nature, can accommodate them all.

Introduction
Advent and acceptance of plate tectonic theory for the Phanerozoic has led in turn to examination of the applicability of such mobilist tectonic concepts to the Precambrian. Although Proterozoic sequences and tectonic regimes can be shown to fit plate tectonic concepts (e.g., Hoffman, 1973; Hoffman *et al.*, 1974; Burke, 1977) with some conviction, most workers would contend that such is not the case for the Archean. As pointed out by Burke *et al.* (1976) this might be due to the extreme complexity of plate tectonic processes. On the other hand, it might simply indicate that the uniformitarian principle cannot be applied, and that other tectonic models are more valid.

The intention of this paper is to document tectonic and stratigraphic data pertinent to development of Archean crust in a portion of the western end of the Wabigoon Subprovince and adjacent portions of the English River and Quetico Subprovinces in Ontario (Fig. 1) and to analyse how well they can be explained with reference to the opposing concepts of "mobilist", including plate tectonic models, and vertical tectonic "fixist" models.

The Models
Most models that have been proposed for Archean development can be categorized as either fixist or mobilist. "Fixist" models are those whereby all Archean rocks, whether volcanic, intrusive, or sedimentary are conceived as being emplaced essentially where they now lie relative to one another (i.e. autochthonous). Crustal movements are conceived as being essentially vertical, though this does not necessarily apply to mantle motion.

Conversely, "mobilist" models are based on the concept of horizontal crustal movement, vertical movement being consequent on this horizontal movement. Rock units may in large measure be allochthonous.

Fixist Models. Most of the early fixist models (Anheusser *et al.*, 1969; McGlynn and Henderson, 1970; Windley and Bridgewater, 1971; Viljoen and Viljoen, 1971) postulated rifting along fundamental fractures in sialic crust, with development of long, linear troughs now recognized as synclinal keels of greenstone and sedimentary fill. Subsequently, granitic batholithic emplacement was viewed as having deformed these belts.

More recently a number of workers have given more specific indication of possible mechanisms by which the troughs might have subsided. Gorman *et al.* (1978) have used modelling by Ramberg (1973) to suggest that mafic volcanics overlying granitic crust of lower specific gravity, as necessitated by the rifting model, lead to a fundamental instability, and sagging of the greenstones into the sialic "underburden". Talbot (1974) has used similar arguments to suggest that pleurotoid nappes develop by the same process. Citing Ramberg's (1973) models, Gorman *et al.* (1978) suggest that thrust faulting will develop, even to the extent of producing gravity-driven nappes. In the Uchi Subprovince, Thurston and Breaks (1978), although not necessarily supporting the fixist connotations, have extended this model to suggest that the entire Red Lake greenstone belt may be the overturned portion of such a nappe, the root zone of which lies to the south, possibly within the English River Subprovince.

The crux of Gorman *et al.*'s (1978) model is that it predicts the direction of thrusting to be toward the centre of the subsiding greenstone belt.

Another model recently developed by Young (1978, Fig. 3), seeks to explain both the structure of the volcanic-rich subprovinces ("volcano-sedimentary superbelts" of Young's terminology) and the sedimentary-rich subprovinces ("sedimentary superbelts") by a single mechanism. It is essentially a "fixist" model, and relies for its validity on three major assumptions: 1) the two types of "superbelts" are contemparaneous, 2) they are ensialic, 3) mantle convection cells are operative. The first two assumptions can be checked directly by field work, and evidence for and against in the area under consideration will be given later.

Glikson (1978) has argued for a primary simatic crust and although his model could be adapted to a converging plate boundary, he treats it as a fixist model, with crustal rifting. He argues for a two stage development of greenstones, and that there is no evidence of sialic crust contemparaneous with "early greenstones".

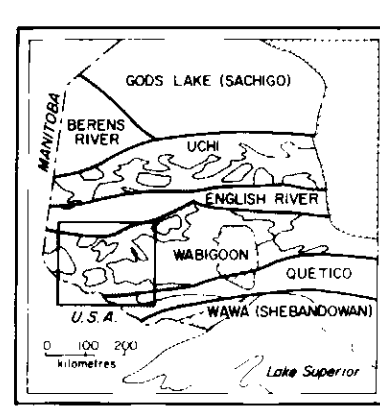

Figure 1
Sketch map showing the subprovinces of the Archean Superior Province in northwestern Ontario, and location of Figure 2. Archean supracrustal rocks (shaded) are both volcanics and sediments; Proterozoic (striped) is cover.

Mobilist Models. Suggested application of plate tectonic theory to the Archean is not new (e.g., Talbot, 1973). While Goodwin and West (1974) suggested plate tectonic models along with others, Langford and Morin (1976) and Burke *et al.* (1976) have more specifically attempted to show that the theory has applicability in the Archean of northwestern Ontario. Burke *et al.* (1976) use the term permobile rather than plate tectonic, because "Greenstone terraines preserve few obvious signs of the torsionally rigid behaviour at rupture and collision which became general during the Proterozoic". Langford and Morin's (1976) arguments are based primarily on morphological comparision between the subprovinces of the Superior Province and the Phanerozoic Cordilleran belts of Western Canada, coupled with meagre geochemical, geochronologic and geophysical evidence. Burke *et al.* (1976) rely on the uniformitarian principle, strengthening their comparisons by quoting from literature on many scattered areas within Superior Province as a whole and, like Langford and Morin (1976), using morphological comparisons with Phanerozoic examples.

The strength, but also paradoxically, the weakness, of mobilist models is that many variations on the basic theme of colliding crustal plates are permissible. Because, at the present time, the mechanism of modern plate movement is not entirely understood, processes like mantle convection, that may equally be applied to fixist models, may be invoked.

How, then, may the applicability of mobilist versus fixist models be investigated? A thorough understanding of regional field geology is essential. With this must be integrated regional lithogeochemical data, and regional tectonic considerations. Geochronologic and paleomagnetic data can also begin to be applied to these problems.

Regional Geology: the Wabigoon Subprovince and its Boundaries

The Superior Province of Northwestern Ontario is composed of east-west trending Belts or Subprovinces (Gill, 1949; Wilson, 1949; Stockwell, 1964; Goodwin, 1970; Riley *et al.*, 1971; Mackasey *et al.*, 1974), each subprovince being categorised by a predominance of either volcanic or sedimentary components, and attendant granitoid plutonic rocks. The area considered here (Fig. 1) straddles the western end of the Wabigoon Subprovince, predominantly composed of volcanic and lesser amounts of sedimentary rocks comprising greenstone belts, which have been intruded by granitoid batholiths. Adjacent to the Wabigoon Subprovince on the north is the English River Subprovince and on the south the Quetico Subprovince (Fig 2). These latter subprovinces are predominantly composed of clastic sedimentary rocks and granitoid rocks largely derived by anatexis of sediments (Beakhouse, 1977; Breaks *et al.*, 1978; Pirie and Mackasey, 1978). The relative ages of the subprovinces and the nature of their mutual boundaries have been the subject of considerable discussion (Ayres, 1969; Wilson, 1971; Riley *et al.* 1971; Mackasey *et al.*, 1974; Kehlenbeck, and Mackasey, Goodwin, 1976; Blackburn and Mackasey, 1977; Breaks *et al.*, 1978).

