SEDIMENTOLOGY AND RELATIONSHIP TO VOLCANOLOGY OF FORMATION K, FAVOURABLE LAKE METAVOLCANIC - METASEDIMENTARY BELT, NORTHWESTERN ONTARIO

by

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Submitted in partial fulfillment of the requirement
for the degree of Master of Science

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ABSTRACT

Many Archean volcano-tectonic models that have been proposed for the evolution of greenstone belts utilized incomplete and inconclusive sedimentological data. In many areas, sedimentary basins are the only preserved record of changes in tectonism and composition of the provenance terrain. Quantitative rather than qualitative sedimentology applied to Archean sedimentary basins is essential in clarifying existing ambiguities in these models. Quantitative and semi-quantitative sedimentology was applied to Formation K, a conglomerate-greywacke unit, in the Favourable Lake metavolcanic-metasedimentary belt of northwestern Ontario.

The Favourable Lake belt is composed of 5 cycles of volcanism and sedimentation that are progressively displaced to the northwest. Formation K forms the upper part of Cycle 3 and was deposited, apparently conformably, upon the flanks of a subaqueous basaltic shield volcano (Formation J). Formation K is superceded by subaerial basalt flows of Cycle 4 volcanism (Formation M). The contact between Formation K and Formation M is a bedding plane thrust fault.

At its maximum extent and thickness Formation K is 15 km long and 2 km thick and comprises two members, a lower Conglomerate Member (0.3 km thick) and an upper Sandstone Member (1.7 km thick). The Conglomerate Member is a wedge-shaped unit of interbedded conglomerate and lithic

greywacke and was deposited subaerially as two or more coalescing alluvial fans. Detritus for the member was derived from the east and west of the member. The Sandstone Member is a wedge-shaped unit of interbedded feldspathic greywacke, conglomerate, felsic tuff, siltstone and shale and was deposited as a submarine fan with its apex to the east.

Sandstones of the Sandstone Member have unusually high contents of sand-size quartz forming up to 90 percent of the framework grains and averaging 68 percent. The remainder of the framework grains is composed of plagioclase and lithic fragments. The high content of quartz sand in the Sandstone Member coincides with the increase in importance of felsic volcanic clasts relative to the Conglomerate Member and the presence of interbedded felsic tuffs. The high quartz sand content was derived by the erosion and transportation of tuffs related to a pre-existing felsic volcanic sequence in the source terrain to the east. The presence of a possible orthoquartzite pebble in the member suggests that some of the quartz may have been derived from erosion of a pre-existing sedimentary terrain. In addition, associated felsic plutonic, subvolcanic and quartz vein clasts in the member suggests that some of the quartz was derived from the erosion of felsic plutons and felsic subvolcanic plutons with quartz veins.

The Sandstone Member is a sedimentary record of concomitant felsic volcanism that is presently not exposed in the Favourable Lake belt and thus is an integral part of the volcanic record. In addition, Formation K documents the possible existence of a pre-existing orthoquartzite sedimentary terrain possibly related to a relatively stable cratonic terrain represented today by crustal enclaves such as that exposed 3 km north of Formation K. The similarities between Formation K and sedimentary rocks at North Spirit Lake, 65 km to the southeast suggests a similar mode of occurrence. The existence of orthoquartzite pebbles at North Spirit Lake indicates that the area of tectonic stability, where such sediments can occur, may be more extensive than previously considered. The area of tectonic stability may be an original early Archean sialic crust of regional proportions represented today by crustal enclaves.

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INTRODUCTION

General Statement

Archean sedimentary basins are poorly documented. In part this reflects a lack of detailed study, in conjunction with the fact that many volcano-tectonic models proposed for the evolution of the greenstone belts (eg. Goodwin and Shlanka, 1967; Goodwin and Ridler, 1970) utilized incomplete and inconclusive sedimentologic information (eg. Turner and Walker, 1973; Walker, 1978a).

In many regions sedimentary basins are the only preserved record of changes in tectonism and composition of the provenance terrain. The nature of the tectonic regime can be deduced from the developmental history of the sedimentary basin as recorded by the nature and frequency of the transition from one sedimentary environment to another. The presence or absence of a sialic hinterland and changes in composition and type of volcanism in the provenance area will be recorded by the clastic input into the basin.

