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- Clastic Sediments of the Cullaton Lake Area, N.W.T. -

" Evidence for Archean Turbidites "

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Abstract

The clastic sediments of the Cullaton Lake area, N.W.T. belong to the Henik Group, an Archean volcanic-sedimentary assemblage. A petrographic study of the sediments indicate interbedded graywacke-argillite and modal analysis defines them as calcareous arkosic/feldspathic graywacke and calcareous argillite. Provenance studies support an igneous plutonic source. Petrographic features of the sediments resemble turbidite sequences deposited by turbidity currents. A portion of the classical turbidite sequence is represented in the sediments; a basal graded graywacke; overlain by parallel laminated graywacke; which fines upward to argillite. An alternating quiescent - turbulent depositional environment is proposed to explain the rather thin nature of Archean Iron Formations found in turbidite sequences.

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Introduction

Scope

Exploration work indicates gold occurring in Iron-Rich sedimentary rocks or Iron Formation situated in a belt of clastic sediments at O'Brien Energy and Resources Ltd., B-Zone deposit.

The purpose of this study is to define mineralogic composition and sedimentary structures of the clastic rocks in which the auriferous Iron Formations occur. This may aid in determining provenance and depositional environment of these sediments.

Location

The B-Zone property is located in the District of Keewatin, N.W.T., at approximately 61° 17', north latitude and 98° 31', west longitude. The property is situated 150 miles west of Eskimo Point, N.W.T., a small community on the west shore of Hudson Bay; 250 miles northwest of Churchill, Manitoba, and 325 miles north of Lynn Lake, Manitoba (fig. 1).

Previous Work

The gold-bearing Iron Formation has been extensively drilled and explored, but the surrounding clastic rocks have

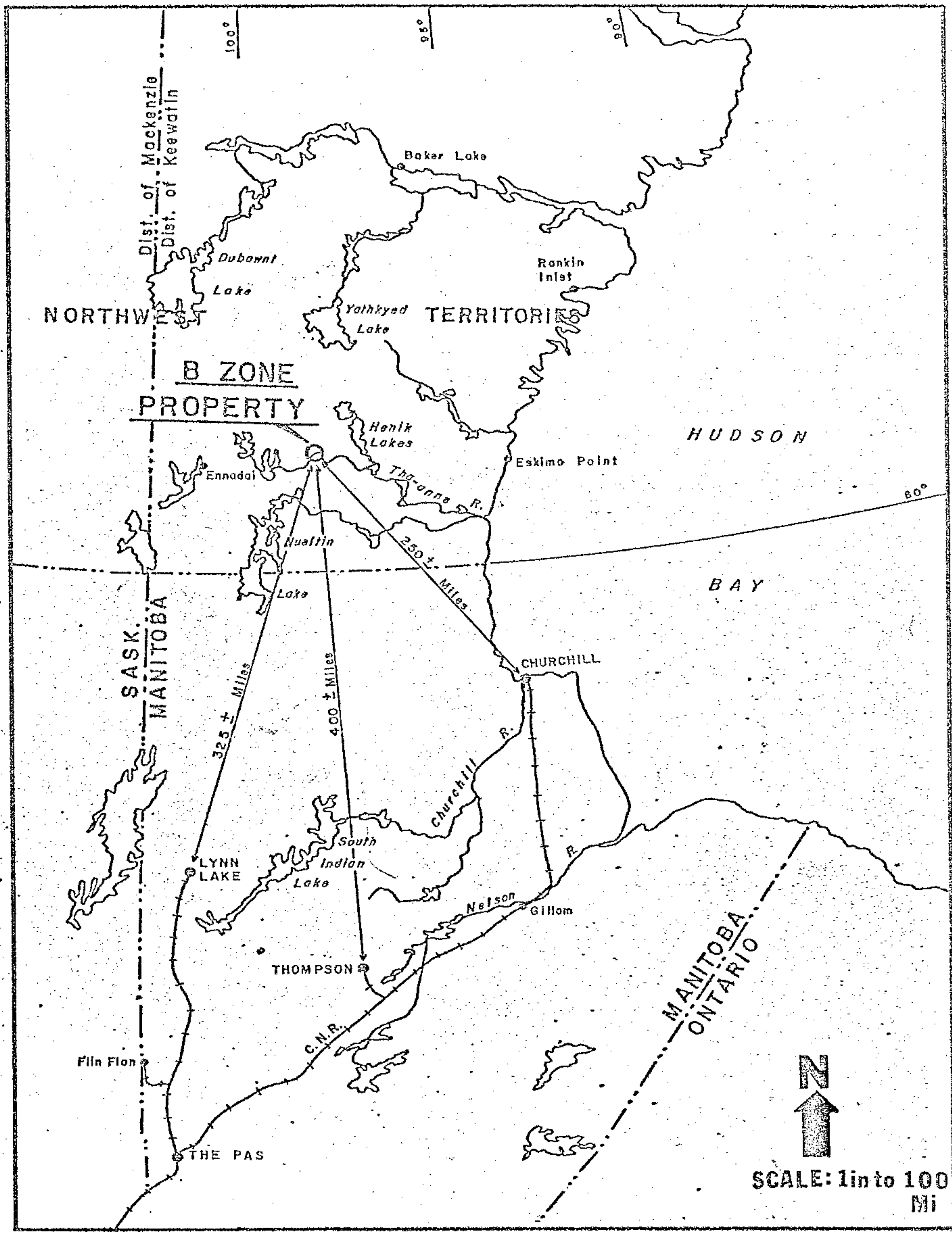

Fig. 1 LOCATION MAP

been virtually neglected.

Eade (1974) mapped the clastic sedimentary rocks as graywacke and argillite and classified the graywacke as occurring in both lithic and feldspathic varieties.

Geology

Regional

The study area lies within the Churchill Structural Province of the Canadian Shield and all known bedrock is Precambrian in age. Figure 2 lists the table of formations encountered in the Cullaton Lake region.

The oldest units are intercalated volcanic and sedimentary rocks of Archean age forming the Henik Group. They are extensively folded and faulted and are intruded by granitic rocks.