Wabigoon - Quetico Boundary. Debate about the geology in the vicinity of this boundary began in the early years of this century, before the subprovinces, or indeed provinces, were recognised, when Lawson (1888) formulated his classical relationship of volcanics (Keewatin) overlying sediments (Couchiching) in the Rainy Lake area (Fig. 2). Subsequently he was to recognise a second sequence of sediments (Seine) that he considered to overlie the Keewatin (Lawson, 1913), but the geological relations have been hotly disputed, even to the present. Considerable geochronologic work in the Rainy Lake area, summarised in Peterman *et al.* (1972) and further discussed by Birk and McNutt (1977) has failed to settle issues that essentially rely on detailed field mapping for resolution. Recent detailed mapping by Wood (1977, 1980a) has led to the interpretation (Wood, 1979, 1980b) that the Seine is a proximal alluvial facies probably equivalent to the more distal submarine Quetico sediments (that Lawson equated with Couchiching) so that sediments (Seine) of the Wabigoon Subprovince are probably therefore coeval with sediments (Couchiching) of the Quetico Subprovince. Similar relationships have been suggested along the Wabigoon-Quetico boundary further east in the Beardmore-Geraldton area (Ayres, 1969; Mackasey, 1972; Mackasey *et al.*, 1974), although Kehlenbeck (1976) has suggested the boundary is more typically defined on structural and metamorphic criteria, a view disputed by Blackburn and Mackasey (1977).

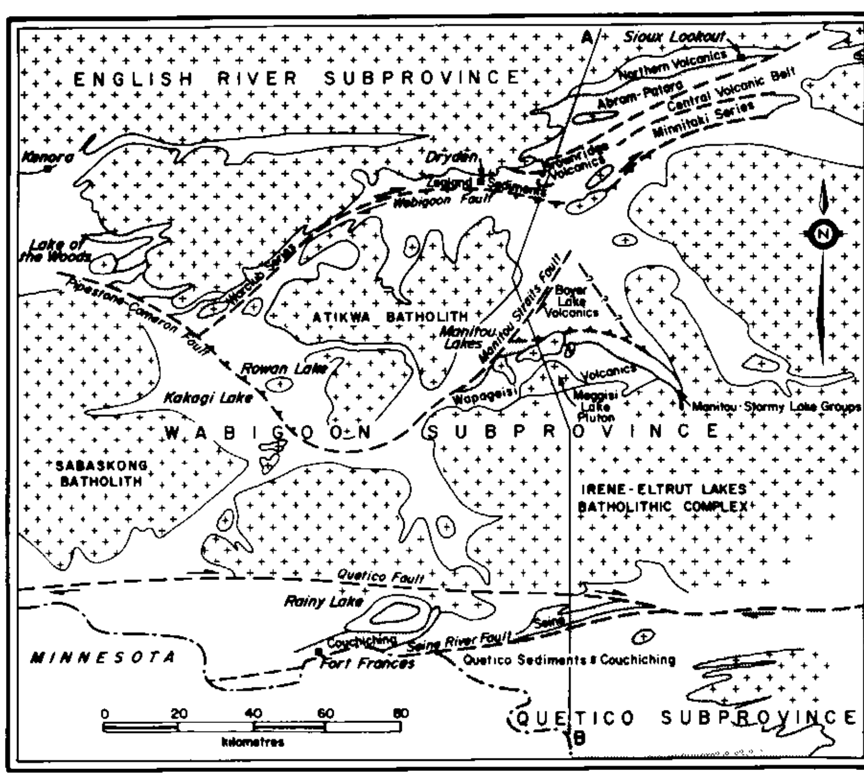

Figure 2

Prominent lithologies and structural features of the western end of the Wabigoon and adjacent subprovinces in Ontario. Granitoid rocks (crosses) include felsic plutonic, subvolcanic, and gneissic terraines, and some mafic rocks. Sedimentary rocks (shaded) are clastic, with some chemical sediments. Volcanic rocks are shown without pattern. Faults (broken lines) include transcurrent (with half-arrows), thrusts (barbs on up-thrust or over-thrust sides), and unkown movements (no ornament); some show evidence of multiple, differing movements. Cross-section A-B illustrated in Figure 4.

Wabigoon-English River Boundary. The Wabigoon-English River boundary has similarly been controversial. Wilson (1971) suggested that the boundary is fault-defined, and preferred to use the term Block in place of Belt or Subprovince. Recent mapping over a period of years has led Breaks *et al.* (1978) to the conclusion that the boundary is not fault-defined, but that granitic intrusives have been emplaced between gneisses of the English River Subprovince and metavolcanics of the Wabigoon Subprovince.

Harris and Goodwin (1976) suggested that the boundary near Sioux Lookout (Fig. 2) is transitional and defined by gneisses on the north interlayered with volcanics of the Wabigoon Subprovince on the south.

Migmatization, amply documented by Breaks *et al.* (1978), has obscured the relationships between various sequences of sediments within the English River Subprovince. However, it was recognised some years ago by Pettijohn (1972) that sediments characteristic of the English River Subprovince that occur along its southern border near Dryden (Fig. 2) can be shown to be continuous with sediments within the Wabigoon Subprovince. Therefore, as suggested for the Wabigoon-Quetico boundary, there is also a distinct time correlation between clastic sediments of the Wabigoon and of the English River Subprovinces.

Near Sioux Lookout (Fig. 2) two distinct sedimentary sequences, the Abram and Patara (Pettijohn, 1934; Johnston, 1972; Turner and Walker, 1973), and the Minnitaki Series (Pettijohn, 1936; Walker and Pettijohn 1971; Johnston, 1972; Turner and Walker, 1973) are separated by a thick volcanic sequence variously termed the Central Volcanic Belt (Turner and Walker, 1973) in the east and the Brownridge Volcanics (Satterly, 1943) in the west. The stacking order of this sedimentary-volcanic succession remains unresolved: it has been interpreted to be either Abram-Patara/Central Volcanics-/Minnitaki in upward progression (Turner and Walker, 1973) or that the Abram-Patara and Minnitaki are folded and/or faulted equivalents (Johnston, 1972). Fault contacts are confirmed along both margins of the Central Volcanic Belt by Trowell *et al.* (1980), following interpretations by Pettijohn (1934, 1936, 1937), Johnston (1969, 1972) and Turner and Walker (1973), though amount and sense of movement has not been determined.

The Minnitaki Group can be shown (Fig. 2) to be continuous westward along strike with the Zealand sediments (Satterly, 1943) at Dryden and the Warclub "Series" (Burwash, 1934) further west. The contact between these sediments and volcanics to the south is a sharp curvilinear line, some 150 km long. The contact was locally interpreted by Pettijohn (1937) to be a fault on the basis of abutment of fold axes against this lithologic contact at the southwest end of Minnitaki Lake. Satterly (1943) locally interpreted the contact southwest of Eagle Lake to be a fault The author has subsequently mapped over 100 km of the contact between these three areas and on the basis of 1) opposing and variable facings, and abutment of fold axes, across the contact, and 2) its great horizontal length, interprets this Wabigoon Fault (Satterly, 1943) to be a major fault (Blackburn, 1979b).

The Wabigoon Fault is of considerable significance in that it separates mixed sedimentary-volcanic sequences on the north from entirely volcanic sequences on the south over a distance in excess of 150 km. On this basis it is interpreted to be primarily a dip-slip fault, although a later component of dextral strike-slip movement is indicated by ubiquitous Z-drags on the mesoscopic to macroscopic scale found north of the fault only (Blackburn, 1979b).

