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RE-DEFINITION AND SUBDIVISION OF THE RAPITAN GROUP, MACKENZIE MOUNTAINS

G.H. EISBACHER





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RE-DEFINITION AND SUBDIVISION OF THE RAPITAN GROUP, MACKENZIE MOUNTAINS

Abstract

The Proterozoic Rapitan Group of the Mackenzie Mountains has been subdivided into four formations, from bottom to top as follows: Sayunei, Shezal, Twitya, and Keele. The Keele Formation has been included in the redefined Rapitan Group because of a gradual transition between the Twitya Formation and facies variations of the Keele Formation. Thickness changes, facies patterns, and sedimentary environments suggest that the basal Sayunei Formation was deposited in fault controlled basins. It consists of maroon or green siltstone and argillite and is interbedded with sharpclast-siltstones shed from tectonic scarps. The Shezal Formation consists of glacial-marine diamictites deposited in a relatively shallow marine environment. The Twitya Formation is composed of shale and sandstone laid down on an unstable prograding shelf. The Keele Formation is a varied assemblage of cyclic carbonates and clastics which was deposited on shallow-water banks. It grades laterally into deeper-water facies comprising mass-flow deposits. The role of contemporaneous faulting during the initial stages of Rapitan deposition is significant in the appraisal of stratabound copper and iron deposits of the Mackenzie Mountains.

Résumé

Le groupe de Rapitan des monts Mackenzie, du Protérozoïque, a été subdivisé en quatre formations, de la base au sommet, comme suit: Sayunei, Shezal, Twitya, et Keele. On a inclus la formation de Keele dans la nouvelle définition du groupe de Rapitan, en raison d'une transition graduelle entre la formation de Twitya, et les variations de faciès de la formation de Keele. Les variations d'épaisseur, la disposition des faciès et les divers milieux sédimentaires semblent indiquer que la formation basale de Sayunei s'est déposée dans des bassins à contrôle tectonique. Elle consiste en siltstone et argillite marrons ou vertes, et elle est interstratifiée avec des siltstones et sharpclasts provenant d'escarpements de faille. La formation de Shezal consiste en diamictites glacio-marines déposées dans un milieu marin relativement peu profond. La formation de Twitya est composée d'argile litée et de grès déposés sur une plate-forme instable en progression. La formation de Keele est un assemblage varié de dépôts cycliques de carbonates et roches clastiques qui se sont déposés le long du littoral en eau peu profonde. Elle passe latéralement à un faciès d'eau plus profonde, comprenant des dépôts d'écoulement en masse. Le rôle des failles produites pendant les étapes initiales du dépôt des sédiments de la formation de Rapitan est important, pour l'évaluation des gîtes stratiformes de fer et cuivre des monts Mackenzie.

INTRODUCTION

A large portion of the Canadian Cordillera is underlain by Proterozoic rocks. In the northern Cordillera Proterozoic carbonate sequences, clastic successions, volcanics, and intrusive breccias have become significant in the exploration for iron, copper, zinc, lead, and uranium.

First order regional reconnaissance work has established a rough outline of the principal Proterozoic rock units. Present studies by the Geological Survey of Canada are directed towards regional correlation of the various rock packets, the recognition of tectonic controls on the development of the sedimentary basins, and the relationship between stratigraphy and contained ore deposits.

The report deals specifically with the proposed stratigraphic subdivision of the Rapitan Group, a widely exposed clastic succession high in the Proterozoic sequence.

Historically, the scientific study of the Rapitan Group began with the description of presumed glacial deposits (Snake River Tillite) in the Bonnet Plume River area, Yukon Territory (Ziegler, 1959). Three years later a large deposit of iron-formation was discovered and staked in the same region by Crest Exploration Ltd. The rocks associated with the iron-formation were recognized to be those first described by Ziegler, although for several years their age was considered to be early Paleozoic. The iron-bearing clastic rocks were named Rapitan Group by Green and Godwin (1963) after Rapitan Creek in Snake River map-area (106F).

The regional extent and stratigraphic position of the Rapitan Group were subsequently outlined in geological

reconnaissance work by the Geological Survey of Canada during Operations Nahanni, Porcupine, Ogilvie, Norman, and Stewart in the 1960s and early 1970s. These projects aided in delimiting the principal outcrop belt with respect to older and younger strata, and led to the recognition of the Rapitan Group as a Proterozoic succession. The work resulted in a first subdivision of the Rapitan Group into three informal formations which were referred to as Lower, Middle, and Upper Rapitan (Upitis, 1966; Gabrielse et al., 1973), as lower unit, middle unit, and upper unit (Aitken et al., 1973), and as Maroon, Diamictite, and Shale Formation (Eisbacher, 1976). The limits of the Rapitan Group as mapped by the Geological Survey were defined (a) by the marked lithologic change from carbonates to clastics at the base of group, and (b) by its upper contact with an overlying assemblage of carbonate and sandstone of the Proterozoic Keele Formation (Gabrielse et al., 1973). More recent work by Aitken and Cook (pers. comm., 1976) and the author suggests that the transition between upper Rapitan shales and calcareous Keele Formation is gradual and, in places, mappable as a lateral facies change. It is therefore proposed that the Keele Formation be included within the Rapitan Group. In the new definition of the Rapitan Group its *upper boundary is placed at the well defined top of the Keele Formation*. This surface, which also defines the base of the dark grey shales of the Sheepbed Formation, is mappable throughout the Mackenzie Mountains and is an extremely useful marker that can be traced westward into the Wernecke Mountains. For these reasons the top of the Keele Formation becomes significant in the correlation of the Rapitan Group from the Mackenzie Mountains westward (Fig. 1).

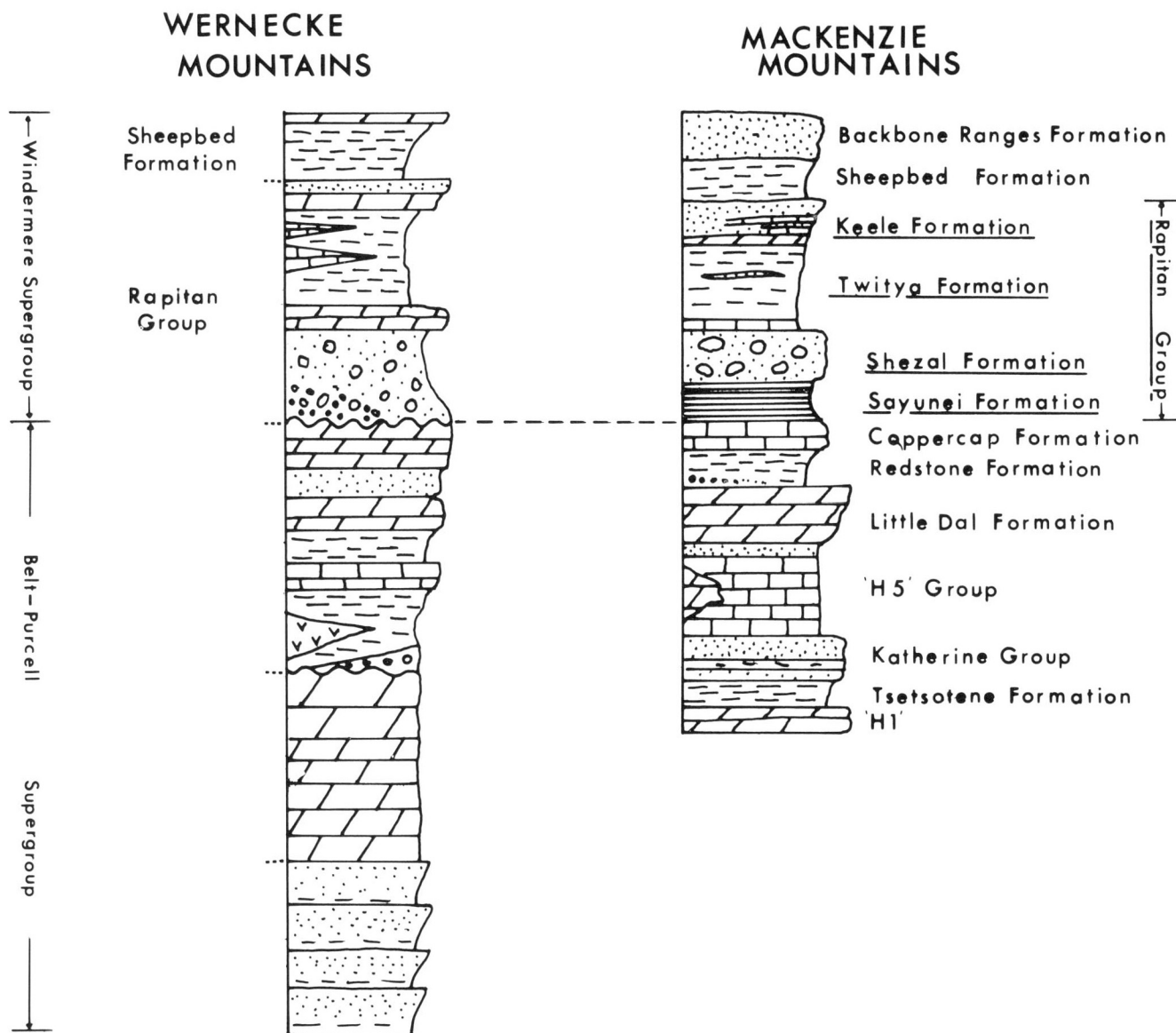


Figure 1. Generalized diagram of presently used terminology of Proterozoic rocks in the Mackenzie and eastern Wernecke Mountains.