The volcanic rocks are part of the Kaminak Greenstone Belt and form the basement. The unit is extreamely heterogeneous and includes lavas, fragmental or pyroclastic rocks, and minor intrusive bodies ranging in composition from basic to acidic. About 70 to 75 percent of the unit consists of andesite and basalt, commonly in thick massive flows (Eade 1974). Small amounts of rhyolite are intercalated with the basic volcanic rocks. They are extensively sheared which obliterates evidence of origin.

TIME			GROUP	LITHOLOGY	
CENOZOIC					Morainic Material, Sand, Gravel, Silt & Clay
PRECAMBRIAN	PROTEROZOIC	HELIKIAN		INTRUSIVES	Gabro Dykes
					Granite
					Granite, Quartz Monzonite, Granodiorite
		APHEBIAN	HURWITZ GROUP	CLASTICS	Quartzite, Arkose, Minor Dolomite, Argillite
					Intrusive Gabro Sills
					Impure Quartzite, Arkose, Dolomite
					Greywacke, Siltstone
					Dolomite, Argillite, Siltstone, Iron Formation
					Slate, Shale, Siltstone, Greywacke
					Orthoquartzite, Arkose
					Boulder Conglomerate, Greywacke
			MONTGOMERY LAKE GROUP	CLASTICS	Siltstone
					Quartzite, Greywacke
					Boulder Conglomerate
	ARCHEAN			INTRUSIVE & METAMORPHOSED SEQUENCE	Gabro, Metagabro Dykes
					Granodiorite, Quartz Diorite, Monzonite
					Granodiorite Gneiss, Granite Gneiss
					Quartz-Feldspar-Biotite Schist & Gneiss
					Hornblende-Chlorite-Feldspar Schist & Gneiss
			Henik Group	CARBONATES	Dolomite Metadolomite
				CLASTICS	Graywacke, Tuff, Argillite Minor Quartzite, Conglomerate Banded Iron Formation "B-Zone" With Associated Carbonate, Oxide, Sulfide Phases (Au, Po, Py, AsPy, CPy)
				VOLCANICS	Pillow Lava Andesite Basalt Minor Rhyolite

Fig. 2 : Table of Formations (modified after Eade 1974).

The clastic rocks, dominantly consist of graywacke , tuff, and argillite. They are conformable with and for the most part stratigraphically above the volcanic rocks. It is within this clastic assemblage that the auriferous Iron Formations are situated. Rare, thin bands of carbonate rocks consisting of dolomite or metadolomite conclude the Henik Group.

A series of plutonic and metamorphic rocks separate the Lower Proterozoic, Montgomery Lake Group from the Archean, Henik Group. This sequence consists of various bodies of granodiorite and monzonite, forming a variety of gneisses and schists out of the Henik Group rocks.

The Montgomery Lake Group lies unconformably above the Henik Group and the Intrusive-Metamorphosed sequence (fig. 2). This unit consists of thick sequences of boulder-conglomerate, graywacke, quartzite and siltstone (Eade 1974).

The Hurwitz Group, Late Aphebian in age, lies unconformably above the Montgomery Lake Group. It consists of a broad assemblage of clastic sedimentary rocks; conglomerate, orthoquartzite, slate, shale, dolomite, graywacke and arkose (Eade 1974).

A group of Middle Proterozoic intrusive rocks, comprised of granite, quartz monzonite, granodiorite, gabbro and diabase dykes intrude the rocks of the pre-described units.

The area is structurally complex. Faulting, flexture-slip folding and shearing are extensive locally and regionally. Two periods of folding and faulting are recognized in the Aphebian sediments. The major fold axis has an apparent trend of N 66° W and the axis of subsidiary folding has a N 40° E trend. The major fault direction is NNW. The prominant N 50° E trend of cleavage is a reflection of the post-Proterozoic tectonic period, the most extensive period of structural deformation the area has undergone (Eade 1974).

Local

The bedrock geology of the B-Zone, Cullaton Lake area is outlined in figure 3.

The B-Zone deposit consists of gold occurring with sulphides in an Archean Iron Formation. The banded, 250 foot thick Iron Formation is made up principally of four distinct mineralogical facies: carbonate, oxide, silicate and sulphide. The gold mineralization has a direct affinity towards the pyrite, pyrrhotite and arsenopyrite units of the sulphide facies and it is proposed that the gold, sulphides and Iron Formation are consanguineous.

The B-Zone Iron Formation as well as other ferriginous deposits lie in a 6 to 8 mile wide belt of generally north-west striking, southwest dipping clastic sediments of the Henik Group. This unit consists dominantly of graywacke and argillite in the map area. The graywacke occurs in beds from 2 inches to 6 feet or more in thickness. These beds are very massive and compact whereas the finer argillite beds are very finely laminated. The argillite is normally interlayered with