The Wabigoon Subprovince. Within the greenstones of the Wabigoon Subprovince the considerable complexity of fold and fault structures must be attributed at least in part to the emplacement of granitic batholiths, around which the greenstones wrap in arcuate and anastomosing forms. Centrally located in the arcuate belt between Lake of the Woods in the west and the Manitou Lakes in the east (Fig. 2) is a zone of schistosity that can be traced almost continuously a distance in excess of 150 km. Fault movement on this zone is equivocal, and probably variable at different points along it. At the west end, at Kakagi-Rowan Lakes it is possible that a thick sequence of calc-alkaline pyroclastic rocks that overlie an equally thick sequence of tholeiitic basaltic flows southwest of the schist zone, here called the Pipestone-Cameron Fault, is missing and probably removed by erosion northeast of the fault, indicating the northeast side to be upthrown. However, Edwards (*in* Trowell *et al.*, 1977) has been unable to correlate any units across the fault. At the east end, at Manitou Lakes, correlation has been made across the schist zone (Blackburn, 1976) between sequences of tholeiitic basaltic flows overlain by calc-alkaline pyroclastics that occur on either side of the schist zone across a tightly folded and strongly sheared syncline, indicating fault movement along this portion to be minimal. However, correlation cannot be made across this schist zone between the uppermost unit of tholeiitic basaltic flows on the southeast side of the zone, and sequences northwest of it, thus indicating considerable movement on the schist zone, here called the Manitou Straits Fault. This upper sequence, the Boyer Lake Volcanics, has been shown (Blackburn, 1979a) to be allochthonous, and overthrust on top of the Manitou and Stormy Lake Groups of sediments and pyroclastics, as discussed below.

In this part of the western end of the Wabigoon Subprovince all observations point to batholiths being younger than the lowermost volcanic sequences: their contacts are everywhere intrusive; schlieren and xeonoliths of pillowed basaltic rocks are found both projecting into and also well within and engulfed by the granitic rocks; conglomeratic sequences that contain granitoid clasts everywhere overlie thick lowermost volcanic sequences, allowing ample time for emplacement of batholiths into these lowermost sequences. At no place has any field evidence for ensialic emplacement of lowermost volcanic sequences been obtained.

Volcanic Sequences and their Geochemistry

Wilson *et al.*, (1974) have attempted to show, from geochemical study of stratigraphic sections in two separated areas, one at Kakagi Lake, the other at Stormy Lake, that the greenstone terrain of the Wabigoon Subprovince (termed Kenora Block by them) can be characterised by a vertical subdivision into four groups, namely, lower mafic, middle mafic, middle felsic and upper diverse. They noted, in the two sections studied, a correlation between lithologies and chemistry and, on the basis of literature research, extended this subdivision throughout the region. Although their section at Kakagi Lake is valid, that at Stormy Lake has been shown (Blackburn *in* Trowell *et al.*, 1977; Blackburn, 1976, 1979a) to be complicated by folding. On this basis, their subdivision of the region as a whole is questionable.

Trowell *et al.* (1980) have found that within separate areas in the western end of the Wabigoon Subprovince the generally well recognised upward progression in Archean volcanic sequences (Goodwin, 1968) from mafic to felsic can be recognized. They have also found that in places thick sequences of mafic volcanic units overlie thick sequences composed of mixed mafic felsic units, or felsic assemblages. In some of these places a structural discontinuity can either be demonstrated or inferred, such that the stacking order of mafic platform, mixed edifice, and overlying mafic volcanics is not necessarily a younging order: in at least one case, in the Manitou Lakes area (Fig. 2), the allochthonous Boyer Lake Volcanics may be the equivalent of lower sequence basalts.

The lowermost sequences of mafic volcanics are very thick, some on the order of 10,000 m, and virtually devoid of either felsic volcanics or sediments. As shown in Fig. 3a (Wapageisi Volcanics), they are tholeiitic, with a high Mg/Fe ratio, though unequivocal komatiite flows have not been found. Mafic volcanics higher in successions (Fig. 3a, Wabigoon Volcanics), although being predominantly tholeiitic, show a distinctly lower Mg/Fe ratio than the lowermost sequences, implying that they are more differentiated. In addition, trace element geochemistry (Figs. 3b and c) suggests that notwithstanding the lower TiO_2 contents than to be expected and the mobility of Sr during metamorphism, lowermost sequences show more affinity with ocean floor basalts than with calc-alkaline basalts, compared with those mafic volcanics higher in successions.

Diapirism Versus Crustal Shortening

It was stated previously that the complexity of fold and fault structures within the Wabigoon Subprovince must be attributed at least in part to emplacement of granitic batholiths. Schwerdtner *et al.* (1979) have shown convincingly that shortening by continuous deformation with the Kakagi Lake portion of the greenstone terrain is due to diapirism of the surrounding batholiths. However, their structural analysis, as they point out, does not account for any discontinuous deformation, e.g., slip along possible thrust faults. As discussed above, there is good reason to believe that greenstones northeast of the Pipestone-Cameron Fault are uplifted relative to those southwest of the fault. Whether such faulting is thrust faulting is conjectural.

It should be borne in mind that the present attitude, mostly steeply dipping, of many faults may be misleading, in that low-angle thrusts could have been steepened during later phases of horizontal shortening.

In the Manitou Lakes area (Fig. 2) the author has demonstrated (Blackburn, 1979a) that a gabbro body intruded as a horizontal tabular sheet is locally discordant to a large syncline in a thick sequence of tholeiitic basalts (Boyer Lake Volcanics). The present, vertical, attitude of the sheet implies that the fold was recumbent at time of emplacement of the gabbro. Such recumbent folding is best explained by low angle overthrusting of the Boyer Lake Volcanics southward upon a thick sequence of sediments and calc-alkaline volcanics (Manitou and Stormy Lake Groups) that conformably overlie another thick sequence of tholeiitic basalts (Wapageisi Volcanics). It is also suggested,