In the Mackenzie Mountains the base of the Rapitan Group also serves as the base of the Windermere Supergroup. The Windermere Supergroup has been defined by Young et al. (1973) in the southern Cordillera as a thick packet of highly varied, predominantly clastic rocks which occupy a position between an older Precambrian carbonate-quartzite succession (Purcell or Belt Supergroup) and a younger (Phanerozoic) carbonate-quartzite succession. In the Mackenzie Mountains the basal unconformity beneath the Windermere strata may not be as profound as in the southern Cordillera of Canada, and parts of the Belt-Purcell Supergroup may be younger in the north than in the south. However, the change from carbonate-quartzite to partly immature clastic successions is as fundamental in the understanding of the geological history of the northern Cordillera as it is in the south (Gabrielse, 1972).

On numerous reconnaissance maps and geological compilations of western Canada Windermere strata are shown as Hadrynian in age, and older carbonate complexes are classified as Helikian. This *chronostratigraphic* subdivision has

been imposed on two different *lithostratigraphic* packets of the Cordilleran region without consideration that the time intervals used on the Canadian Shield may not be those represented by the Precambrian rocks of the Cordillera. It is therefore advisable that use of chronostratigraphic terminology be deferred in favour of lithostratigraphic groups or supergroups until it is possible to bracket the major Precambrian rock units of the Cordillera radiometrically.

Although rocks possibly correlative with the Rapitan Group of the Mackenzie Mountains have been mapped and described by Green (1972) in the Wernecke and Ogilvie mountains, this report will focus only on the central Mackenzie Mountains. Knowledge of stratigraphy and structure west of the Wernecke Mountains is still limited and is being updated by the Geological Survey. A summary diagram (Fig. 1) outlines the terminology presently in use for the Mackenzie and Wernecke mountains. Except for parts of the Rapitan Group (e.g. iron-formation), correlation of Proterozoic units from the Mackenzie Mountains westward must be deferred until detailed mapping across major structural breaks has been completed.

In the Mackenzie Mountains it has been demonstrated that the basal units of the Rapitan Group were deposited within an extensional tectonic environment characterized by block faulting. This type of taphrogenic deformation also was of profound significance during deposition of the youngest units of the older Belt-Purcell carbonate succession (Eisbacher, 1977). From mappable relationships it is clear that major angular unconformities are to be expected beneath the Rapitan Group. However, great care needs to be exercised in appraising the magnitude of erosion from the top of the carbonate complexes (e.g. Little Dal Formation). One such estimate of pre-Rapitan erosion has been given as 1300 m for a section near Redstone River (Gabrielse et al., 1973, p. 21 and 12). Re-mapping of the area revealed that a previously unmapped thrust-fault gives the erroneous impression of an angular unconformity form across the valley. The actual amount of pre-Rapitan erosion therefore cannot be estimated in this area. Another hampering factor with respect to estimating erosion prior to deposition of the Rapitan Group is the occurrence of thick conglomerates and breccias in the Redstone River Formation which suggests that erosion of underlying and adjacent carbonate complexes was active before the deposition of Coppercap limestone. Thus erosional surfaces between the Little Dal Formation and Rapitan Group may have originated during deposition of the Redstone River and Coppercap formations (see below). Detailed mapping and documentation of marginal overlap, erosion, or continuity of sedimentation across the boundary

between pre-Windermere carbonate strata and Windermere clastics is of considerable economic importance and will be touched upon briefly in this report.

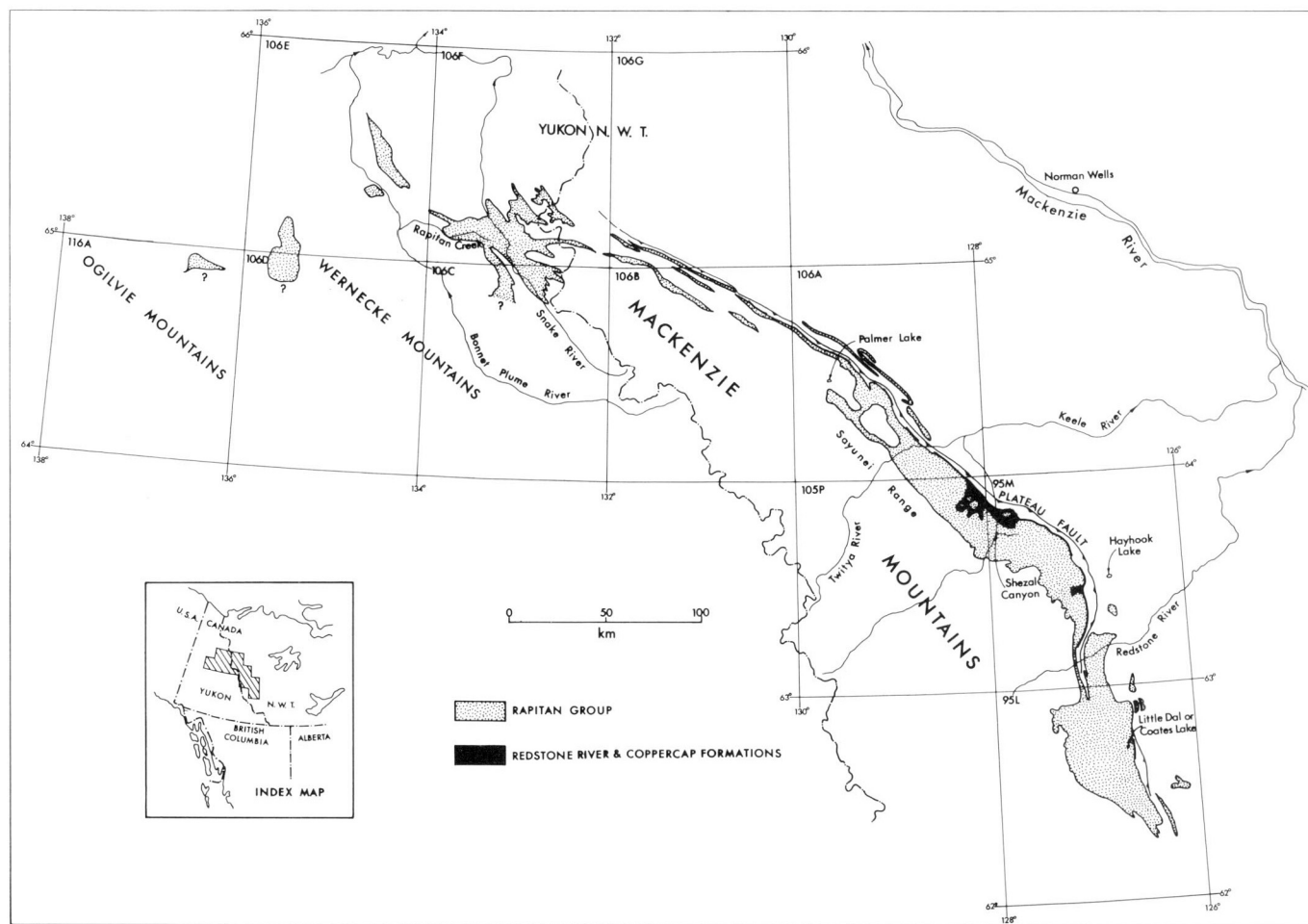
In the Mackenzie Mountains the following four subdivisions are proposed for the re-defined Rapitan Group (in ascending stratigraphic order): *Sayunei Formation*, *Shezal Formation*, *Twitya Formation*, and *Keele Formation*. They will be discussed individually in the subsequent sections of this paper. Single formations or members of the Rapitan Group may extend westward or southward. However, preliminary study suggests that major facies changes may necessitate introduction of new names.

Stratigraphic sections through the Rapitan Group or formations belonging to it have been published previously in Green and Godwin (1963), Gabrielse et al. (1973 and including the work of Uptis, 1966), Aitken et al. (1973), and Eisbacher (1976, 1977). Location of map-areas and topographic features mentioned in this report are shown in Figure 2.

SAYUNEI FORMATION

Definition

The Sayunei Formation is named after Sayunei Range, northwest of Keele River, where it was first seen by Keele (1910). The Sayunei Range straddles the border of map-areas 95M (Wrigley Lake) and 105P (Sekwi Mountain). The Sayunei Formation is the basal unit of the Rapitan Group throughout



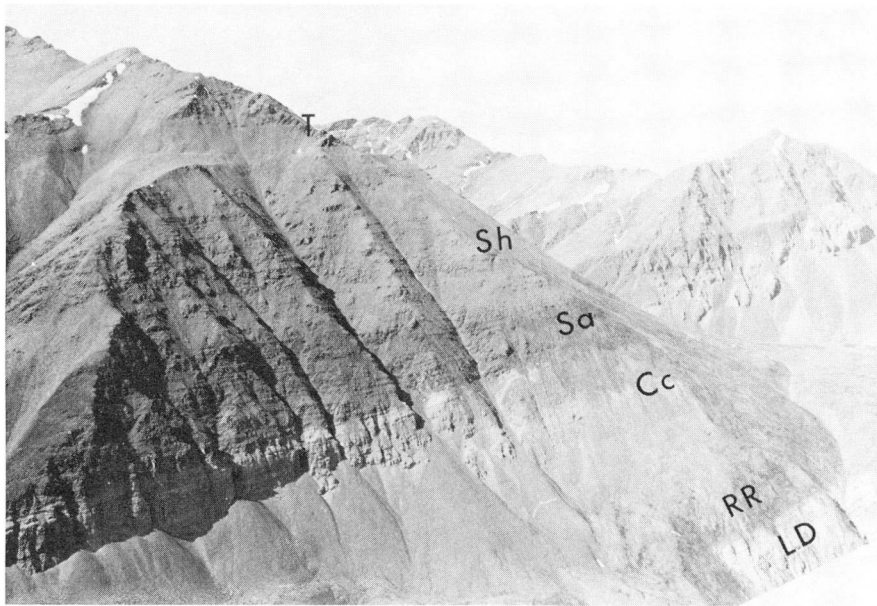


Figure 3.