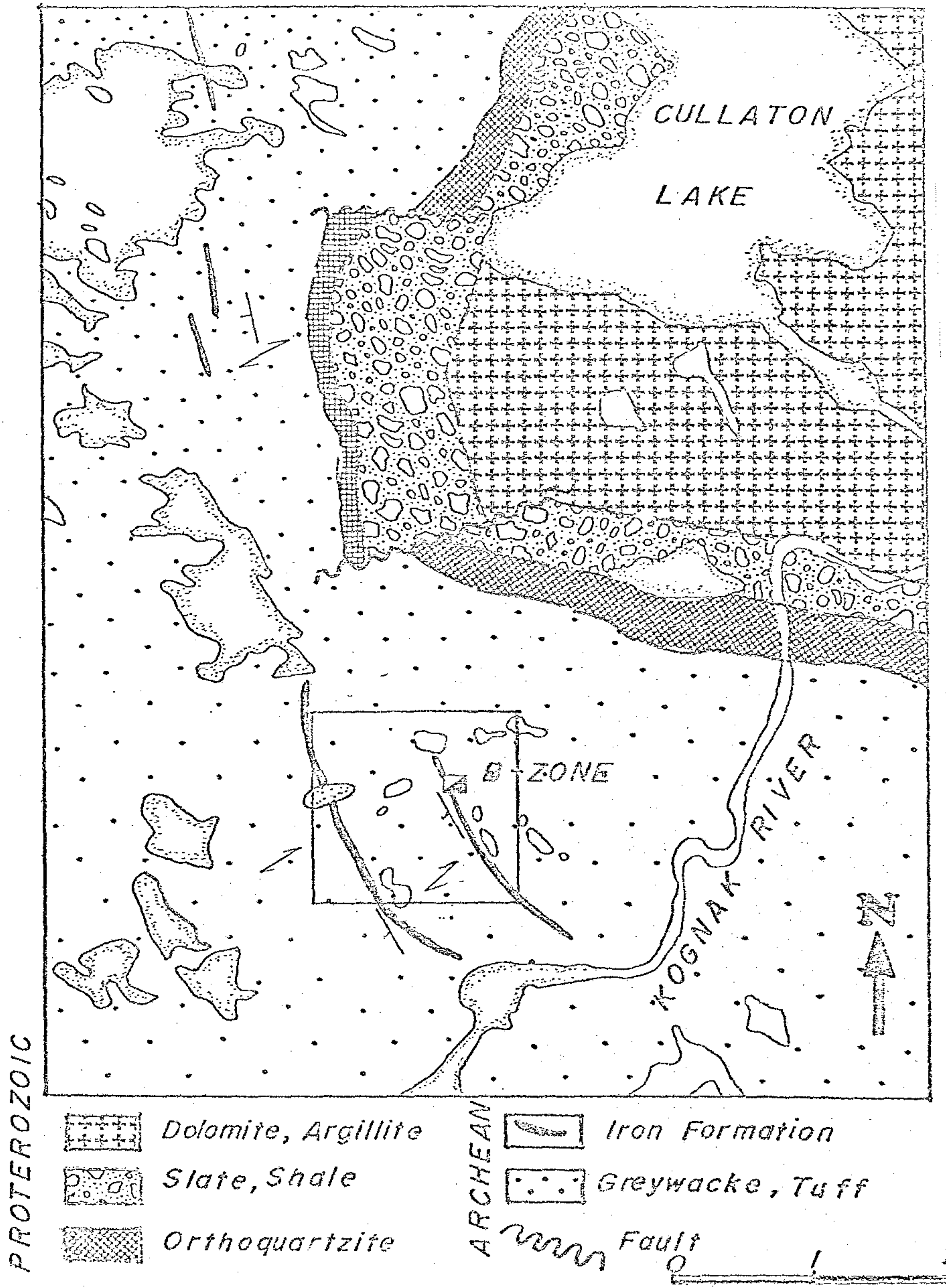

Fig. 3 : Geology of Cullaton Lake area.

the graywacke forming the upper part of each graded bed, but may in itself form thick homogeneous beds.

A N 50° E cleavage is predominant in the argillite and graywacke throughout the map area. Nearly all the rocks in the area have been affected by slight to moderate regional metamorphism. The Archean clastic sediments are in the lowest subfacies of the greenschist facies of metamorphism (Eade 1974).

The north-eastern part of the map area is dominated by Aphebian sediments of the Hurwitz Group. This folded - faulted orthoquartzite, shale-slate, dolomite-argillite assemblage has an apparent fold axis trend of N 66° W. Numerous faults parallel the axial plane and later cross-faults cut and offset the folds.

Petrology

The actual study area is centered around the B-Zone deposit (fig. 3) and constitutes an area of approximately 1 square mile.

Field work and samples were collected during the 1975, 1976 and 1977 field seasons while employed with the Company.

A total of 12 samples were obtained from outcrops for petrographic descriptions. Outcrop in the study area is sparse and sampling was limited to available exposures. Sample locations are illustrated in figure 4. Samples 77-5 and 77-7 were classified in the field as argillites and the remainder