Quantitative rather than qualitative sedimentology applied to Archean sedimentary basins is essential in clarifying existing ambiguities in Archean volcano-tectonic models. Until recently, modern sedimentological methods were largely neglected in the Archean because of structural and metamorphic complications that hindered their application. In spite of these complications modified sedimentological techniques have been applied successfully to several Archean basins (Walker and Pettijohn, 1971; Turner and Walker, 1973; Henderson, 1972; Ojakangas, 1972 (a,b); Donaldson and Jackson, 1965; Bouttcher et al, 1966).

Compositionally and texturally mature Archean sandstones have volcano-tectonic implications for the evolution of greenstone belts. There are three main hypotheses for the evolution of greenstone belts (Glikson, 1978). In the first model, greenstone belts evolved as intrasialic basins. In this model sediments would be derived from both the sialic margins of the basins and volcanic rocks within the basins. In the second model greenstone belts evolved above oceanic crust in ensialic rift zones. In this model sediments would be derived from the rift margins and volcanic rocks within the rift zone. In the third model greenstone belts evolved by rifting or downbuckling of a simatic crust. Partial melting of the crustal root zones result in granite diapirism and ultimately cratonization. In this model the sediments would be derived from the erosion of the volcanic pile and adjacent cratons.

Archean sandstones that are unusually rich in clastic quartz have been reported from several localities in northwestern Ontario by Donaldson and Jackson (1965). At the North Spirit Lake locality (Figure 1) the high quartz content was attributed by Donaldson and Jackson (1965) to intense mechanical weathering of a combined granitic and sedimentary source terrain. This has since been corroborated by the discovery of orthoquartzite pebbles in the sandstone (Donaldson and Ojakangas, 1977). In the North Spirit Lake area the presence of orthoquartzite pebbles in sedimentary rocks derived from a combined sedimentary and granitoid terrain implies relative tectonic stability for long periods of time with intense chemical and mechanical weathering followed by redeposition in flanking, relatively unstable volcanic terrains. This would be consistent with the first two models of greenstone evolution but not necessarily the third. Isotopic age dates from the North Spirit Lake area (Nunes and Wood, 1979) indicate a 300 Ma hiatus between the extrusion of the volcanics and deposition of the sediments. It is possible that the high clastic quartz content of the sandstones is the result of upgrading by cyclic erosion and redeposition, during this period of sediment derived from felsic volcanics in addition to sediment derived from a granitoid and sedimentary terrain.

Controversy exists in the literature as to the relative importance of felsic volcanics in the provenance terrain. Some workers have discounted the importance of felsic volcanics as a source of clastic quartz (Donaldson and Jackson, 1965) while other workers have stressed the importance of clastic quartz derived from felsic volcanic terrains (Ayres, manuscript). The relative importance of felsic volcanics as a source terrain could be significant and would be consistent with all three models of greenstone belt evolution.