- LD = Little Dal Formation
 RR = Redstone River Formation
 Cc = Coppercap Formation
 Sa = Sayunei Formation
 Sh = Shezal Formation
 T = Twitya Formation

Onlap of Sayunei Formation against Coppercap limestone as seen looking northward from a locality 18 kms north of Redstone River.

the Mackenzie Mountains, except in areas where younger formations overstep the depositional margin of the unit. Stratigraphic equivalents of the Sayunei Formation have been recognized as far west as the Yukon – Alaska border region (G. Kline, pers. comm. 1976). Deposition of this unit marks the onset of Windermere Supergroup sedimentation in the Mackenzie Mountains.

Throughout most of the region the Sayunei Formation rests on older Proterozoic carbonate units such as the Little Dal and Coppercap formations. The base is either regionally unconformable, broadly conformable or characterized by onlapping of Sayunei beds against older carbonate rocks (Fig. 3). The base of the Sayunei Formation is placed at the first occurrence of numerous, monotonously laminated siltstone or sandstone beds, commonly intercalated with lenses of coarse, angular material above a well defined surface of older Proterozoic carbonate units. The siltstone, sandstone and argillite beds generally display a distinct dark red to maroon hue, although shades of green or grey are common. Changes of rock colour in siltstones from maroon-red to green-grey are subtle and locally abrupt. Due to this variability, rock colour cannot be used to define the formation, despite the fact that the maroon colour has served well during geological reconnaissance work in the Mackenzie Mountains (Gabrielse et al., 1973; Aitken et al. 1973). Irrespective of colour changes the most distinctive feature is the monotonous succession of thinly bedded to laminated siltstones separated by argillite.

Thickness of the Sayunei Formation varies from 0 to 500 m. Towards the top the unit displays regionally significant lithological changes which break the monotony of the siltstone-argillite couplets. In some parts of the Rapitan basin the highest unit is iron-rich and locally grades into true iron-formation with interlayered thin carbonate beds. The iron-rich member of the Sayunei Formation is particularly well developed near Snake River, where it may range stratigraphically into the Shezal Formation. In other parts of the Rapitan basin the Sayunei Formation changes to green or grey towards the top. A third, very common variant is the appearance of coarse, angular extrabasinal and intrabasinal material in mass-flow deposits within delicately bedded siltstones of the upper Sayunei Formation. Towards the margins of the Rapitan outcrop area maroon beds of siltstone or iron-rich argillite grade into or are interlayered with

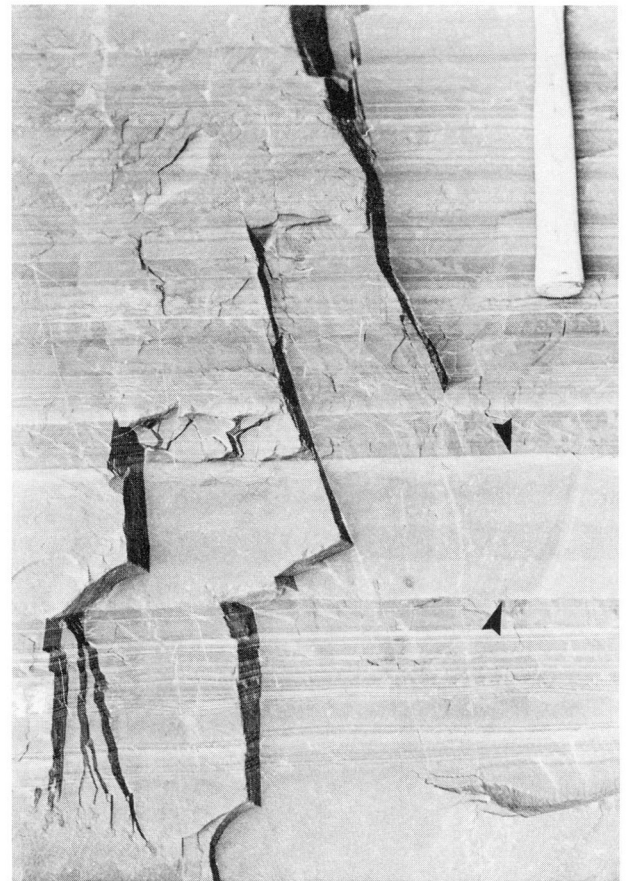


Figure 4. *Laminated siltstone and argillite of the Sayunei Formation. Interbedded sandstone layers are graded and commonly display well developed Bouma sequences. (GSC 203219-A).*

Figure 5.

Distinctly graded coarse sandstone interbedded with argillite of the Sayunei Formation. Most of the coarser particles in this bed are carbonate and intraformational mudchips. (GSC 203219-B).

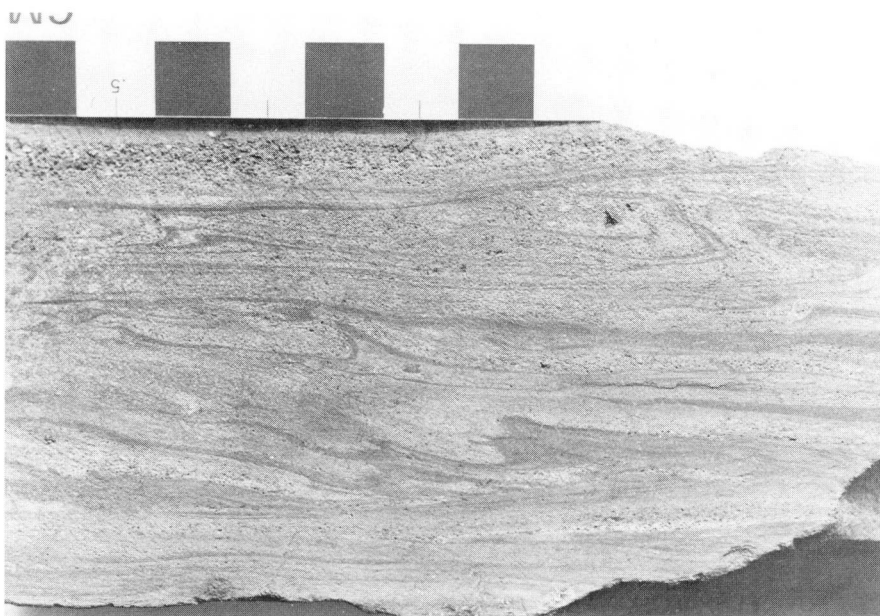


Figure 6.

Recumbent flow folds and flame structures in graded sandstones and interlayered argillite of the Sayunei Formation. Scale in centimetres. (GSC 203219-C).

diamictite of Shezal Formation (Green and Godwin, 1963; Eisbacher, 1977). In these areas differentiation of the two formations may be impractical in regional mapping. In general, the top of the Sayunei Formation is placed with the first appearance of numerous rounded clasts in diamictite of the Shezal Formation.

Description

The character of the Sayunei Formation is determined by an alternating pattern of innumerable thin beds of siltstone and argillite. Wherever the Sayunei Formation is maroon the intricate laminations are made evident by the contrast between darker shades in argillite and lighter tones of red in the coarser layers. In siltstones overall bedding is defined by internal parallel lamination and cross-lamination on scales ranging from a millimetre to several centimetres. Grading occurs on the same scale and the upward transition from siltstone to argillite is commonly imperceptible (Fig. 4).

These subtle changes impart a wispy or undulating top to siltstone beds. Cross-laminations can be used as paleocurrent indicators. Intricate lamination on all scales also caused amalgamation of siltstone beds with beds below and above. As a consequence bedding surfaces are rarely exposed.

Interlayered with the bulk of the fine clastics are coarser beds of sandstone, grit, and sharpstone (Fig. 5). The sandstones are parallel-laminated or graded; bedding thickness ranges from centimetres to tens of centimetres. The sand layers are generally accompanied by stretched and recumbently folded layers of argillite and siltstone; the tops are commonly deformed into flame structures (Fig. 6). Many graded beds display Bouma sequences, typical of turbidites. Compositionally the sandstones are sub-quartzose lithic arenites (Upitis, 1966). However many coarser beds consist entirely of intraformational argillite chips and carbonate grains. An interesting aspect of the Sayunei Formation is the widespread occurrence of subangular 'lonestones' enveloped



Figure 7. Upper bedding surface within siltstones of the Sayunei Formation. Note tool mark, faint lineation, and microtopography caused by 'lonestones' scattered throughout the well laminated finer clastic groundmass. (GSC 203219-D).

by layers of siltstone and argillite. Laminae of siltstone and argillite are draped around the 'lonestones'. A rare exposed bedding surface within a zone containing pebble-sized clasts illustrates the effect of lonestones on the micromorphology of bedding (Fig. 7). The bedding plane is weakly lineated and contains a linear tool mark parallel to the weak lineation. Numerous convexities and concavities betray lonestones now embedded below and formerly above this surface. The tool mark is about 10 cm long and has a width compatible with the diameter of the lonestones. The directional trend of the tool mark and lineation agrees with the polarity of current-induced flame structures seen on surfaces perpendicular to bedding. This relationship suggests that draping of siltstone and argillite layers around lonestones is not entirely due to post-depositional compaction (see discussion below). Some bedding surfaces display irregular cracks which are generally filled with silty material injected from below or above. However, none of the cracks observed resemble the regular patterns characteristic of mudcracks or syneresis cracks.