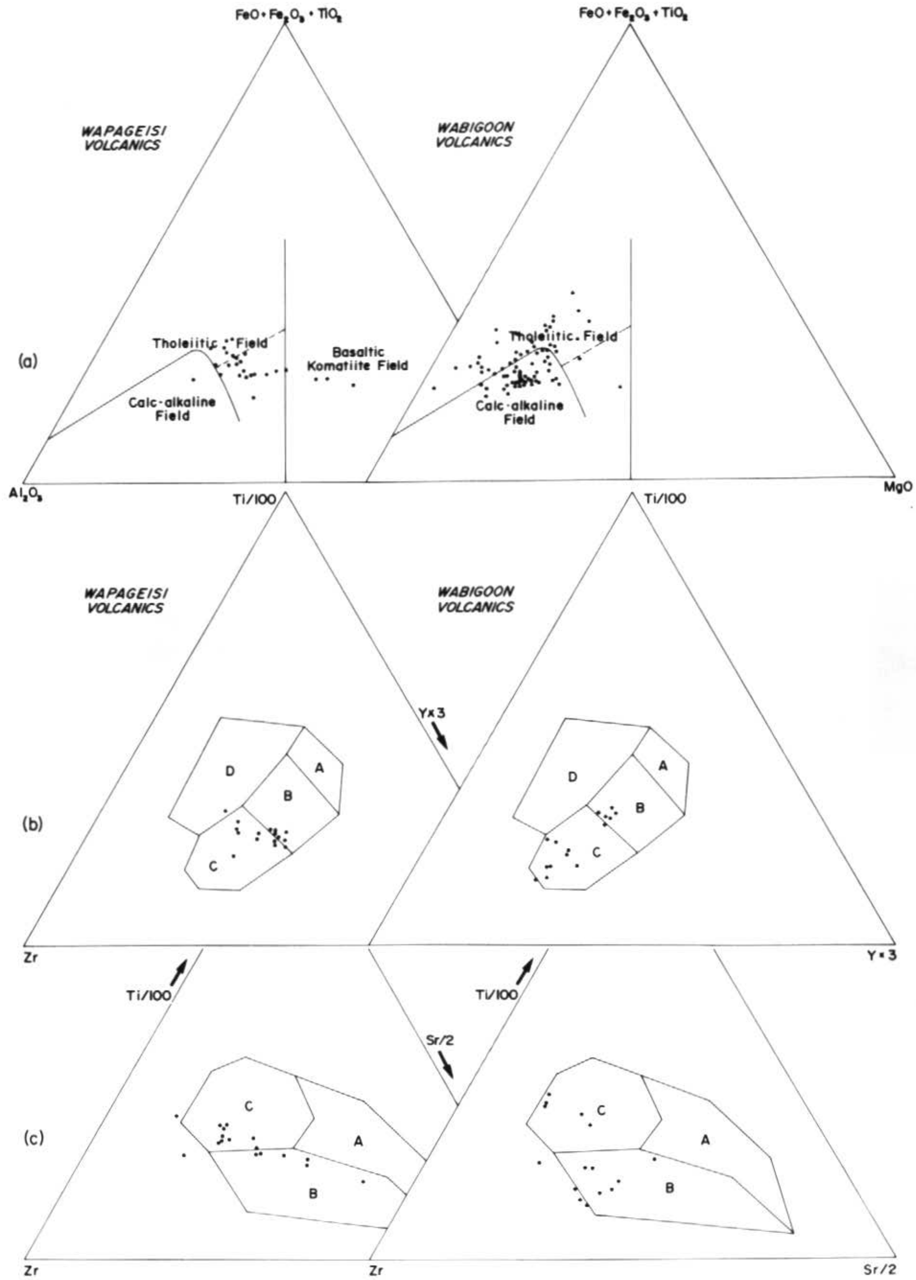

Figure 3a

Lower sequence Wapageisi Volcanics, when plotted on a cation percentage plot of Al_2O_3: $FeO + Fe_2O_3 + TiO_2$: MgO (Jensen 1976) show a distinct tholeiitic basalt affinity with high Mg/Fe ratio: upper sequence Wabigoon volcanics, on the same plot, show a mixed mafic-felsic, tholeiitic to calc-alkaline affinity, the uppermost basalt being tholeiitic, but with a lower (more differentiated) Mg/Fe ratio.

Figures 3b and 3c

Wapageisi Volcanics, when plotted on trace element discrimination diagrams of Pearce and Cann (1973), show a distinct grouping that suggests ocean-floor affinity; mafic Wabigoon Volcanics, on the same plots, show two distinct groupings, into lower calc-alkaline and upper ocean-floor affinities. (In Figure 3b fields A plus B encompass low-potassium tholeiites, field B alone encompasses ocean floor basalts, fields B plus C encompass calc-alkali basalts, and field D alone encompasses ocean island or continental basalts; in Figure 3c field A alone encompasses calc-alkali basalts, and field C alone encompasses ocean floor basalts; in both figures only samples that lie in the range 20% > CaO + MgO < 12% are plotted).

based on field relationships as well as similar mineralogy and major and minor oxide geochemical evidence (Blackburn, 1980), that granitic rocks of the Meggisi Lake Pluton, a part of the Irene-Eltrut Lakes Batholithic Complex to the south, are the sub-volcanic equivalent of the calc-alkaline volcanism. Because the Boyer Lake Volcanics have been overthrust on the calc-alkaline volcanics of the Manitou and Stormy Lake Groups it can be inferred that this thrusting postdated emplacement of the Meggisi Lake Pluton. The Meggisi Lake Pluton has been grouped by Schwerdtner *et al.* (1979) with late, non-diapiric plutons that intrude the large, diapiric, gneiss dome that constitutes the major portion of the Irene-Eltrut Lake Batholithic Complex. Since it is this early diapiric rise that has been invoked by Schwerdtner *et al.* (1979) to have continuously deformed the greenstone terrain, it follows that the thrusting in the greenstones is later than and therefore not due to diapirism in surrounding batholithic areas.

Similarly, application of the diapirism model of Gorman, *et al.* (1978), as discussed previously, requires thrusting to be toward the centre of the subsiding greenstone belt. Demonstrably, such is not the case in the Manitou Lakes, where the Boyer Lake Volcanics are thrust southward, away from the centre of the belt.

Other faults that show evidence of vertical movement include the Wabigoon Fault: since there is no evidence for the later dextral strike-slip movement to be large-scale, the sharp juxta-position of sediments against volcanics over a distance in excess of 150 km suggests dip slip movement, though relative movement remains speculative. On the basis of the argument that elsewhere sediments are found to post-date thick sequences of volcanics, it might be suggested that volcanic terrain on the south is now uplifted relative to sediments on the north.

One is left with the conviction that no "internal" mechanism can be found for either the suggested uplift of volcanic terrain surrounding the Atikwa Batholith, or for overthrusting of the Boyer Lake Volcanics.

An external stress system must be postulated. The only mechanism that allows both for uplift and thrusting is collision tectonics and crustal shortening, a necessary adjunct of plate tectonic theory.

Because physical and chemical characteristics of the Boyer Lake Volcanics and the Wapageisi Volcanics, although both tholeiitic, differ markedly (Blackburn, 1979a), it is probable that these sequences were developed in widely separated domains, and that subsequent crustal shortening was on the order of tens of kilometres or more.

Recent work in the Rainy Lake area (Fig. 2) by Poulsen (1979, and pers. commun.) suggests that downward facing units which can only be explained by nappe structures exist in the vicinity of the boundary between the Wabigoon and Quetico Subprovinces. Upthrusting or overthrusting may therefore by characteristic of subprovince boundaries in view of the model for the Red Lake greenstone belt (Thurston and Breaks, 1978), of the possibility of thrusting along the Wabigoon Fault (Blackburn 1979b), and of the proposed nappe structures near the Wabigoon-Quentico boundary (Poulson, 1979).

Geochronology

A number of workers (Goodwin, 1968, 1974; Langford and Morin, 1976) have suggested, on the basis of preliminary isotopic data in the literature on Manitoba, northwestern Ontario and Minnesota, that there is evidence for a younging southward from about 3 Ga in the north to about 2.6 Ga in the south, and therefore evidence of accretion of crustal material southward around a nucleus to the north. As further data are published it is becoming increasingly evident that within any one subprovince there is a spectrum of ages (Nunes and Wood, 1980; Nunes and Thurston, 1980; Davis *et al.*, 1980), that overlap each other from one subprovince to the next, but that the oldest ages are consistently being found within "gneissic" terrain in the sedimentary-rich subprovinces (e.g., Krogh *et al.*, 1976; Hinton and Long, 1979). These results support the concept of a temporal overlap in the development of subprovince lithologies.