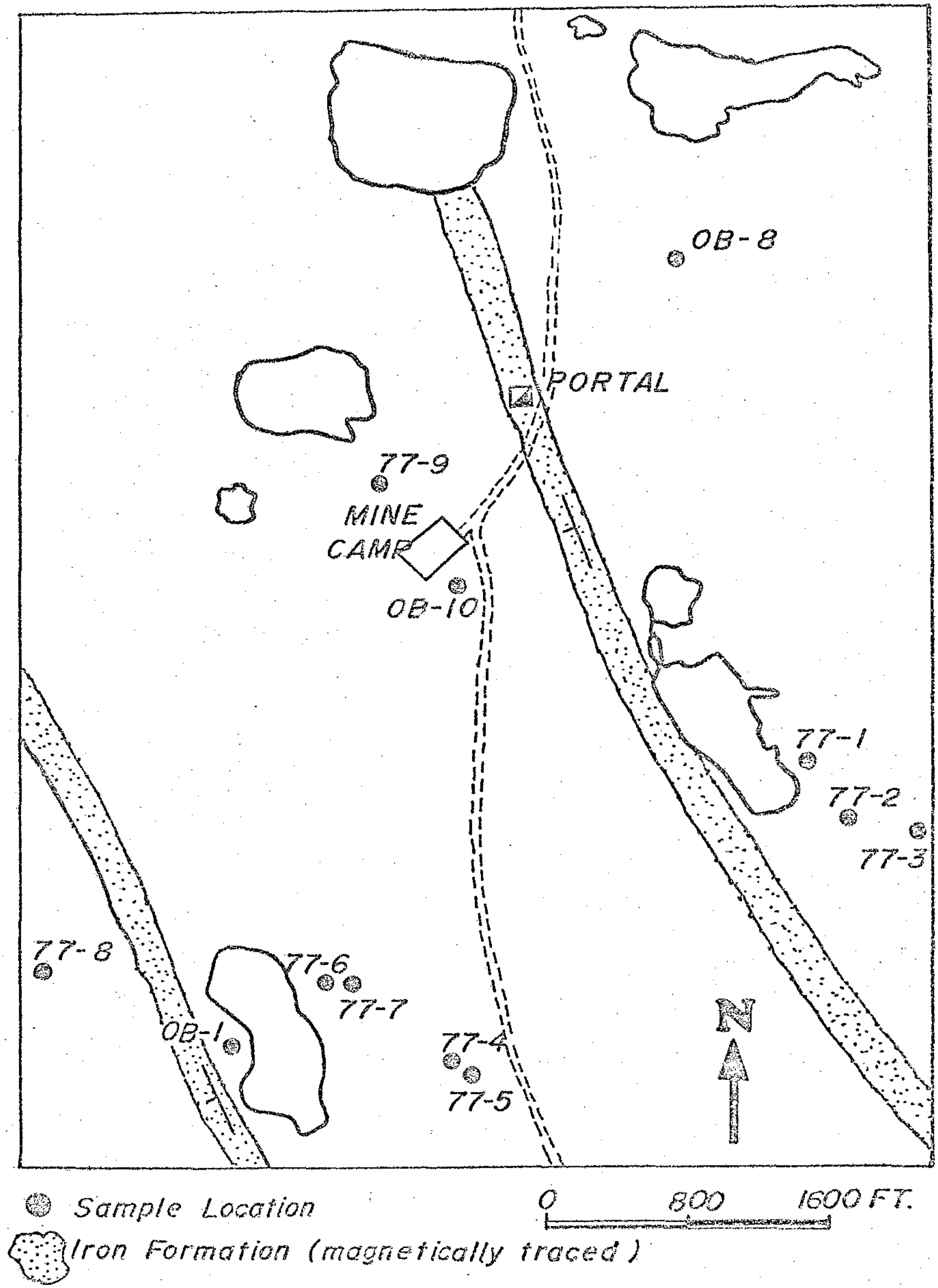

Fig. 4 : Sample locations.

as graywackes.

Macroscopic Description

The fine to medium-grained graywacke is greenish gray or light buff on weathered surfaces and dark gray or greenish gray on fresh surface. The rock breaks with a rather concoidal fracture. Feldspar grains are visible on weathered surfaces as white-bleached grains and quartz grains are visible on fresh surfaces as black, glassy fragments. The graywacke appears to contain abundant carbonate which is characterized by a dominant oxide stain. Occasional pyrite grains are evident displaying euhedral cubes.

Slump bedding and graded bedding are common features in the graywacke but are difficult to observe because of heavy lichen cover. In the graded graywacke beds a colour gradation is usually evident with the finer upper portion being darker.

The fine-grained argillite is dark brown on weathered surfaces and black-green on fresh surfaces. Cleavage is well developed in many of these units, trending near normal to bedding.

Microscopic Description

" Graywacke " *

Thin section analysis indicates that grain size ranges from 1.5 to 0.3 mm in the graywacke, suggesting a

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* not a modal classification but rather a field classification.

poorly sorted coarse to medium sized sand.

The composition of the graywacke is composed of : quartz, feldspar, rock fragments, and matrix. Each of these components will be disscussed separately.

Quartz

Quartz is the most abundant framework mineral, ranging between 32 percent to 80 percent in abundance and averages 50 percent. The quartz grains are the largest averaging 0.5 mm in size. Two types of grains occur; 1. single grains, and 2. polycrystalline grains. Over 90 percent of the quartz is of the single grain nature, angular to subangular in shape and exhibit undulatory extinction.

Feldspar

Plagioclase (albite) is by far the most abundant feldspar mineral, contributing up to 90 percent of this fraction. The other 10 percent is made up of microcline. The large majority of the grains are altered enough to obscure the optical properties of the grains. The feldspar grains average 0.25 mm in size, are subrounded and are partially being replaced by sericite and carbonate.

Rock Fragments

Rock fragments make up only a minor portion of the total composition, averaging 12 percent. Felsic volcanic fragments, 0.2mm in size, make up the majority of this unstable component. These cryto-crystalline fragments resemble recrystallized chert but can be distinguished by the presence of chlorite and feldspar scattered within the fragments. Many of the lithic fragments are unidentifiable and their separation from matrix is subjective.

Matrix

The matrix constitutes between 15 to 40 percent of the total sediment with the average somewhere around 25 percent. The matrix consists dominantly of sericite, carbonate and minor chlorite. The fine grained carbonate makes up to 20 percent of the matrix. Pettijohn (1957) suggests that this carbonate (likely ankerite) is a diagenetic product replacing both matrix and coarser detrial grains. It appears that the matrix is growing at the expense of both the rock fragments and feldspars.

Accessories

Pyrite, biotite and zircon are present in minor amounts in the graywacke. Biotite and zircon are believed to be primary detrial minerals and pyrite is believed to be authigenic. Pettijohn (1957) suggests that the pyrite is perhaps the product of penecontemporaneous diagenesis and is either the product of sulfate reducing bacteria or the product of decomposition of sulfur-bearing organic matter.

" Argillite" *

The argillite units separate the thicker, massive graywacke units. The graywacke appears to be grading upward into the argillite.

Microscopically the argillite is very fine grained composed of over 75 percent clay and silt sized particles. Detrial subangular grains of quartz and feldspar, 0.25 mm in size, make up approximately 10 percent of this sediment. The remainder is composed of unidentifiable clay sized particles.

The argillite is relatively rich in fine grained carbonate that contributes some 20 percent to the total composition. Euhedral grains of pyrite are encountered and are believed to be diagenetic in origin.

Fissility is absent in these fine grained sediments.

Classification

" The term graywacke has proved one of the most troublesome, and some writers have even recommended its abandonment, without proposing a substitute term for the important group of rocks which have been and still are called graywackes ", Pettijohn (1957).

Many quantitative compositional definitions of graywacke are in literature today and as might be expected dissagreement arises as to the precise location of the boundary between graywacke and other rocks.

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* field classification.

A liturature review shows that most classification schemes for these impure sandstones are characterized by : 1. stable grains, consisting dominantly of quartz, chert and orthoquartzite, 2. unstable grains, including both feldspar grains and sand-sized rock fragments, and 3. interstitial matrix (10 percent or more).