Very prominent within parts of the Sayunei Formation are units of fine siltstones containing stringers, lenses, or masses of angular clasts of dolomite and limestone (Fig. 8). After consultation with J.D. Aitken of the Geological Survey of Canada the present author proposes the term 'sharpclast — siltstone' for these rocks characteristic of the Sayunei Formation. They are known to occur as far west as the Alaska-Yukon border region (G. Kline, pers. comm., 1976). The freely suspended clasts are very angular and probably were derived from the carbonate units directly underlying the

Rapitan Group. Associated with the sharpclasts of carbonate are clasts of other lithologies, such as quartzite and greenstone which are much better rounded than the bulk of the carbonate clasts. The units of sharpclast-siltstone, although internally chaotic, are distinctly stratified. Bases and tops are siltstone with only local sharp, channelized basal contacts (Eisbacher, 1976). Many of the layers of sharpclast-siltstones can be traced laterally into sandstone beds which contain oversize clasts or stringers of lonestones. The lateral pinchouts are interesting in terms of the origin of lonestones and will be discussed later. In Mount Eduni map-area (106A) (between section A and B, Fig. 11) sharpclast-siltstones of the Sayunei Formation appear to grade laterally into distinctly channelized and slumped units of densely packed sharpstone conglomerate and grit (Fig. 9). Some of the sandy beds in the channelized units display planar cross-beds and grading is absent. These units are considered proximal with respect to the sharpclast-siltstones and such a relationship is supported by the paleocurrent orientation in this area.

Maroon argillaceous zones in the upper part of the Sayunei Formation commonly have a background iron content between 5 and 10 per cent Fe_2O_3 . These maroon argillites grade imperceptibly into true iron-formation with Fe_2O_3 contents as high as 30-50 per cent. Within the iron-formation nodular-oolitic or laminated facies are the principal varieties. Hematite and jasper form intricate syndepositional or diagenetic patterns which commonly are complicated by the presence of carbonate layers. Wherever there is evidence of reworking of iron-formation the content of Fe_2O_3 varies



Figure 8. Sharpclast-siltstone of the Sayunei Formation. Although the basal bedding surface of the sharpclast-siltstone units are generally well defined, clearly recognizable channeling is rare. Part of geological pick on the right for scale. (GSC 203219-E).

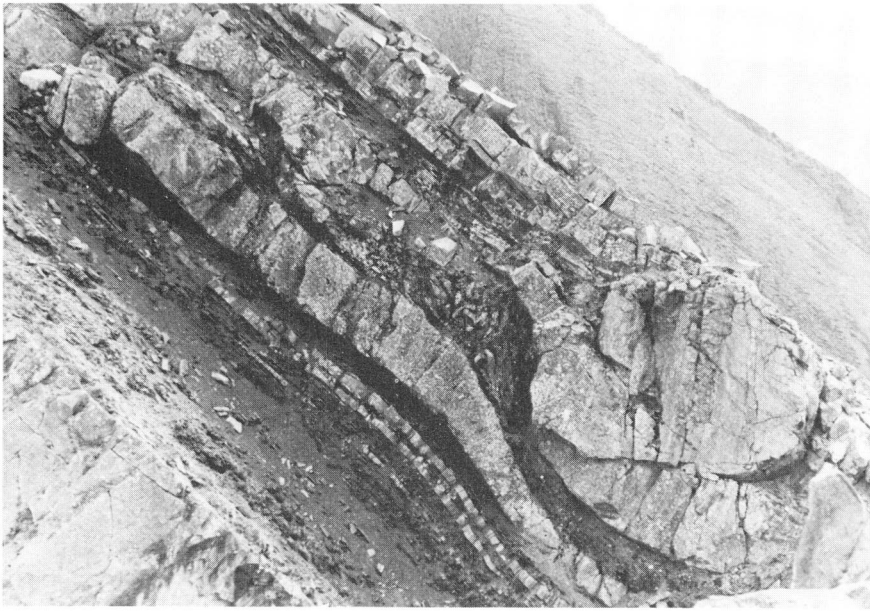


Figure 9.

Densely packed and slumped channels of carbonate sharpstone in the Sayunei Formation. Location is between Sections 1 and 2 of Figure 11. Height of outcrop about 10 m. (GSC 203219-F).

between 10 and 20 per cent. Reworked clasts of iron-formation also can be seen sporadically within units of sharpclast-siltstones of the Sayunei Formation and suggest relatively rapid diagenesis of the iron-formation. Towards the northwestern limit of the Rapitan Group iron-formation occurs in commercially important quantities (Green and Godwin, 1963).

Type Section

The type section chosen for the Sayunei Formation is exposed on a ridge 11 km due west of Hayhook Lake in map-area 95M. The section is located at latitude 63°30'N and longitude 126°58'W, and is 165 m thick (Fig. 10). Its base is defined by 5 m of lenticular units of sharpclast-siltstone overlying grey laminated and cherty dolomite of the Coppercap Formation. Most of the sharpclasts are limestone. The bulk of the subsequent 125 m of section is composed of monotonous maroon siltstone-argillite couplets with occasional layers of sandstone. Towards the top two zones of jasper-hematite iron-formation, each about 10 m thick, are interbedded with graded sharpclast channels and occasional limestones. The uppermost unit is an 8 m zone of green siltstone, grey argillite, and calcareous laminite grading upwards into diamictite of the Shezal Formation.

Southwards from the type section the green siltstone-argillite member increases in thickness at the expense of maroon siltstone-argillite, whereas towards the north the maroon siltstones increase markedly in thickness (Fig. 10).

Interpretation

Monotony and grain size of the Sayunei siltstone-argillite couplets suggest a relatively quiet subaqueous depositional environment. Most of the unit probably was deposited below wave base. Many of the siltstones and fine grained sandstones are graded and display Bouma sequences typical of turbidites. Over large areas of the Rapitan basin floor these turbidite phases must have interrupted the tranquility suggested by interlayered iron-rich laminites and argillites. The margins of the Sayunei basin, however, were clearly dominated by a topography which produced, from time to time, coarse and angular debris. This material must have been transported far into the quiet, central parts of the basin. In a few cases it is possible to document that coarse angular

debris was shed from active syn-sedimentary fault scarps within the Sayunei basin (Eisbacher, 1977). The origin of some of the sharpclast-siltstones is probably due to subaqueous slumping of coarse channel material (Fig. 9). Having been set in motion, currents and channel material scoured into the finer material thereby converting the moving mass into a low-viscosity slurry. The mechanism envisaged would be transitional between grain flows and debris flows as analyzed by Middleton and Hampton (1973). The coarser fragments were isolated from each other and dispersed throughout the mobile matrix by dense clouds of silt and clay. Upon settling, the massive sharpclast slurry was so diluted by finer debris that neither grading, inverse grading nor contact between individual clasts was achieved. It is conceivable that towards their margins the debris flows consisted of individual clasts isolated from the main slurry which settled within a moving cloud of silt and clay. The result of such a process would be limestones enveloped by current-agitated finer sediment. The wispieness and rare lineated bedding surfaces (Fig. 7) suggest that currents had sufficient strength to move silt although they might have been insufficient to transport the coarser clasts once they had settled. This activity of waning currents upon the finer material results in a bedded structure in which many oversize clasts do not appear to belong to any particular bed. The interpretation of all limestones in the Sayunei Formation as dropstones related to ice-rafting (Young, 1976) is therefore not justified. The dropstone hypothesis may hold for rounded and striated extrabasinal clasts of the uppermost Sayunei Formation (Gabrielse, 1972). It was noted by Eisbacher (1977) that towards the margin of the basin thick basal siltstone-argillite successions correlate with and grade into diamictite with glacially striated clasts. It is therefore entirely possible that the Sayunei Formation was deposited under climatic conditions that were deteriorating relative to the climate which existed during deposition of the older Proterozoic carbonate formations of the region. Increasing glacial cover might explain a waning of fluvial input and predominance of coarse intrabasinal debris which was shed directly from tectonic fault scarps. In summary, sedimentary structures indicate deposition from highly dilute subaqueous debris flows, turbidity currents, and other forms of sudden particulate flow. Distinct glacial influence, as displayed by striated extrabasinal dropstones, is pronounced within the highest part of the Sayunei Formation.

A discussion of the iron-formation of the Rapitan Group is deferred until detailed mapping is completed and possible influence of contemporaneous volcanism can be clearly demonstrated or refuted (Gross, 1965).