Preliminary results (Davis *et al.*, 1980) obtained in an on-going zircon U/Pb study of the geochronology of the Savant Lake-Crow Lake area, which includes the portion of the Wabigoon Subprovince considered here, support the concept that batholithic invasion was coeval with or somewhat preceded periods of felsic, calc-alkaline volcanism. Near Kakagi Lake, Eagle Lake, and Wabigoon Lake, for each of three batholith - (sub) volcanic pairs, preliminary ages in Ma are in that order: 2748.5 ± 3.0 vs 2745.2 ± 2.8; 2756.1 ± 12.8 vs 2742.5 ± 6.9; and 2752 vs 2732.1 ± 2.3. For the first two cases, in spite of overlap in the errors, the difference between the ages lies outside the 95% confidence limit of either age, suggesting that the batholith is older than the flow. For the third case the batholith appears to be older than a subvolcanic phase by about 20 Ma though this number is not well defined because of uncertainty in the best-fit line used to define the age of the batholith.

Paleomagnetism

Regional paleomagnetic studies within and east of the present area by Dunlop (1979) have shown coincidence of paleopoles for rocks from the Wabigoon, Quetico, and Shebandowan (Wawa) Subprovinces on the Laurentian apparent polar wander path at about 2.6 Ga ago. This indicates, as noted by Dunlop (1979), that by this time these three subprovinces formed a single unit, presumably continental lithosphere. Because all the radiometric ages presently available for emplacement of Archean supracrustal and intrusive rocks are older than about 2.6 Ga, the paleomagnetic data confirms that cratonisation in this part of Ontario, no matter what tectonic model ultimately prevails, was complete by this time.

Application of a Mobilist Model

A tentative model incorporating plate tectonic theory is presented in Figure 4 Because of many uncertainties, only the part of Section AB (Fig. 2) that crosses the northern side of this part of the Wabigoon Subprovince and the boundary with the English River Subprovince is considered in the developmental stages.

Lowermost tholeiitic basalt sequences are envisaged as forming during opening of a micro-ocean by rifting of an unknown, possibly gneissic, crust (Stage 1). Evidence for such an ancient gneiss continent is only to be found within the English River Subprovince where Krogh *et al.* (1976) obtained radiometric data indicating a trondhjemitic phase, that is part of the sodic suite of Breaks *et al.* (1978), to have been emplaced at least 3.08 Ga ago and probably more than 3.3 Ga ago (Hinton and Long, 1979). These compare with preliminary ages on the order of 2.7 to 2.8 Ga for volcanics and associated intrusives within the Wabigoon Subprovince (Davis *et al.*, 1980). No radiometric data have been obtained from mafic volcanics at the base of the lowermost volcanic sequences but it appears unlikely even allowing for their great thickness that they are older than 3 Ga.

Onset of calc-alkaline volcanism coincided with initiation of closing of the micro-ocean, associated with subduction on either side of the ocean (Stage 2). Batholithic roots of this volcanism were initiated at this time, and are represented by phases of the Atikwa Batholith, the Sabaskong Batholith, and late phases of the Irene-Eltrut Lakes Batholithic Complex, e.g., Meggisi Lake Pluton.

Sedimentation developed peripherally to rising felsic volcanic arcs, and in adjacent troughs above subduction zones,

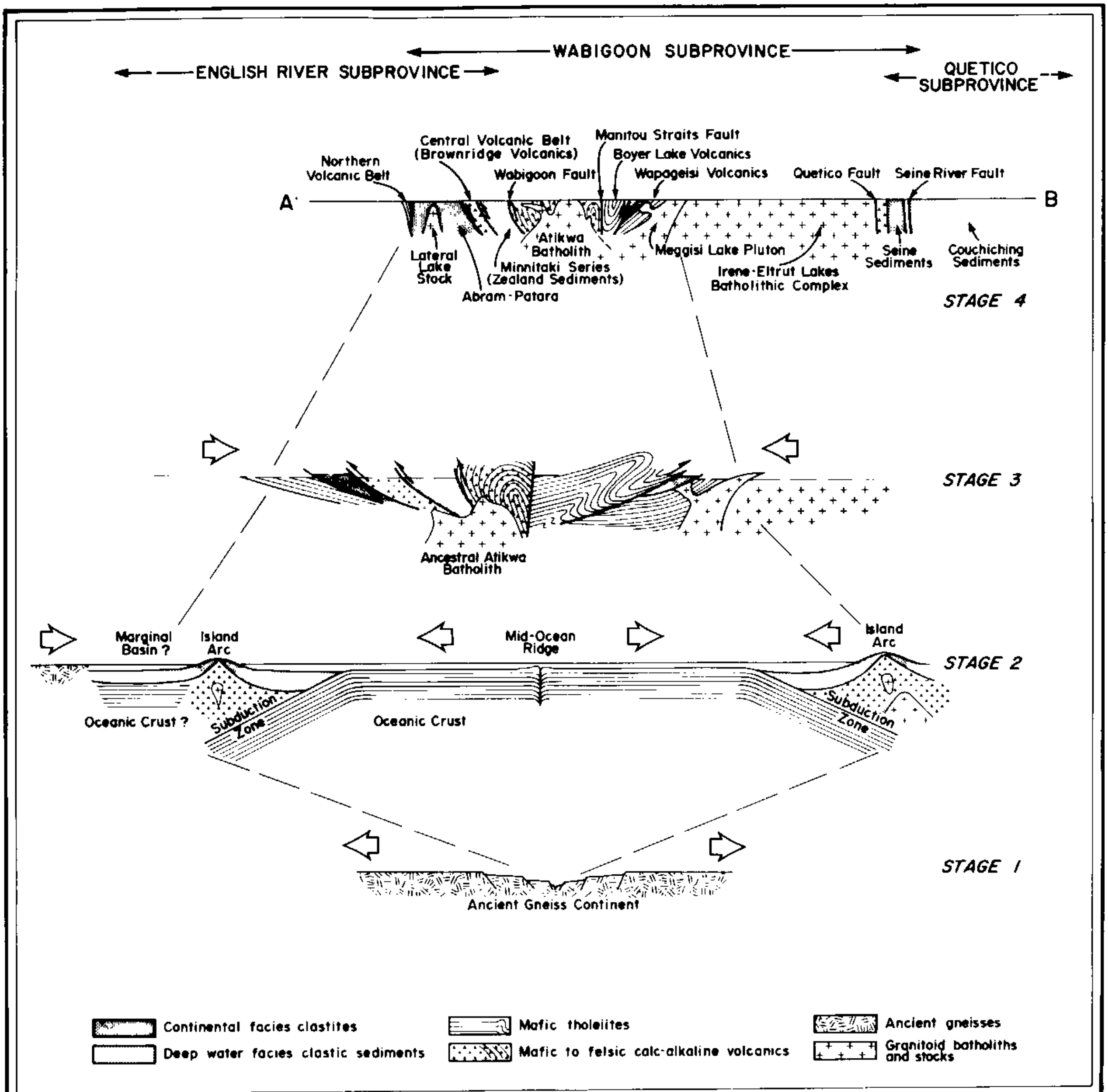

Figure 4

Hypothetical model to explain, according to mobilist concepts, crustal evolution along part of cross section AB in Figure 2. Although beginning stage might be similar, other cross sections would present differing configurations at each succeeding stage. Model envisages a complete Wilson cycle, with opening of a (micro-) ocean, followed by its closure. The sedimentary basins at either side of the "ocean" could have been connected, and pelagic sediments consumed during subduction. Model is somewhat analagous to Model V of Goodwin and West (1974). Open arrows indicate horizontal crustal movements.

such that continental sedimentation (alluvial fan, etc.) may be either below or a lateral facies equivalent of deep water sedimentation (submarine fan).