Gilbert (1954) devised a sandstone classification incorporating two criteria, sorting and composition. He made a distinction between poorly sorted sandstone (immature) and well sorted sandstones (mature) and labelled them wackes and arenites respectively. Wackes are defined as containing more than 10 percent matrix, and arenites are sandstones containing less than 10 percent matrix.

The matrix portion of graywackes have always caused problems in defining and quantifying. It is very difficult to distinguish matrix from altered rock fragments and this undoubtedly enhances error in accurate classification.

Gilbert's (1954) classification (fig. 5) appoints three principal constituents (other than matrix) to each apex of a ternary diagram, namely quartz, feldspars and rock fragments. Two general subdivisions are employed. Those containing more rock fragments than feldspar grains are called lithic wacke, whereas those containing more feldspar grains than rock fragments are called arkosic wacke. This classification was employed to define the Archean clastic sediments of the Cullaton Lake area due to its simplicity and direct application to impure sandstones.

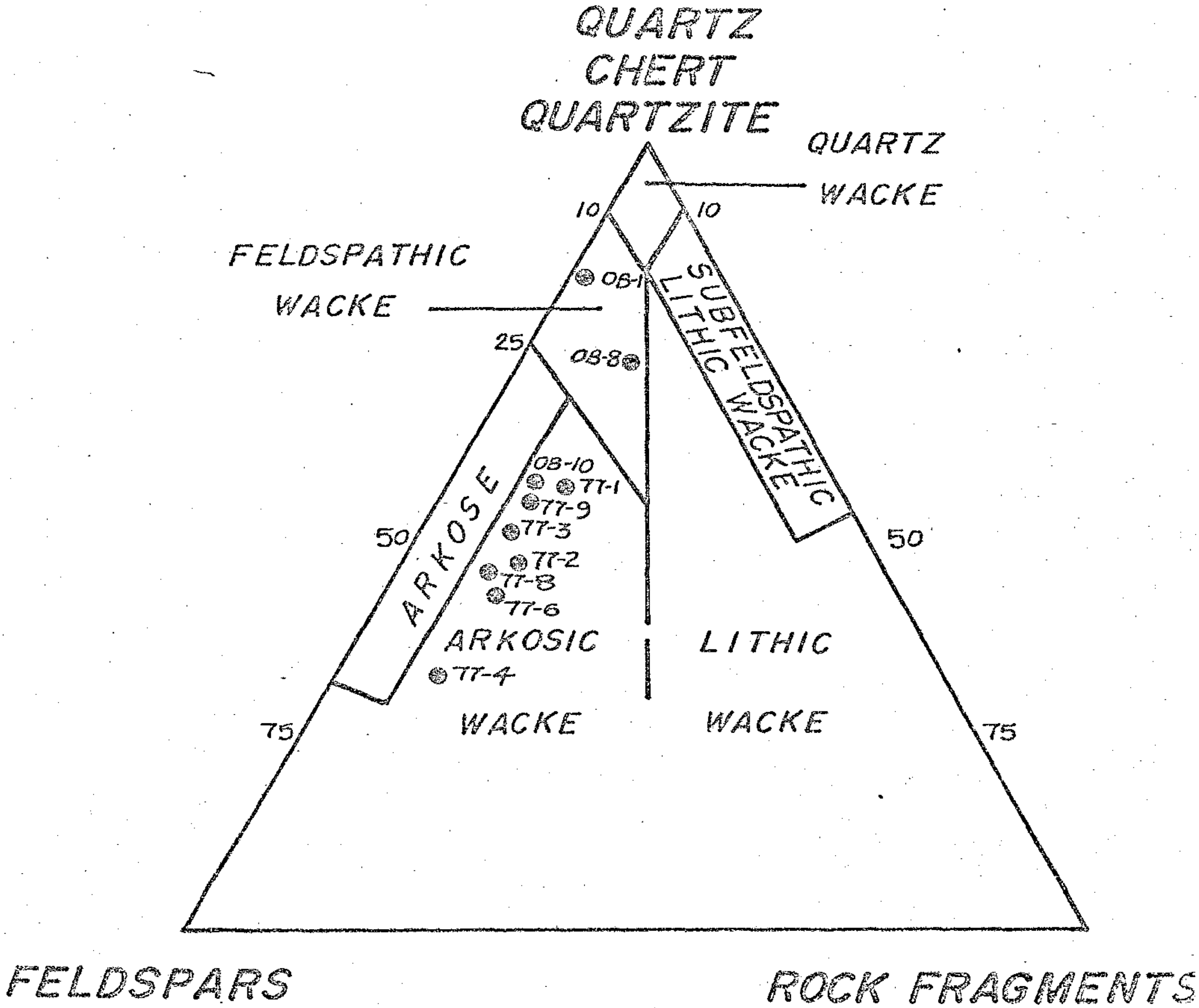

Fig. 5 : Classification of impure sandstones (after Gilbert 1954).

Through thin section examination the various stable, unstable and matrix components of the samples were visually estimated and listed in table 1. These proportions were then plotted on Gilbert's (1954) diagram (fig. 5).

Table 1 : Modal analysis of Archean sediments.

	77-1	77-2	77-3	77-4	77-6	77-8	77-9	OB-1	OB-8	OB-10
Quartz + Chert	58%	45%	52%	32%	45%	45%	55%	80%	73%	60%
Feldspar	(30%)	(40%)	(37%)	(55%)	(40%)	(43%)	(33%)	(19%)	(15%)	(30%)
Plagioclase	28%	35%	30%	50%	38%	40%	30%	14%	12%	29%
Microcline	2%	5%	7%	5%	2%	3%	3%	5%	3%	1%
Rock Fragments	18%	15%	11%	13%	15%	12%	12%	11%	12%	11%
Matrix	15%	20%	30%	30%	30%	15%	30%	40%	20%	15%

(Framework minerals calculated as 100 % of total rock)

Samples 77-1 to 77-4, 77-6, 77-8, 77-9 and OB-10 contain abundant feldspar and plots in the field defined as arkosic wacke. Samples OB-1 and OB-8 contain less feldspar and plot as feldspathic wacke. Since the classification does not account for the presence of abundant carbonate the prefix calcareous is added to the definition. So now samples 77-1 to 77-4, 77-6, 77-8, 77-9 and OB-10 are defined as calcareous arkosic wacke, and samples OB-1 and OB-8 as calcareous feldspathic wacke.