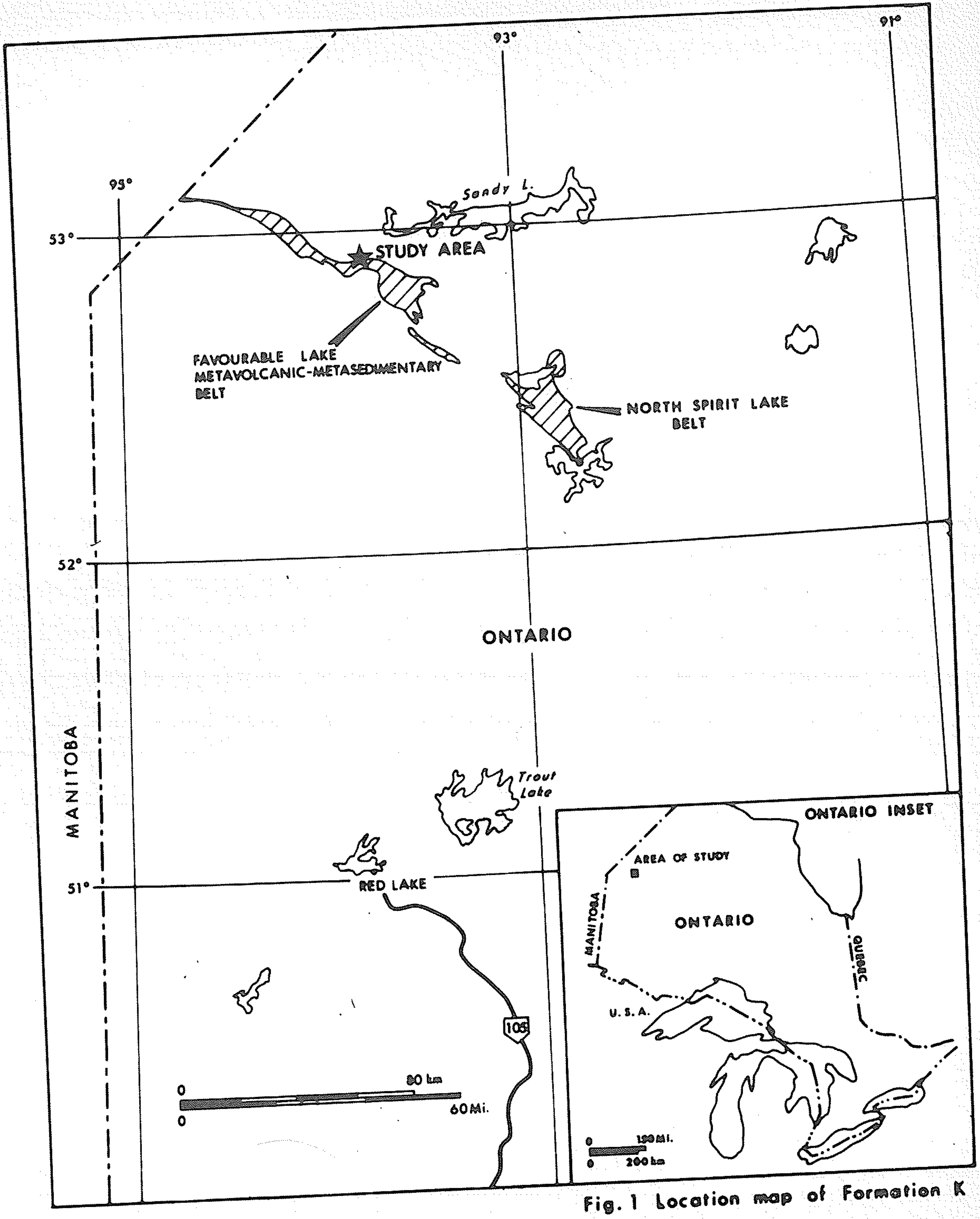

Fig. 1 Location map of Formation K

A new and less deformed quartz-rich sandstone unit (Formation K) has been examined in this study to determine the environment of deposition of the unit and its possible relationship to volcanism. The quartz-rich sandstone unit is within the Favourable Lake greenstone belt 65 km northwest of the North Spirit Lake metasediments (Figure 1). In addition to determining the environment of deposition of the unit an attempt is made to explain the high quartz content of these sandstones.

Location, Access and Previous Work

The study is in the Favourable Lake greenstone belt at latitude 93°44' West and longitude 52°50' North about 200 km north of Red Lake, Ontario (Figure 1). The only access to the area is by float-equipped airplane. The quartz-rich metasediments form a lenticular unit 10 km long and 2 km thick between North and South Trout Lakes. It was termed Formation K by Ayres (1974) and was subdivided into a basal conglomerate member and an upper sandstone member. The conglomerate member was later described (Ayres, 1977) as having been deposited "in a shallow water to alluvial basin on the flank of the volcano", with the sandstone member being deposited in somewhat deeper water indicating progressive subsidence of the basin.

Methods of Study

The eastern half of Formation K was mapped on a scale of 1:15,840 using air photographs with acetate overlays (Figure 2).

The western half was not mapped due to time restrictions and difficulty of access. All outcrops in the eastern half were visited and stripped of moss and light overburden to facilitate examination.