With continued ocean closure, most of the lowermost volcanic sequences would have been consumed, and in the cross-section under discussion, only the Wapageisi Volcanics, the Boyer Lake Volcanics, and the Northern Volcanic Belt testify to their hitherto more voluminous and continuous extent. Lack of recognized oceanic crust and upper mantle near the base of these sequences may be explained by consumption during the subduction process. Elimination of lowermost volcanic sequences from the central part of the belt represented initiation of the cratonization phase (Stage 3). Overthrusting of the Boyer Lake Volcanics southward, above sediments and calc-alkaline volcanics of the Manitou and Stormy Lake Groups, accompanied further crustal shortening, and it is speculated that on the north side of the belt, adjacent to the developing English River Subprovince, the alternating stacked sequences of sedimentary and volcanic belts represent supracrustal slices thrust northward over each other.

Continued crustal shortening (Stage 4) led to completion of cratonization. Previously low-dipping to flat lying structures, including bedding, thrust fault planes, and recumbent fold axial planes, became steep-dipping due to further crustal shortening but also to continued batholithic emplacement. The latter is based on the evidence that at Manitou Lakes, thermal metamorphism due to the Atikwa Batholith, acted late in the deformation history (Blackburn, 1980).

Discussion

A number of workers (e.g., Burke *et al.*, 1976; Bickle, 1978) have suggested that if plate-tectonics was operative in the Archean the necessarily higher thermal gradient compared with the Phanerozoic would necessitate faster convective turnover, therefore longer spreading ridges, and an accelerated production of ocean floor and arc rocks. Because ocean-floor material is consumed in the production of arc material, very little record of its former existence might be expected. The geochemical evidence suggests that only a few isolated remnants of what might be considered mafic volcanics deposited on an ocean floor remain in the western Wabigoon Subprovince, namely (Trowell *et al.*, 1980) the Wapageisi Volcanics, the Northern Volcanic Belt near Sioux Lookout, and the Jutten Volcanics at Savant Lake, northeast of the area considered here.

Horizontal shortening independent of diapiric rise of gneiss domes is demonstrable in only a few places in the western Wabigoon Subprovince. However, diapiric rise of gneiss domes in itself is not incompatible with plate movement. As Burke *et al.* (1976) point out, vertical movement is a necessary consequence of plate interaction and therefore of crustal shortening.

Conclusion

Presently available data, in the absence of complete detailed geologic mapping, the absence of complete correlation of stratigraphic sequences, and the preliminary state of detailed geochronologic studies to support and augment stratigraphic and structural interpretations, prevent the final assignment of a particular tectonic model to the crustal development of this portion of the Archean Superior Province.

None of the data is incompatible with plate-tectonic theory. It is, however, incompatible with some of the fixist models, notably that of Gorman *et al.* (1978) and the earlier rifting models of Anheuser, Viljoen, etc., that require documented presence of a pre-existing sialic, continental-type, basement to the volcanic sequence and absence of any horizontal tectonics. The model of Young (1978), supported by observations of sedimentary sequences crossing the subprovince boundaries, is opposed on these latter counts. Most of the data is compatible with Glikson's (1978) model, apart from the strong inferences of crustal shortening. Sequences like the Wapageisi Volcanics, Northern Volcanic Belt, and Jutten Volcanics could be considered as "early greenstones", all later sequences being the "late greenstones" of his model.

The incorporation of vertical tectonics with horizontal tectonics, as is allowable and also necessary in the plate tectonic model, makes this the preferred hypothesis for crustal development in this part of the Archean of northwestern Ontario. It has the added advantage of being uniformitarian, and therefore allowing comparison with more recent analogues.

As a postscript, Sangster (1979) has recently argued that "plate tectonic theories are woefully inadequate to contribute to our understanding of the origin and distribution of mineral deposits." Part of the argument is based on the justifiable observation that "in the Precambrian . . . plate tectonic processes can be documented only with difficulty, if at all." Maybe "island arc type massive sulphides in the Precambrian" *are* related to subduction, and the paucity of "Precambrian Cyprus-type massive sulphides enclosed in oceanic basalts" is due to the "geodegradable" (Burke *et al.*, 1976) nature of oceanic basalts.

Acknowledgements

My colleagues W. D. Bond, D. W. Davis, J. Pirie, J. Wood, P. C. Thurston, and N. F. Trowell provided many helpful comments on earlier versions of the manuscript, as did reviewers W. R. A. Baragar and W. M. Schwerdtner.

References

Anheusser, C. R., R. Mason, M. J. Viljoen and R. P. Viljoen, 1969. A reappraisal of some aspects of Precambrian Shield geology: Geol. Soc. America Bull., v. 80, p. 2175-2200.

Ayres, L. D., 1969. Early Precambrian stratigraphy of part of the Lake Superior Provincial park, Ontario, Canada, and its implications for the origin of the Superior Province. Unpublished Ph. D. Thesis, Princeton University, 399p.

Beakhouse, G. P., 1977, A subdivision of the western English River Subprovince: Canadian Jour. Earth Sci., v. 14, p. 1481-1489.

Bickle, M. J., 1978, Heat loss from the Earth. A constraint on Archean tectonics from the relation between geothermal gradients and the rate of plate production: Earth Planet. Sci. Letters, v. 40, p. 301-315.

Birk, D. and R. H. McNutt, 1977 Rb/Sr isochrons for Archean granitoid plutons within the Wabigoon Greenstone Belt, northwestern Ontario: a preliminary evaluation: in Report of Activities, Part A: Geol. Survey Canada Paper 77-1A, p. 161-167.

Blackburn, C. E., 1976, Stratigraphy and structure of volcanic-sedimentary assemblages, Manitou Lakes Area. in Geotraverse Conference Prodceeding, University of Toronto, 155p.

Blackburn, C. E., 1979a, Geology of the Boyer Lake-Meggisi Lake Area, District of Kenora. Ontario Geol. Survey Open File Report 5263, 194p.

Blackburn, C. E., 1979b, Wabigoon Fault: A major structural break in Northwestern Ontario?: Abstract with Programs Geol. Assoc. Canada/Mineral Assoc. Canada, v.4, p. 39.

Blackburn, C. E., 1980, Geology of the Manitou Lakes Area, stratigraphy and structure: Ontario Geol. Survey, open file Report 5298, 125p.

Blackburn, C. E. and W. O. Mackasey, 1977, Nature of the Quetico-Wabigoon boundary in the de Courcey-Smiley Lakes area, northwestern Ontario discussion: Canadian Jour. Earth Sci., v. 14, p. 1959-1961.

Breaks, F. W., W. D. Bond, and D. Stone, 1978, Preliminary Geological Synthesis of the English River Subprovince, Northwestern Ontario and its bearing upon Mineral Exploration: Ontario Geol. Survey MP72, 55p.

Burke, K., 1977, Aulacogens and continental breakup: Ann. Rev. Earth Planet Sci., v. 5, p. 371-396.

Burke, K., J. F. Dewey, and W. S. F. Kidd, 1976, Dominance of horizontal movements, arc and microcontinental collisions during the later premobile regime. in b. F. Windley, ed. The Early History The Earth, Wiley, 619p.

Burwash, E. M., 1934, Geology of the Kakagi Lake Area: Ontario Dept. of Mines, Ann. Rept for 1933, v. 42, pt. 4, p. 41-92.

Davies, J. C. and S. N. Watowich, 1958, Geology of the Populus Lake area: Ontario Dept. Mines Ann. Rept. for 1956, v. 65, pt 4, p. 1-24.