The terms wacke and graywacke are very similar and are employed constantly togeather. According to Gilbert (1954) graywackes are deeply buried wackes, characteristically harder, dark coloured nature, finely indurated matrix and contains an abundance of very fine-grained micaceous and chloritic minerals. This description applies to the Cullaton Lake sediments and should be employed replacing the term wacke. Thus the previously defined group of samples will now be termed calcareous arkosic graywacke and calcareous feldspathic graywacke respectively.

Samples 77-5 and 77-7 were obtained from fine-grained argillite units. The term argillite applies to a rock derived from a siltstone or shale that has undergone a somewhat higher degree of induration than is usually present in these rocks (Pettijohn 1957). Argillite is thus intermediate in character between a shale and a slate. The samples are best described as calcareous argillites due to the rather high carbonate content.

Provenance

The subangular, undulatory, monocrystalline quartz grains suggest, as according to Blatt (1967), that this component is derived from massive plutonic rocks rather than from gneisses or schists.

The abundance of zoned plagioclase as apposed to microcline indicates, as suggested by Pittman (1963), that the feldspar is derived from an igneous, plutonic rock source. The subrounded nature of the feldspar grains can be associated to diagenetic breakdown rather than rounding due to transport.

The unstable, fine-grained rock fragments appear to be of volcanic origin.

This study definately points toward a plutonic provenance for the calcareous arkosic and feldspathic graywackes. Due to the high proportion of quartz and feldspar contained in these sediments an alkali granitic provenance is suggested. An area to the west which is now occupied by a large granitic-volcanic complex is implied as the source for the Cullaton Lake Archean clastic sediments.

Sedimentary Structures

The calcareous arkosic graywackes grade upwards from a basal coarse-grained unit to fine-grained argillite at the top. This sequence is defined as comprising one bed which range in thickness from 1 foot to 10's of feet. These beds repeat in succession to form the rather thick sedimentary assemblage.

The basal graywackes display graded bedding, marked by a gradation in grain size from coarse to fine upwards (fig. 6). This fining upward unit grades into a parallel laminated sequence of fine-grained graywacke (fig. 7). The uppermost part of the bed consists of a fine-grained, dark argillite which exhibits a pronounced foliation. The top of this argillite unit displays load structures with intervening flame-like features which intrude into the basal unit of the overlying graywacke bed (fig. 8).

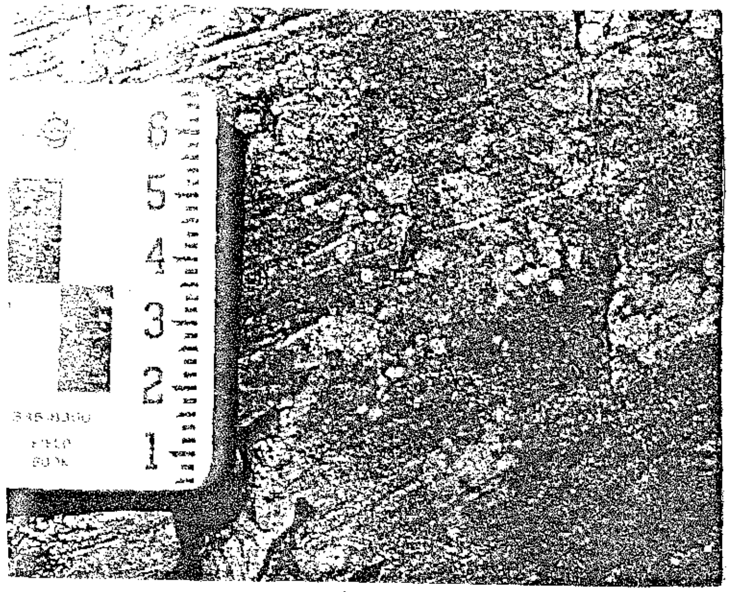

Fig. 6 : Basal Graded Graywacke.

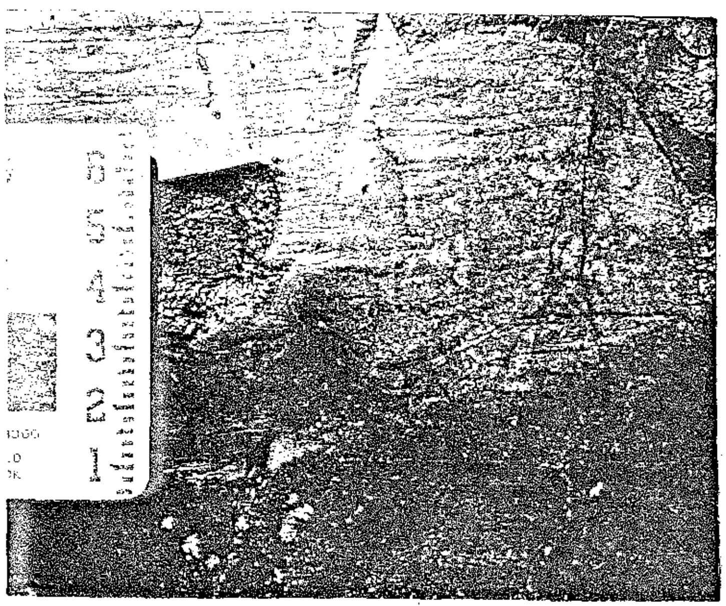

Fig. 7 : Parallel Laminated Graywacke.