SHEZAL FORMATION

Definition

The Shezal Formation is named after Shezal Canyon east of Keele River, in map-area 95M (Wrigley Lake), where 'conglomerates' were seen first by Keele in 1908 (Keele, 1910). The formation is mappable for at least 400 km along the core of the Mackenzie Mountains where it occurs between the Sayunei Formation and the Twitya Formation of the Rapitan Group. However, in exposures close to the original margin of the basin the relationship between the Shezal Formation and other Proterozoic units can be ambiguous.

The base of the Shezal Formation is placed at the first occurrence of numerous subrounded to well rounded clasts of dolomite, limestone, quartzite, greenstone or crystalline rocks embedded in a matrix of unevenly bedded to scaly siltstone and greywacke. The matrix of diamictite (see below) is characterized by vestiges of cross-laminated siltstone beds and weathers in scaly outcrop faces. Intervals of sandstone and shale give the formation a vaguely bedded characteristic. The Shezal Formation, in general, ranges from about 10 to 250 m in thickness. The formational top is sharp and defined by the contact between coarse boulder diamictite and dark pyritic shale, delicately laminated particulate limestone, or sandstone of the Twitya Formation (Fig. 12). An upper contact, characterized by interbedding of conglomerate, dark shale, and micritic limestone reported from one locality by Young (1976), is not typical for the regional situation. There is no recurrence of extrabasinal clasts in the laminated pyritic shale or limestone above the contact. Thus the top of the Shezal Formation is better defined than its base.



Figure 12.

Upper contact of the Shezal Formation as observed north-northeast of Palmer Lake (Sections 1, 2, 4, Fig. 11). The contact between diamictite and delicately laminated, dark grey, fetid limestone is knife-sharp. (GSC 203219-G).

Figure 13.

Boulders and blocks of limestone, dolomite, and greenstone of Shezal diamictite. The picture was taken close to the top of the Shezal Formation. Note typical scaliness of the matrix. (GSC 203219-H).



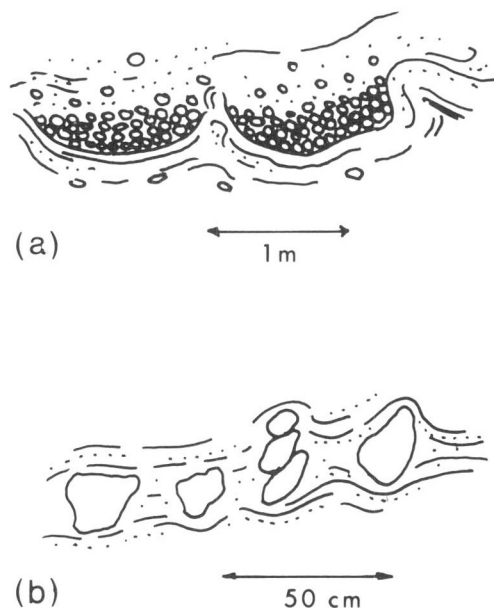


Figure 14. Pocket of densely packed well rounded cobbles in substratum of greywacke and siltstone in Shezal Formation (sketched from photograph). (b) Edgewise position of clasts in Shezal diamictite (sketch from outcrop).



Figure 15. Diamictite in the Shezal Formation. Subangular to well rounded clasts are scattered in a scaly weathering matrix of siltstone and sandstone. (GSC 203219-I).

Description

The Shezal Formation is predominantly diamictite, a term applied to rocks "mingled thoroughly" (Flint, 1960). It describes well the association of rounded pebbles, cobbles, boulders and blocks within a matrix of, commonly bedded, siltstone and greywacke (Figs. 13, 15). The term mixtite, introduced into the literature by Schermerhorn (1966), has been applied to the Shezal Formation by Young (1976). Mixtite, as pointed out by Schwarzbach (1976) literally means the same thing as diamictite and there is no compelling reason to abandon the well established term diamictite. The diamictites of the Shezal Formation also have been referred to as pebbly mudstones. This is only partly valid since much of the matrix material is silt and sand (Aitken et al., 1973).

The colour of the Shezal Formation is variably buff, dark grey-green, or brick red and thus cannot be used with confidence in regional mapping. Buff colours predominate in diamictite with carbonate clasts but green-grey tones prevail where greenstone clasts are common. Red colours are associated with hematite pigment in the finer grained diamictite matrix. The seemingly abrupt change from thick red to relatively thin buff Shezal Formation is illustrated in Figure 11.

The diamictite occurs as thick sheets. Bedding, although visible on a grand scale in cliff exposures or within the matrix as stringers of sand and silt, is commonly obliterated by the loose arrangement of pebbles, cobbles, and boulders within the greywacke-siltstone matrix. Many of the rounded clasts are embedded 'on-edge' with respect to their longest dimension and bedding in the matrix (Fig. 14b). All gradations from very loose, matrix-supported, open clast fabrics to densely packed clast-supported diamictite exist. Erosive channeling of conglomeratic beds into underlying fine grained sediments is rare within the Shezal Formation of the Mackenzie Mountains. It was seen only in a relatively thin

section in Mount Eduni map-area (106A) (Section 1, Fig. 11) where carbonate-rich conglomerates are distinctly bedded and the interlayered sandstones are graded. More common than channeling are pocket-like depressions filled with densely packed diamictite. These pockets are one to two metres wide and underlying siltstones are squeezed up in a style reminiscent of large load casts (see sketch, Fig. 14a). Over a large region straddling Glacier Lake and Wrigley Lake (95L, 95M) the diamictite sheets which occupy the uppermost parts of the Shezal Formation also are the coarsest and most densely packed (e.g. Fig. 13). They show also the greatest diversity of clasts including coarsely crystalline diorite boulders up to 5 m in diameter. In contrast the basal parts of the Shezal Formation commonly show a sprinkling of pebbles in an otherwise homogeneous scaly siltstone. The scaliness of the matrix is strongly emphasized by weathering and upon closer inspection ribs and cracks form an interlacing pattern on outcrop faces (Fig. 15). However, some of this peculiar weathering may have been preconditioned by internal plastic stretching and shearing of siltstone layers during initial compaction of the heterogeneous sediment (Eisbacher, 1976). Vestiges of lenticular siltstones demonstrate the plasticity of matrix and siltstones during an early stage of diagenesis (Fig. 15). In several sections diamictite sheets are interlayered with shale-siltstone



Figure 16. Stretched and smeared-out siltstone layer in fine grained matrix of diamictite of the Shezal Formation. Note scaliness of matrix (GSC 203219-J).



Figure 17. Striated clast within diamictite of the Shezal Formation. (GSC 203219-K).



Figure 18. Close-up of striations on greenstone pebble from Shezal diamictite (scale in centimetres). (GSC 203219-L).

units devoid of oversize clasts. These shale intervals are up to several metres thick. The contact between the shale and diamictite is commonly sharp. Another intriguing feature of the Shezal Formation is the sporadic occurrence of sandstone bodies. These are well bedded and show parallel or cross-bedding. Length of foresets in cross-beds in places exceed 1 m (Eisbacher, 1976). The sandstone beds are commonly slumped or internally distorted but do not seem to have been greatly separated from their locus of deposition; asymmetry of slump folds is difficult to establish. The sandstones are neither graded nor do they show linear sole marks.

An interesting feature of the Shezal diamictite is the occurrence of striated and faceted clasts (Figs. 17, 18). These have been observed, described or illustrated by Ziegler (1959), Uptis (1966), Young (1976), and Eisbacher (1977). Crosscutting of the striae indicates that the striations originated by grinding of the clasts against hard materials within a coherent mass with concomitant slow rotation of the clasts. These grooves are deeper and wider than later tectonic striations that were imprinted on many clasts by small tectonic displacements between matrix and clasts.

Type Section

The type section chosen for the Shezal Formation is exposed along a ridge and adjacent gullies about 13 km west of Hayhook Lake at latitude 63°33'30"N, and longitude 127°03'W. It is 235 m thick (Fig. 10).

At the type locality the underlying rocks of the Sayunei Formation are dark red to maroon, iron-rich siltstone and argillite, and about 10 m of green-grey siltstone and sandstone. Above the green siltstones about 15 m of buff-brown diamictite define the base of the Shezal Formation. Upwards the section alternates between sheets of diamictite with predominantly dolomitic and calcareous clasts and cross-laminated siltstone, sandstone, and minor shale. Towards the top other exotic lithologies such as greenstone and diorite increase in relative frequency among the clasts. The composition of the fine matrix of the diamictites reflects to a great extent the lithology of the included pebbles and cobbles. Well developed cross-lamination is common in the matrix of calcareous to dolomitic diamictite. At the top of the Shezal Formation oversize clasts reach the largest dimension and boulders exceeding 50 cm in diameter are common. The top of the Shezal Formation is sharp and marked by the appearance of dark pyritic shale of the Twitya Formation.