Davis, D. W., C. E. Blackburn, N. F. Trowell and G. R. Edwards, 1980, Geochronology of the Savant-Crow Lakes Area, Western Wabigoon Subprovince, Northwestern Ontario: in E. G. Pye, ed., Summary of Geochronology Studies 1977-1979: Ontario Geol. Survey MP92.

Dunlop, D. J., 1979, A regional paleomagnetic study of Archean rocks from the Superior Geotraverse Area, Northwestern Ontario: Canadian Jour. Earth Sci., v. 16, p. 1906-1919.

Gill, J. E., 1949, Natural divisions of the Canadian Shield: Trans. Royal Soc. Canada, Third Series, v. 43, Sect. 4, p. 61-69.

Glikson, A. Y., 1978, On the Basement of Canadian Greenstone Belts: Geosci. Canada, v. 5, p. 3-12.

Goodwin, A. M., 1968, Evolution of the Canadian Shield: Geol. Assoc. Canada, Proceedings, v. 19, p. 1-14.

Goodwin, A. M., 1970, Metallogenic evolution of the Canadian Shield: in R. J. W. Douglas, ed., Geology and Economic Minerals of Canada (Fifth Edition): Geol. Survey Canada, Econ. Geol. Rept. No. 1, 838p.

Goodwin, A. M., 1974, Precambrian belts, plumes, and shield development: American Jour. Sci., v. 274, p. 987-1028.

Goodwin, A. M. and G. F. West, 1974, The Superior Geotraverse Project: Geosci. Canada, v. 1, p. 21-29.

Gorman, B. E., T. H. Pearce and T. C. Birkett, 1978, On the structure of Archean Greenstone Belts: Precambrian Research, v. 6, p. 23-41.

Harris, N. B. W. and A. M. Goodwin, 1976, Archean rocks from the eastern Lac Seul region of the English River Gneiss Belt, northwestern Ontario, part 1. Petrology, chemistry and metamorphism: Canadian Jour. Earth Sci., v. 13, p. 1201-1211.

Hinton, R. W. and J. V. P. Long, 1979, High-resolution ion-microprobe measurement of lead isotopes: variations within single zircons from Lac Seul, Northwestern Ontario: Earth Planet. Sci. Letters, v. 49, p. 309-325.

Hoffman, P. F., 1973, Evolution of an early Proterozoic continental margin; the Coronation geosyncline, and associated aulacogens of the N.W. Canadian Shield: Royal Soc. London, Phil Trans. A273, p. 547-581.

Hoffman, P., J. F. Dewey and K. Burke, 1974, Aulacogens and their genetic relation to geosynclines with a Proterozoic example from Great Slave Lake, Canada: in R. H. Dott and R. H. Shaver, ed., Modern and Ancient Geosynclinal Sedimentation: S. E. P. M. Spec. Pub. 19, 380p.

Jensen, L. S., 1976, A new cation plot for classifying subalkalic volcanic rocks: Ontario Geol Survey, Misc. Paper 66, 22p.

Johnston, F. J., 1969, Geology of the Western Minnitaki Lake Area: Ontario Dept. Mines, Geol. Report 75, 28p.

Johnston, F. J., 1972, Geology of the Vermilion-Abram Lakes Area, District of Kenora: Ontario Dept. Mines, Geol. Report 101, 51p.

Kehlenbeck, M. M., 1976, Nature of the Quetico-Wabigoon boundary in the de Courcey-Smiley Lakes Area, Northwestern Ontario: Canadian Jour. Earth Sci., v. 13, p. 737-748.

Krogh, T. E., N. B. W. Harris, and G. L. Davis, 1976, Archean rocks from the Eastern Lac Seul region of the English River Gneiss Belt, Northwestern Ontario, Part 2. Geochronology: Canadian Jour. Earth Sci., v. 13, p. 1212-1215.

Langford, F. F. and J. A. Morin, 1976, The development of the Superior Province of Northwestern Ontario by merging island arcs: American Jour. Sci., v. 276, p. 1023-1034.

Lawson, A. C., 1888, Report on the geology of the Rainy Lake region: Geological and Natural History Survey of Canada, Ann. Rept., v. 3, pt. 1, Report F, 182p.

Lawson, A. C., 1913, The Archean Geology of Rainy Lake re-studied: Geol. Survey Canada Memoir 40, 115p.

Mackasey, W. O., 1972, Sturgeon River Metavolcanic-Metasedimentary Formations in the Beardmore-Geraldton Area: in Guidebook, Field Excursion C34, The Precambrian Rocks of the Atikokan-Thunder Bay-Marathon Area, 24th. Internatl. Geol. Cong. Montreal, 74p.

Mackasey, W. O., C. E. Blackburn, and N. F. Trowell, 1974, A regional approach to the Wabigoon-Quetico Belts and its bearing on exploration in Northwestern Ontario: Ontario Div. Mines Misc. Paper 58, 38p.

McGlynn, J. C., and J. B. Henderson, 1970, Archean volcanism and sedimentation in the Slave structural province: *in* Symposium on Basins and Geosynclines of the Canadian Shield: Geol. Survey Canada Paper 70-40, p. 31-44.

Nunes, P. D. and P. C. Thurston, 1980, An absolute age framework for the stratigraphy of the Uchi-Confederation Lakes metavolcanic-metasedimentary belt, Northwestern Ontario: in E. G. Pye, ed., Summary of Geochronologic Studies 1977-1979: Ontario Geol. Survey MP92.

Nunes, P. D. and J. Wood, 1980, Geochronology of the North Spirit Lake Area, Northwestern Ontario - Progress Report: in E. G. Pye, ed., Summary of Geochronologic Studies 1977-1979: Ontario Geol. Survey MP92.

Pearce, J. A. and J. R. Cann, 1973, Tectonic setting of basic volcanic rocks determined using trace element analysis: Earth Planet. Sci. Letters, v. 19, p. 290-300.

Peterman, Z. E., S. S. Goldich, O. E. Hedge and D. H. Yardley, 1972, Geochronology of the Rainy Lake region, Minnesota-Ontario: in B. R. Doe and D. K. Smith, eds., Studies in Mineralogy and Precambrian Geology: Geol. Soc. America Memoir 135, 348p.

Pettijohn, F. J., 1934, Conglomerate of Abram Lake, Ontario, and its extensions. Geol. Soc. America Bull., v. 45, p. 479-506.

Pettijohn, F. J., 1936, Geology of East Bay, Minnitaki Lake, District of Kenora, Ontario: Jour. Geol. v. 44, p. 341-357.

Pettijohn, F. J., 1937, Early Precambrian geology and correlational problems of the northern subprovince of the Lake Superior region: Geol. Soc. America Bull., v. 48, p. 153-202.

Pettijohn, F. J., 1972, The Archean of the Canadian Shield: A Resumé: in B. R. Doe and D. K. Smith, eds., Studies in Mineralogy and Precambrian Geology: Geol. Soc. America Memoir 135, 348p.

Pirie, J. and W. O. Mackasey, 1978, Preliminary examination of regional metamorphism in parts of Quetico metasedimentary belt, Superior Province, Ontario: J. A. Fraser and W. W. Heywood, eds., Metamorphism in the Canadian Shield: Geol. Surv. Canada Paper 78-10, 367p.

Poulsen, H., 1979, Polyphase deformation of Archean rocks at Rainy Lake, Ontario (Abst.) in Tech. Sess. and Abstracts, 25th Ann. Inst. on Lake Superior Geol. Duluth, Minn., 42p.

Ramberg, H., 1973, Model studies of gravity-controlled tectonics by the centrifuge technique: in K. A. de Jong and R. Scholten, eds., Gravity and Tectonics: New York, John Wiley p. 49-66.