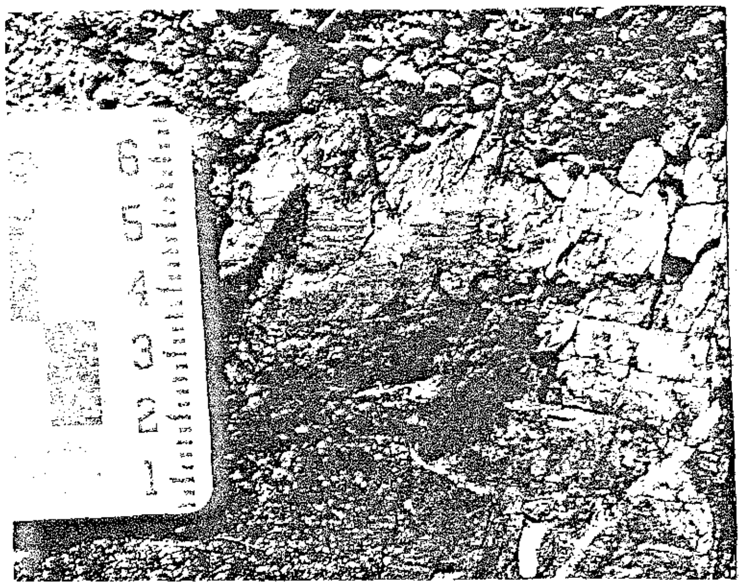

Fig. 8 : Fine Grained Argillite.

Discussion

Turbidite Model

From the petrological textures exhibited by the various stable and unstable clast components it is concluded that the calcaeous arkosic/feldspathic graywackes are a result of rapid erosion and deposition. They appear to be deposited rapidly without extensive working over by currents and waves which would round the clast grains considerably. Therefore accumulation in deep water with very little reworking is postulated.

The fine-grained argillite (clay) portion of the beds appear to have been deposited during periods of quiet sedimentation (i.e. settling out of clay sized particles).

All the features described in the petrology and sedimentary structure sections of this report points toward turbidite deposition. Turbidites are a group of graded sediments deposited by turbidity currents (Blatt 1972). They consist of graded sandstone beds alternating with shales. Each turbidite is the result of a single, short lived event, and once deposited it is extremely unlikely to be reworked by other currents (Walker 1976).

Bouma (1962) introduced the classical turbidite model after examining a number of flysch deposits in Europe. The Bouma sequence incorporates a number of internal sedimentary structures consisting of a basal graded division (A), a parallel laminated division (B), a ripple cross-laminated division (C), followed by an upper parallel laminated division

(D), and finally the pelitic division (E). Figure 9 illustrates these five divisions of the Bouma model for turbidites.

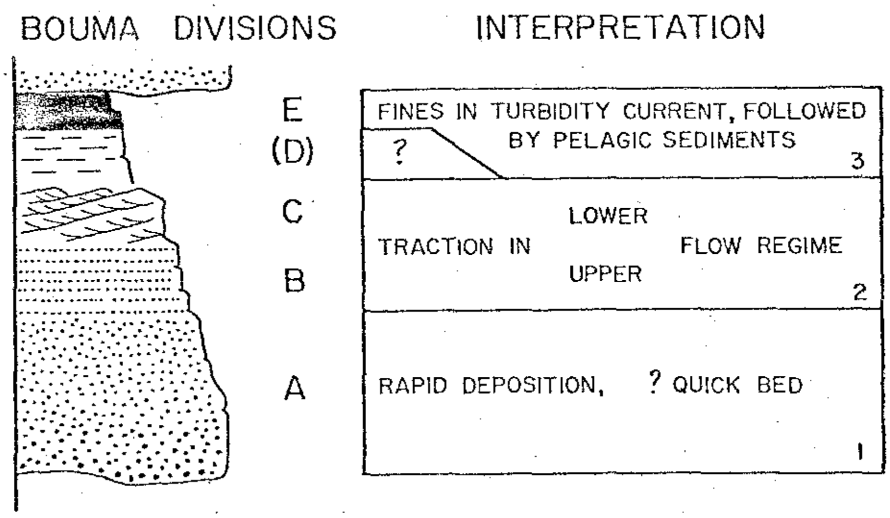

Fig. 9 : Five divisions of the Bouma (1962) model for turbidites (after Walker 1976).

The turbidite sequence as derived from the sedimentary structures in the study area is illustrated in figure 10. The sequence displays 3 of the 5 divisions portrayed in the Bouma (1962) model; a basal graded graywacke, overlain by a parallel laminated graywacke which fines upward to a fine-grained argillite. Although this cycle is incomplete the divisions present occur in a consistent sequence. Similar Archean turbidite cycles have been described by Henderson (1972), in the Yellowknife district of Northwest Territories, and by Turner and Walker (1973) in a greenstone belt near Sioux Lookout, Ont.