Interpretation

Almost all previous descriptions have considered the possibility of a glacial origin for the Shezal diamictites. The most compelling evidence relates to the polished, faceted and striated clasts (Ziegler, 1959). Although the percentage of faceted and striated clasts is generally low it is probable that these clasts obtained their surface morphology within sheared glacial material such as that within deformed ground moraine. However, the bulk of the diamictite of the Shezal Formation is clearly not ground moraine and a secondary transport mechanism has to be considered in order to explain the presence of oversize cobbles and boulders within a matrix of bedded siltstone and sandstone. Near the eastern margins of the basin (e.g. section 1 of Eisbacher, 1977) there may be true morainal deposits but even there bedded, fine grained deposits are sandwiched between massive diamictites (Fig. 19). The most probable solution to the problem of how glacially striated clasts were redeposited is through ice rafting, as demonstrated by Plafker and Addicott (1976) in Miocene to Holocene glacial-marine diamictites of the Gulf of Alaska, and by Ovenshine (1970) in front of actively calving glacier ice in the same region. Submarine debris flows probably played a limited role in the deposition of the Shezal Formation in the Mackenzie Mountains. The one section

measured to date which consists of well stratified deposits of turbiditic sandstones and mass-flow deposits is plotted in Figure 11 as Section 1. However, subaqueous debris-flow deposits might be more important in sections down-dip from the present erosional margin of the Shezal Formation. The turbiditic sands of Section 1 (Fig. 11) consist of carbonate particles, similar in composition to the pebbles, cobbles and boulders in adjacent mass-flow deposits. This fact is significant with respect to the problem of carbonate deposits versus the inferred glacial-marine environment of diamictites (see Schermerhorn, 1974). If the carbonates associated with diamictites are reworked particulate deposits this problem is not serious. Truly chemical or biological precipitates would pose a serious problem with regard to the glacial environment inferred for the Shezal Formation.

In outcrop the sediments associated with the diamictites are well bedded sandstones or cross-laminated siltstones suggesting normal traction-current transport of sand and silt prior to deposition. The incorporation of oversized clasts in pulses or as sporadic dropstones had little to do with the currents which were apparently active near the bottom of the basin, the presence of which is suggested by current structures in the matrix of the diamictites (Eisbacher, 1976). The author favours the mechanism of ice rafting of coarse materials by icebergs or floating glacier tongues for the emplacement of oversize material into bedded, fine grained sands and silts. This mechanism could



Figure 19. Diamictite of the Shezal Formation near the southeastern margin of the Rapitan Basin (Section 1 of Fig. 46-2 in Eisbacher, 1977). In contrast with most sections of Shezal Formation the matrix weathers in angular fragments rather than scales such as illustrated in Figure 13. (GSC 203219-M).

also account for the relatively isolated pockets of clasts within finer siltstones referred to above. Upon melting, breaking or tilting of large icebergs, debris could have been unloaded en-masse and sink through the column of water into the sediments below without being greatly scattered. This mechanism has been described from a recent glacial-marine setting by Ovenshine (1970).

The progressive coarsening of diamictites near the top of the Shezal Formation and the sharp break at the upper boundary is another interesting aspect of the possible glacial-marine environment in which most of the formation was laid down. In the final phases of glaciation more ice than usual could have broken away from ice sheets or glacier tongues because of their melting and rise in sea level. Consequently more and coarser debris would have reached the sea where it was dropped into current-agitated sands and silts of the continental margin.

The depth of water during deposition of the Shezal Formation is difficult to appraise. However, the general absence of turbidites and the presence of sandstones with large scale cross-beds suggests that much of the Shezal Formation, as exposed in sections, was laid down on the continental shelf. The abrupt contact between the Shezal Formation and pyritic shale and laminated limestone of the overlying Twitya Formation signals the establishment of stagnant waters within a basin which was dominated by an entirely new climatic regime.

In two recent publications Aalto (1971) and Young (1976) have interpreted glacial-marine sediments in Proterozoic sequences of western Canada in terms of the thoughtful and imaginative model proposed by Carey and Ahmad (1961). The model implies that "wet-base" and "dry-base" ice sheets create different types of sedimentary assemblages in adjacent marine basins. A word of caution is in order. More recent investigations into Pleistocene and Holocene glacial-marine environments have yielded some insights into the influence of active glaciers or ice sheets on the sedimentary characteristics of the basins nearby (Anderson, 1972; Anderson and Wheeler, in press; Plafker and Addicott, 1976; Armstrong, in press and pers. comm., 1977). From these studies it seems that *ice-rafting and thick accumulation of coarse material occur at or near the front of floating ice*. Thick glacial-marine diamictite therefore indicates that the frontal part of floating glacier ice was situated above or near the site of deposition for a considerable length of time. Consequently, any geological section of glacial-marine diamictite might portray, in a relative sense, how often and for how long an active frontal lobe of a regional ice sheet was above or near the zone of sedimentation. It is, however, difficult to see how glacial-marine deposits could depict "relative severity of glaciation" (Young, 1976, Fig. 4).

In some areas of the Rapitan Basin the Shezal Formation consists of at least 12 distinct sheets of diamictite separated by sandstone or shale. Such sections could imply large oscillations in the position of the active front. As mentioned above, truly massive diamictites that might represent lodgement tills are extremely rare and where suspected they deserve closer study.

TWITYA FORMATION

Definition

The Twitya Formation is named after Twitya River in Sekwi Mountain and Mount Eduni map-areas (105P, 106A). It is a very distinct unit of the Rapitan Group throughout the Mackenzie Mountains and occurs between the Shezal Formation and the Keele Formation. The Twitya Formation is in conformable contact with the underlying Shezal Formation



Figure 20. Parallel bedded, internally laminated sandstones of the Twitya Formation. The sandy unit illustrated by the photograph rests with sharp contact on shale and grades upwards into siltstone and shale. (GSC 203219-N).

and grades upwards into the Keele Formation. An angular unconformity between the Twitya Formation and Shezal Formation postulated by Blusson (1971) for map-area 105P could not be substantiated for other areas during the present study. The sharp contact is defined by *dark grey to black pyritic shale or thinly laminated limestone above coarse diamictite* of the Shezal Formation. This contact can be placed very accurately, particularly where laminated grey limestone occurs at the base. In bulk, the Twitya Formation consists of dark grey to brown shale and siltstone, and beds of green to buff sandstone. Higher in the section cross-bedded sandstones are more common than in the lower part. The top of the Twitya and the base of the Keele Formation are defined by the first appearance of carbonate rocks. The thickness of the Twitya Formation ranges generally from 400 to 900 m.

Description

The Twitya Formation is predominantly shale with intercalated siltstone and sandstone. Major stratigraphic intervals consist entirely of shale with sporadic layers of brown weathering siltstone cemented by carbonate minerals. Beds of fine or coarse grained sandstone occur as well defined packets. In some sandstone units thickness of individual beds decreases towards the top (Fig. 20), in others the reverse is true, and yet others show no recognizable polarity. Particularly in the lower part of the formation, the packets of light weathering sandstones tend to be deformed into slump

structures such as folds or zones of chaotic bedding (Fig. 21). Upper surfaces of individual sandstone beds are well defined and adorned by a variety of current ripples and rill marks (Fig. 22). On the basal surfaces directional structures such as flute casts are extremely rare and only occasionally load structures seem to indicate a faint preferred shape orientation (Fig. 23a, b). Internally, fine grained beds are parallel- or cross-laminated; coarser beds also are laminated and occasionally cross-bedded. Internal dewatering structures are common (Fig. 24).

Compositionally the sandstones are reported to be quartzofeldspathic or arkosic arenites (Upitis, 1966). Towards the northwest, beds and channels of chert-quartz pebble conglomerates are found locally.

A locally very distinct member of the Twitya Formation is a basal limestone which is delicately laminated, fetid, dark grey and particulate, and which grades upward into black pyritic shale. Towards the northwest (Wernecke

Mountains) the Twitya Formation generally intertongues with carbonate complexes of considerable thickness. This signifies a deviation from the prevalent clastic nature of the unit in the Mackenzie Mountains.

Type Section

The type section chosen for the Twitya Formation is exposed along a ridge 15 km west of Hayhook Lake in map-area 95M (Wrigley Lake). The section is located at latitude 63°33'30"N, and longitude 127°03'30"W. It is 672 m thick and overlies the type section of the Shezal Formation (Fig. 10). With the exception of a cross-bedded quartzose sandstone near its base the lower half of the section is dominated by shale and siltstone. Occasional zones of disturbed bedding interrupt the sequence. Grain-size and bedding thickness increase towards the top where the cross-bedded quartz arenites are very similar to those of the overlying Keele Formation. The top of the Twitya Formation is placed at the base of a buff to orange weathering dolomite unit which is about 7 m thick.

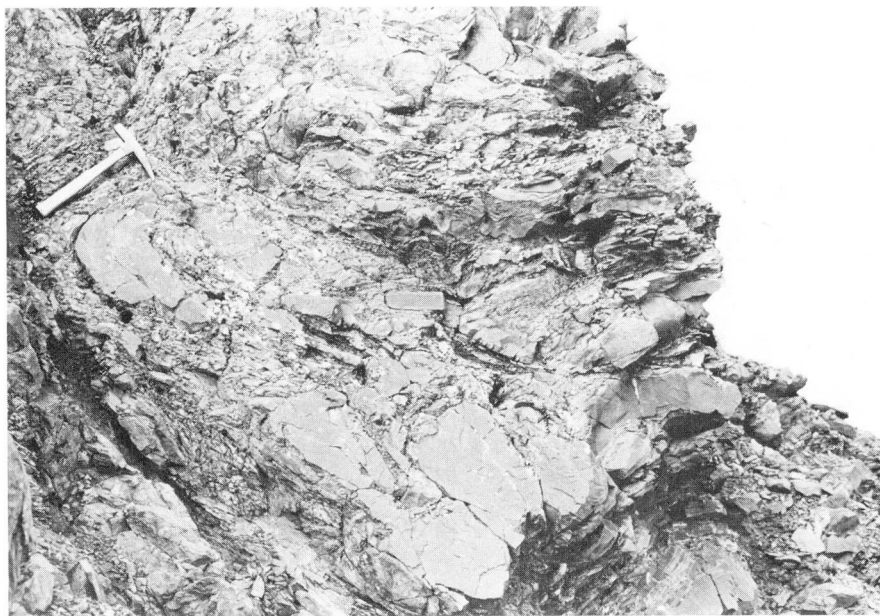


Figure 21.