Riley, R. A., H. L. King and C. R. Kustra, 1971, Mineral exploration targets in northwestern Ontario: Ontario Dept. Mines and Northern Affairs Misc. Paper 47, 72p.

Sangster, D. F., 1979, Plate tectonics and mineral deposits: a view from two perspectives: Geosci. Canada, v. 6, p. 185-188.

Satterly, J., 1943, Geology of the Dryden-Wabigoon Area: Ontario Dept. of Mines Ann. Report for 1941, v. 50, pt. 2, p. 1-67.

Schwerdtner, W. M., D. Stone, K. Osadetz, J. Morgan and G. M. Stott, 1979, Granitoid complexes and the Archean tectonic record in the southern part of northwestern Ontario: Canadian Jour. Earth Sci., v. 16, p. 1965-1977.

Stockwell, C. H., 1964, Fourth report on structural provinces, orogenies, and time classification of rocks of the Canadian Precambrian Shield: in Age Determinations and Geological Studies, Part II Geological Studies: Geological Survey of Canada Paper 64-17 (Part II), 29p.

Talbot, C. J., 1973, A Plate Tectonic Model for the Archean Crust: Phil. Trans. Royal Soc. London, v. A 273, p. 413-427.

Talbot, C. J., 1974, Fold nappes as asymmetric mantled gneiss domes and ensialic orogeny: Tectonophysics, v. 24, p. 259-276.

Thurston, P. C. and F. W. Breaks, 1978, Metamorphic and tectonic evolution of the Uchi-English Subprovince: in J. A. Fraser and W. W. Heywood, eds., Metamorphism in the Canadian Shield: Geol. Survey Canada Paper 78-10, 367p.

Trowell, N. F., C. E. Blackburn, G. R. Edwards and R. H. Sutcliffe, 1977, Savant Lake-Crow Lake Special Project, Districts of Thunder Bay and Kenora: in V. G. Milne, O. L. White, R. B. Barlow, and J. A. Robertson, eds., Summary of Field Work, 1977, by the Geological Branch: Ontario Geol. Survey MP75, 208p.

Trowell, N. F., C. E. Blackburn and G. R. Edwards, 1980, Preliminary Geological Synthesis of the Savant Lake-Crow Lake Metavolcanic-Metasedimentary Belt, Northwestern Ontario, and its bearing upon Mineral Exploration: Ontario Geol. Survey MP89, 32p.

Turner, C. C., and R. G. Walker, 1973, Sedimentology, stratigraphy, and crustal evolution of the Archean greenstone belt near Sioux Lookout, Ontario: Canadian Jour. Earth Sci., v. 10, p. 817-845.

Viljoen, R. P., and M. J. Viljoen, 1971, The geological and geochemical evolution of the Onverwacht volcanic group of the Barberton Mountain Land, South Africa: Spec. Publ. Geol. Soc. Australia, v. 3, p. 133-149.

Walker, R. G. and F. J. Pettijohn, 1971, Archean sedimentation: analysis of the Minnitaki Basin, Northwestern Ontario, Canada: Geol. Soc. America Bull., v. 82, p. 2099-2130.

Wilson, H. D. B., 1971, The Superior Province in the Precambrian of Manitoba: Geol. Assoc. Canada Spec. Paper 9, p. 41-49.

Wilson, H. D. B., M. G. Morrice and D. V. Ziehlke, 1974, Archean Continents: Geosci. Canada, v. 1, p. 12-20.
Wilson, J. T., 1949, Some major structures of the Canadian Shield: Canadian Instit. Mining and Metal., Bull., v. 52, p. 543-554.
Windley, B. F. and D. Bridgewater, 1971, The evolution of Archean low- and high-grade terrains: Geol. Soc. Australia Spec. Publ. 3, p. 33-46.
Wood, J., 1977, Mine Centre Area, District of Rainy River: in V. G. Milne, O. L. White, R. B. Barlow, and J. A. Robertson, eds., Summary of Field Work by the Geological Branch: Ontario Geol. Survey Misc. Paper 75, 208p.
Wood, J., 1979, Archean epiclastic sedimentation in the North Spirit Lake and Rainy Lake areas: A comparison: Abstract with Programs, Geol. Assoc. Canada/Mineral Assoc. Canada, v. 4, p. 86
Wood, J., 1980a, Mine Centre Area, District of Rainy river: Ontario Geol. Survey, Prelim Maps, 2201, 2202, Geol. Ser. Scale 1:15, 840.
Wood, J., 1980b, Epiclastic sedimentation and stratigraphy in the North Spirit Lake and Rainy Lake Area: A comparison: Precambrian Research, in press.
Young, G. M., 1978, Some Aspects of the Evolution of the Archean Crust: Geosci. Canada, v. 5, p. 140-149.

Published with permission of the Director, Ontario Geological Survey.

MS received February 21, 1980
Revised March 14, 1980

Positions Available

University of Regina Coal Petrologist

The Energy Research Unit, University of Regina, has a contract-supported position open for a coal petrologist. The position, as Professional Research Associate, is oriented toward applied research in lignite and bituminous coals. A current area of investigation is the relationship between coals and their conversion (liquefaction and gasification) properties. An advanced degree with specialization in coal petrography would be desirable but is not a requirement. A knowledge of carbonization and/or conversion residues would be advantageous. Write or telephone Dr. Laurence Vigrass, Director of Energy Research, University of Regina, Regina Saskatchewan S4S 0A2, Telephone: (306) 584-4269.

Dalhousie University Chairman, Department of Geology

The Department of Geology, Dalhousie University seeks a Chairman from July, 1981. The post could carry the rank of Full Professor. The new chairman should be able to provide leadership to the department and develop the present teaching and research activities, which emphasize marine earth science, Appalachian geology, and undergraduate teaching, including a proposed new B.Sc. programme in marine geological resources.

The Department has a faculty of 12, excellent technical support, is well equipped for marine work, geophysics and geochemistry, and graduates around 20 B.Sc. and 10 M.Scs. and Ph.Ds. each year.

Confidential enquiries from suitable persons in all the sub-disciplines of the earth sciences should be directed to D.J.W. Piper, Chairman, Department of Geology, Dalhousie University, Halifax, Nova Scotia, B3H 3J5 (902) 424-2363. Formal applications, giving the names of three referees should be made to the Dean of Arts and Science, Dalhousie University, Halifax, N.S.

Memorial University of Newfoundland Head of Department of Geology

Applications are invited for the position of **Head of Department of Geology**, Memorial University of Newfoundland. Candidates should have a strong background in research and administration and have interests in teaching. The appointment will be at senior academic rank. No specific field of research is required but candidates must have the ability to understand and encourage a wide range of geological research, much of it involving close co-operation with other university departments, government and industry.

The Department has 19 faculty members and a full technical and secretarial staff. The physical plant contains a full range of teaching and research laboratories and equipment (Automated Microprobe, S.E.M., X.R.F., X.R.D., A.A., Solid Source Mass Spectrometer, etc.). Departmental research is currently directed toward aspects of Appalachian geology and the Precambrian of Labrador. Future expansion is anticipated in offshore geology of the adjacent Atlantic margin.

Written applications, including a curriculum vitae and the names of a minimum of three referees, should be sent to the Dean of Science, Chairman of the Geology Headship Search Committee, Chemistry-Physics Building, Memorial University of Newfoundland, St. John's, Newfoundland, Canada, A1B 3X7, by August 30, 1980.