A general examination of the eastern half of the formation was followed by detailed stratigraphic measurements at selected localities. In the Conglomerate Member the following parameters were noted in outcrop:

a) range and average bedding thickness of conglomerate and sandstone beds;

b) bedding character (horizontal, lenticular, etc.) and presence or absence of channeling, scour and fill, cross-bedding and any other sedimentary structures;

c) presence or absence of grading in the sandstone and conglomerate beds;

d) intrabed distribution of clasts in the conglomerate and pebbly sandstone beds (i.e. pebbles only at base of bed, irregularly distributed, etc.);

e) the nature of the contact between sandstone and conglomerate beds.

In addition, 17 outcrops were selected for detailed analysis of clast populations. The method used consisted of two tape measures placed on a conglomerate bed parallel to bedding with a string marked in 1 cm segments placed perpendicular to the tape measures. The clast lithology under the string was noted at 1 cm intervals and the string was then moved in 10 cm intervals along the tape measure. Between 200 and 500 counts were made over 1 linear metre of conglomerate at each locality. The size range, average size and angularity of each clast type was noted.

In the Sandstone Member the following parameters were noted:

a) types of beds, and the average thickness and thickness range of each bed type;

b) presence or absence of graded bedding, and the nature of the grading;

c) presence or absence of pebbles, and their distribution and lithology;

d) sedimentary structures in addition to grading and their size and distribution;

e) presence or absence of shale, conglomerate, tuffaceous horizons, flows and brecciated units.

In addition, detailed stratigraphic measurements were made at 20 outcrops over thicknesses of 5-8 m. In these sections each bed was measured to the nearest centimetre and its grain size distribution, sedimentary structures and the presence or absence of lamination was noted. Grain size distribution was determined by comparison on outcrops with a grain size card produced by the Geological Speciality Company.

About 250 samples were examined in thin section and modal analyses were made on 40 of these from Formation K. The boundary between framework grains and matrix was placed at 0.06 mm and was determined using a micrometer eyepiece. Chemical analyses of 32 samples were made using a combination of atomic absorption, X-ray fluorecence and Leko induction furnace by the chemical laboratory of the Department of Earth Sciences, University of Manitoba.

Rock Nomenclature

The classification of the sandstones follows that proposed by Pettijohn (1954) and modified by Dott (1964). This classification uses 15% matrix as the boundary between arenites and wackes with further subdivisions based on the relative percentages of quartz, feldspar and rock fragments. The scale of stratification thickness described by Ingram (1954) is used where bedding thickness is described semi-quantitatively. The grain size limits are those proposed by Wentworth (1922) and modified by Lane (1947). Terms defining roundness and sorting follows that described by Pettijohn (1972). Granitic rock nomenclature follows that of Ayres (1972).

Without exception all sedimentary rocks in the study area are metamorphosed and should carry the prefix meta. However, for convenience and clarity, the prefix is omitted and terms such as greywacke are used when the proper reference should be metagreywacke.

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GEOLOGICAL SETTING

Formation K is in the east part of the 7.5 km thick Favourable Lake metavolcanic - metasedimentary sequence in northwestern Ontario (Figure 3). The sequence comprises 5 cycles (Ayres, 1977) that represent a subaerial, andesitic to dacitic stratovolcano (cycle 1) with three successive, predominantly subaqueous, basaltic shields (cycles 2, 3, and 4) developed on its northwestern flank (Figure 4). The upper part of cycle 2 is a subaerial, dacitic caldera complex. The shields represent continued growth of the volcanic complex northwest and upward (Ayres, 1977). Cycle 5 unconformably overlies cycles 2, 3, and 4 and represents subaerial to shallow water, andesitic to dacitic volcanism.

Formation K forms the upper part of cycle 3 and overlies pillowed tholeitic basalt flows of Formation J which represents a subaqueous shield volcano (Figure 2) (Ayres, 1977). The contact between Formation K and overlying basalt flows of Formation M, the basal part of cycle 4, is a fault. The overlying flows lack pillows and may be subaerial (Ayres, 1977).

Formation K is on the north limb of an east trending, upright, isoclinal syncline and the sequence faces south. The exposure is thus a near-vertical cross-section through the formation. The metamorphic grade in the eastern part of the Favourable Lake belt ranges from mid-greenschist facies in the centre of the belt to amphibolite and hornblende