Zone of chaotic bedding with slumped sandstone and siltstone of the Twitya Formation. (GSC 203219-O).

Figure 22.

Well defined upper bedding surface of fine grained sandstone with current induced rill marks. Commonly these rill marks are associated with current ripple marks. Rill trend perpendicular to the orientation of the ripple marks. (GSC 203219-P).

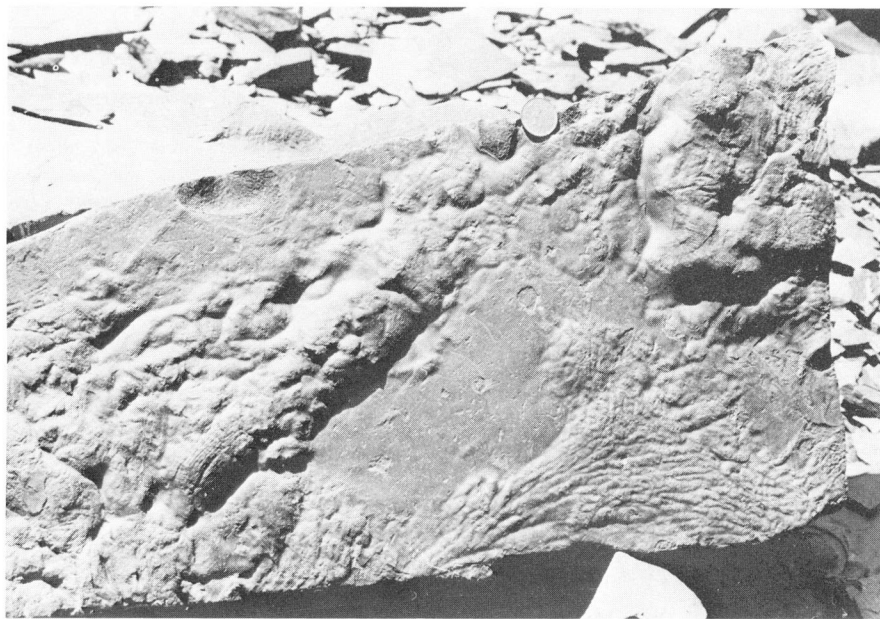


Interpretation

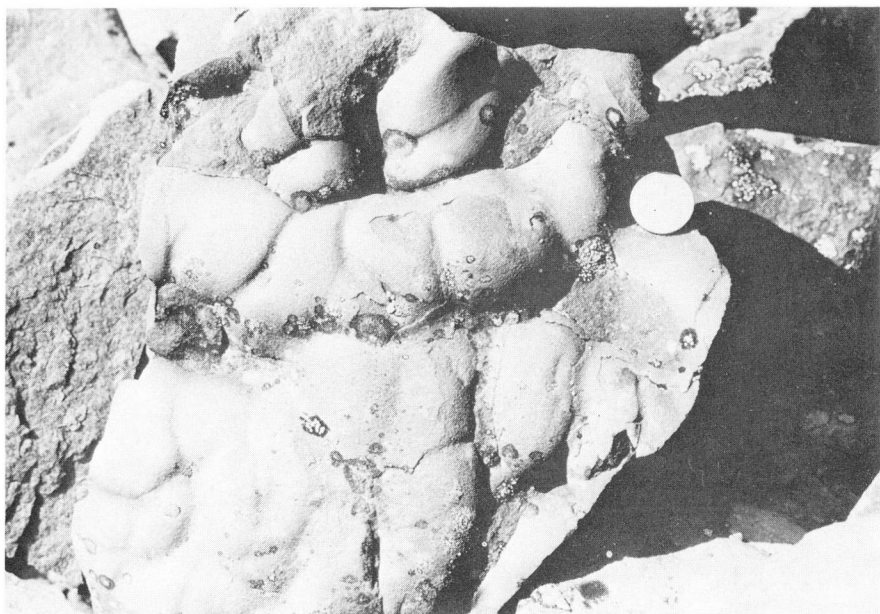
Throughout the Mackenzie Mountains the base of the Twitya Formation is well defined. The juxtaposition of coarse boulder diamictite and shale or carbonate at the base of the Twitya Formation signals an abrupt change in the conditions of sedimentation. If a glacial-marine origin is accepted for the Shezal diamictite the contact relationships with the Twitya Formation indicate a geologically instantaneous climatic change which terminated the influence of floating ice margins on basin sedimentation and caused re-establishment of carbonate banks in nearby shelf areas. From regional mapping it is also evident that the Twitya basin overstepped the margins of older basins in a northeasterly direction. It might be speculated that such increase in the size of the basin is partly due to the rise in sea level following the melting of the Shezal ice sheet (Eisbacher, 1976; Young, 1976). However, to substantiate such a model more detailed mapping of the margins of the Rapitan Basin has to be carried out.

The nature of the clastics within the shale of the Twitya Formation suggests that most of the sand was transported by and deposited from traction currents. The bundling of beds might be due to filling, progradation and general shifting of channel systems on a continental shelf or slope. The ubiquity of slump folds and load structures indicates that during deposition and shortly after deposition of the sandy material the clays beneath the channel systems suffered plastic deformation with down-basin creep of semi-consolidated material. Some of the distorted zones are up to 50 m thick which suggests that slumping was due to laterally and vertically extensive instabilities in the thick sedimentary material of the shelf. Preliminary analysis of slump folds reveals that mass transport was directed to the southwest. However, the intertonguing of the Twitya shales with carbonate in the northwestern parts of the Rapitan Basin might signal the existence of another nearshore environment in the Wernecke Mountains. This possibility also is borne out by preliminary paleocurrent work in this region.

In summary it is proposed that the Twitya Formation, composed of shale and some coarse clastic material, was deposited by traction currents on a gravitationally unstable shelf. Turbidity currents were not significant in the deposition of the Twitya Formation.



a) Lode casts and elongate brush- or tool marks;



b) Slightly elongate load casts

Figure 23.

Sole marks on bottom surfaces of sandstones in the Twitya Formation.

KEELE FORMATION

Definition

The Keele Formation was named by Gabrielse et al. (1973) after Keele River, in Wrigley Lake map-area (95M). It is defined as a well-bedded, orange and buff weathering varied assemblage of sandstone, dolomitic sandstone, dolomite and limestone which overlies the Twitya Formation. The basal contact of the formation is placed at the *first carbonate unit above the shale and sandstones of the Twitya Formation*. This base can be mapped on the ground and is probably useful in delimiting the formation in drillcore, although it may be difficult to recognize on air photographs. The varied nature of the Keele Formation suggests a number of superimposed and laterally interfingering sedimentary environments. Local low-angle unconformities occur near the base (Gabrielse et al., 1973; Blusson, 1971), and within the formation. The top of the Keele Formation is well defined by a light buff or grey, dense dolomite in sharp contact with recessive shales and minor grey limestone of the overlying Sheepbed Formation.

In the Mackenzie Mountains the composition of the Keele Formation varies from sandstone-rich to carbonate-rich end members. It is between 300 and 600 m thick. A section published as U8 in Aitken et al. (1973) from Mt. Eduni map-area (106A), is reported to be about 700 m thick. However, this section is broken by a thrust fault and thus is tectonically thickened.

Towards the southwest, clastic and carbonate rocks of the Keele Formation undergo abrupt lateral facies changes. One of these has been pointed out by Aitken and Cook (pers. comm. 1976) in Mt. Eduni map-area (106A). These facies changes are essentially transitions from carbonate banks to allochthonous mass-flow deposits in adjacent deeper parts of the sedimentary basin. Because the matrix of the mass-flow deposits grades from dolomitic and calcareous sandstones to shale the definition of the Keele Formation with respect to underlying shales of the Twitya Formation in these areas is uncertain (see Section 6, Fig. 11).



Figure 24.

Internal dewatering and load structure, common in sandstones of the Twitya Formation. Unidirectional flame structures are due to current agitation of coarse sand layers above silt bands. (GSC 203219-S).



Figure 25.

Thinly bedded to laminated limestone facies of the Keele Formation. Note incipient stromatolites within limestone rhythmites (arrows). (GSC 203219-T).



Figure 26.

Crossbedded sandstone facies of the Keele Formation. Note bi-polarity of foresets suggesting the possibility of tidal environments. Field of view is about 1.5 m wide. (GSC 203219-U).