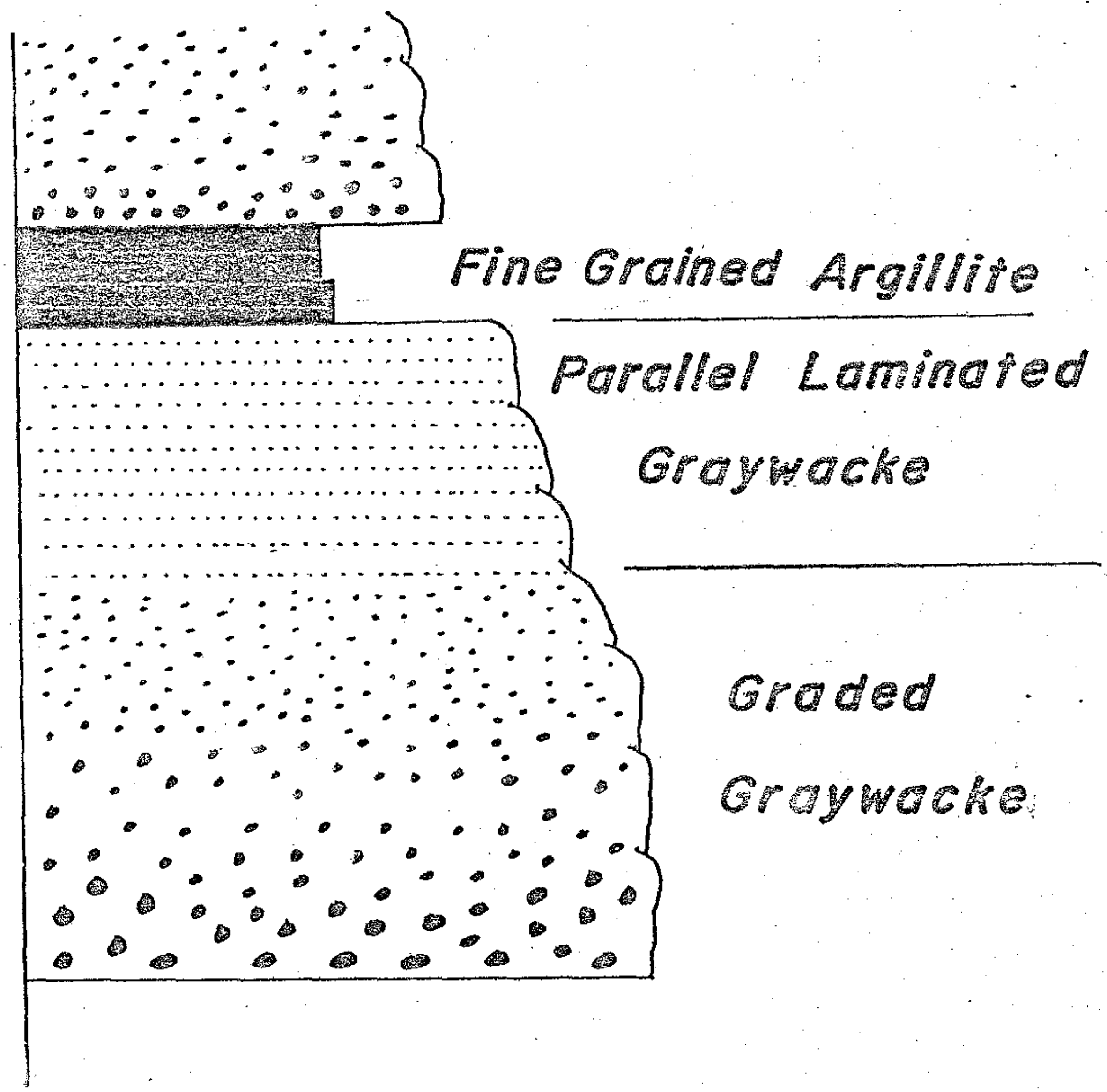

Fig. 10 : Divisions of the Cullaton Lake Archean turbidites.

The basal unit consists of graded coarse to medium-grained graywacke (fig. 6). This is the most commonly found unit in the succession of the study area. This unit varies from well defined sequences to others which display no grading at all.

The parallel laminated graywacke sequence (fig. 7) displays fine laminations in a medium to fine-grained graywacke. This unit of the cycle is least common in the study area.

The upper most portion of the turbidite sequence consists of massive, fine-grained argillite (fig. 8). The argillite units display post-depositional load structures which destroy primary features. The argillite forms sharp contacts with overlying basal units of the following turbidite.

An experimental approach to the amount of matrix in modern, coarse-grained turbidites was estimated by Kuenen (1966) to be less than 5 percent. This questions the excess of matrix (average 25 percent) in the graywackes of the study area. Whetten and Hawkins (1970) conducted hydrothermal experiments on samples of graywacke and concluded that minerals commonly found in graywacke matrices have been formed by the alteration (hydration) of unstable clasts (feldspar and rock fragments) during diagenesis. This diagenetic approach accounts for the abundant matrix and absence of excessive unstable rock fragments in the Cullaton Lake graywackes.

Depositional Environment

Turbidites are deposited by tubidity currents, which are turbulent density flows occurring in lakes, reservoirs, delta fronts, continental shelves and deep sea fans/abyssal plain environments. Turbidity flows are generated by submarine slumps, triggered by seaquakes, or unstable tectonic environments (Pettijohn 1957).

The volcanic-sedimentary sequence of the study area is typical of Archean eugeosynclinal assemblages in the Canadian Shield. Goodwin (1965) suggests that such assemblages result from a three stage sequence of events : widespread effusion of basalt and andesite flows; the explosive eruption of felsic pyroclastic material upon the mafic platform; and the erosion of the volcanic rocks with the formation of volcanogenic sedimentary blankets.

The sedimentary assemblage, which contains turbidites is believed to have been deposited in tectonically unstable regions of the eugeosynclinal belt. Eposodic, tectonic disruptions during periods of clastic sedimentation in deep, high angled eugeosynclinal troughs would provide the impetus for turbidity currents and hence the deposition of turbidites. This type of depositional environment it favoured for the formation of the Cullaton Lake turbidites.

Summary

This study suggests evidence that the Archean clastic sediments, of the Cullaton Lake, N.W.T. district, contain features that are characteristic of turbidites. These turbidites have been attributed to deposition by turbidity currents during unstable tectonic periods in an Archean basin.

The presence of these type of deposits in the Cullaton Lake area has a direct influence on the auriferous B-Zone Iron Formation. It is postulated that such Archean Iron Formations form in isolated, reducing basins and therefore are highly environmentally controlled. If such is the case an apparent contradiction arises, for the Iron Formations lie in turbidite-type sequences which suggest unstable environmental conditions.

This type of environment, alternating quiescent and turbulent deposition, may explain the rather thin nature of Archean Iron Formations.

A model arises for the formation of these thin natured ferrúginous sediments : a quiet period of deposition with ideal environmental conditions deposit iron-rich sediment (Iron Formation) in eugeosynclinal basins ; tubidity currents are triggered by unstable conditions in the basin and turbidites are deposited, blanketing the previously laid down Iron Formation ; quiescent conditions return and the deposition of Iron Formation is continued. This type of cyclic deposition explains the presence of thin Iron Formation scattered stratigraphically throughout the Archean clastic sedimentary assemblage of the Cullaton Lake area.

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