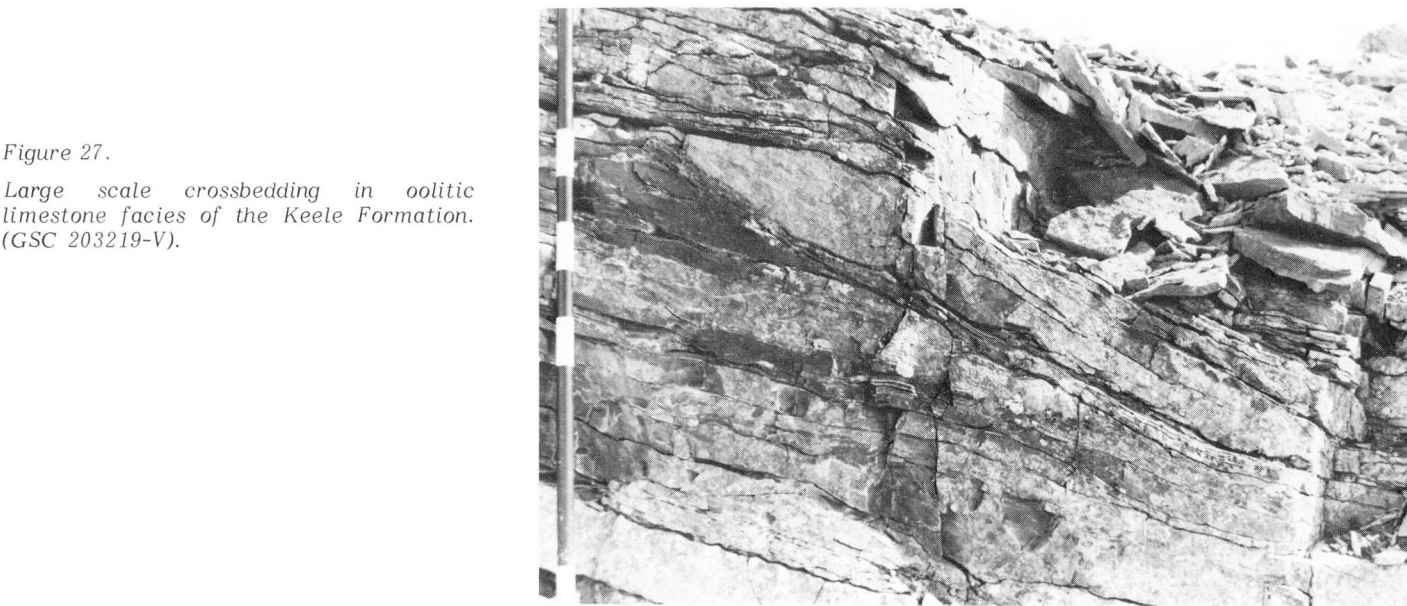


Figure 27.

Large scale crossbedding in oolitic limestone facies of the Keele Formation. (GSC 203219-V).

Description

The outstanding characteristic of the Keele Formation is its lithologic variability and internal cyclicity (Eisbacher, 1976). In a general way the cycles in the Keele Formation are tens of metres thick and start with shale or laminated bituminous limestone. The fine grained and delicately bedded strata grade upwards into cross-bedded coarse grained sandstones, cross-bedded oolitic limestones, or massive recrystallized dolomite (Figs. 10, 11). The tops of the cycles are defined either by rusty weathering, crystalline dolomite or well bedded sandstone overlain by fine detrital or calcareous deposits of the next cycle. In some sections more than 20 cycles exist; in others four or five cycles compose the whole section. There are also distinct regional differences in the relative proportions of carbonate and sandstone within the Keele Formation. In the Palmer Lake area carbonates account for as much as 75 per cent of the section, whereas near Hayhook Lake carbonates compose only 15 to 20 per

cent of the Keele Formation (Fig. 10, 11). Stromatolites, thrombolites and cryptalgal laminites (Fig. 25) can be recognized in the limestone facies of the Keele Formation throughout the region, but individual units do not seem to continue for a great distance along strike. Many of the sandstones and coarse particulate limestones are cross-bedded (Figs. 26, 27). Although in most outcrops the foresets of cross-bedded units indicate a singular direction of sediment transport there are cases of distinct bi-polarity (Fig. 26). Paleocurrent measurements made so far in the Mackenzie Mountains indicate southwestward progradation of the Keele sedimentary complex. Towards the southwestern margin of the cyclic complex the Keele Formation is interlayered with or grades into a coarse facies composed of olistostromes, allochthonous debris-flow deposits, limestone-pebble conglomerate, and detrital carbonate beds. Although a full discussion of this facies change is beyond the scope of this report, one example will be described to illustrate some of the relationships critical for the understanding of the Keele Formation.

Figure 28.

Stringers of limestone olistoliths derived from carbonate platform succession of the Keele Formation and deposited over slumped siliciclastics of the Twitya Formation northeast of Palmer Lake (Section 4, Fig. 11). (GSC 203219-W).



Figure 29.

Close-up of slabs of limestone surrounded by siltstones and fine-grained sandstones which were deposited against the sides of the limestone blocks. (GSC 203219-X).

In the Palmer Lake area (Sections 3 to 6, Figure 11) the Keele Formation is composed of well bedded limestone and dolomite interlayered with coarse grained sandstone. The unit has a well defined base and cross-bedding indicates southwesterly directed paleocurrent flow. However, a short distance along strike the base of the Keele Formation is defined by olistoliths (allochthonous slabs) of limestone (Fig. 28,29). Detailed mapping in this area reveals that the olistostrome overlies a highly contorted sequence of siliceous clastics of the Twitya Formation, and is in turn overlain by shale and siltstone indistinguishable from Twitya rocks below (Fig. 28). The margin of the slumped carbonate bank can be mapped and shows a northerly trend (Fig. 30, 31). The blocks of limestone, which were detached from the carbonate bank, are up to 50 m in diameter and rest on a carpet of smaller blocks and debris of carbonate. The upper two thirds of the large blocks are enveloped by undisturbed siltstone and shale. The orientation of bedding within the limestone blocks is random with respect to bedding in the surrounding siliceous

clastics and there is no indication that post-depositional relative motion between olistoliths and surrounding matrix has occurred. Therefore the limestone blocks must have broken off the bank in response to failure of the unstable Twitya Formation, and once in motion they tumbled into the basin where they were covered by silts and clay. Farther to the southwest most of the Keele Formation changes into allochthonous carbonate debris, shale, and siltstone (Section 6, Fig. 11).

Type Section

The type section of the Keele Formation is located in Glacier Lake map-area (95L) in the central Backbone Ranges (latitude 62°37'N, longitude 125°17'30"). The section was proposed and measured by Gabrielse et al. (1973). The type section consists predominantly of dolomite and limestone, with only minor sandstone. Towards the top, two units of calcareous debris flow deposits are intercalated with orange

weathering dolomite. The chaotic subaqueous debris flows were mistakenly identified as basalt flows by Gabrielse et al. (1973). Since the 'basalt flow' was included with the type section of the Keele Formation it is necessary to point out that volcanic rocks are not typical of the Keele Formation in the Mackenzie Mountains. It is proposed that sections near Hayhook Lake (Fig. 10) and Palmer Lake (Fig. 11) be used as reference sections of the Keele Formation for carbonate-poor and carbonate-rich facies respectively (Figs. 10 and 11).

Interpretation

Many features of the sandstones and carbonates in the Keele Formation suggest that this unit was deposited in a shallow marine environment where oolite shoals alternated laterally with more quiet settings characterized by deposition of delicately bedded cryptalgal laminites. The carbonate banks were dissected by channels with vigorous current systems. Cross-bedded sandstones possibly were deposited by tidal currents as suggested by bi-polar 'herring-bone' cross-bedding (DeVries-Klein, 1970).

In sections where thick units of cross-bedded siliceous clastics predominate (e.g. Hayhook Lake area), it also is possible that alluvial systems characterized by braided streams prograded over a shallow marine environment.

The cyclicity of the Keele Formation suggests that progradation and shoaling occurred repeatedly in both carbonate and clastic environments. The rim of the carbonate banks facing the deeper basin probably was abrupt and further work will be required to define its precise location throughout the Mackenzie Mountains. Twitya, Keele, and Sheepbed formations thicken towards the southwest, which, if extrapolated farther into the subsurface would predicate an enormous section of shale under most of the western Mackenzie Mountains.

Two examples of regional variations and the relationship of the Rapitan Group to Coppercap and Redstone River formations

To illustrate thickness variation and to demonstrate the relationship of the clastic Rapitan Group to the underlying Coppercap and Redstone River formations two areas have been chosen. One is west of Hayhook Lake in Wrigley Lake map-area (95M), the other is east of Palmer Lake in Mt. Eduni map-area (106A). The facies changes in all units discussed are possibly significant to the subsurface exploration for copper which is known to occur in mineralized beds at the top of the Redstone River Formation and as scattered occurrences throughout the Coppercap Formation.

Redstone River Formation

The Redstone River Formation has been defined by Gabrielse et al. (1973) as a distinct succession of recessive, dominantly pink weathering, siltstones. The type section is on the eastern flank of Coppercap Mountain near Little Dal (or Coates) Lake. Thickness variations of the Redstone River Formation are spectacular, as are facies changes. Although pink calcareous or dolomitic siltstones with interstitial anhydrite and gypsum are the characteristic lithology, the formation comprises coarse angular alluvial fan deposits, well rounded fluvial conglomerates, bedded evaporites (mainly anhydrite or gypsum), and cryptalgal carbonates. Copper mineralization occurs towards the top of the Redstone River Formation, but showings also are known from within the underlying Little Dal Formation and the overlying Coppercap Formation. The Redstone River Formation was deposited in a tectonically active environment near sea level where salt pans and mudflats graded into alluvial fans and fluvial systems, a setting similar to that of the present northern Gulf of California.

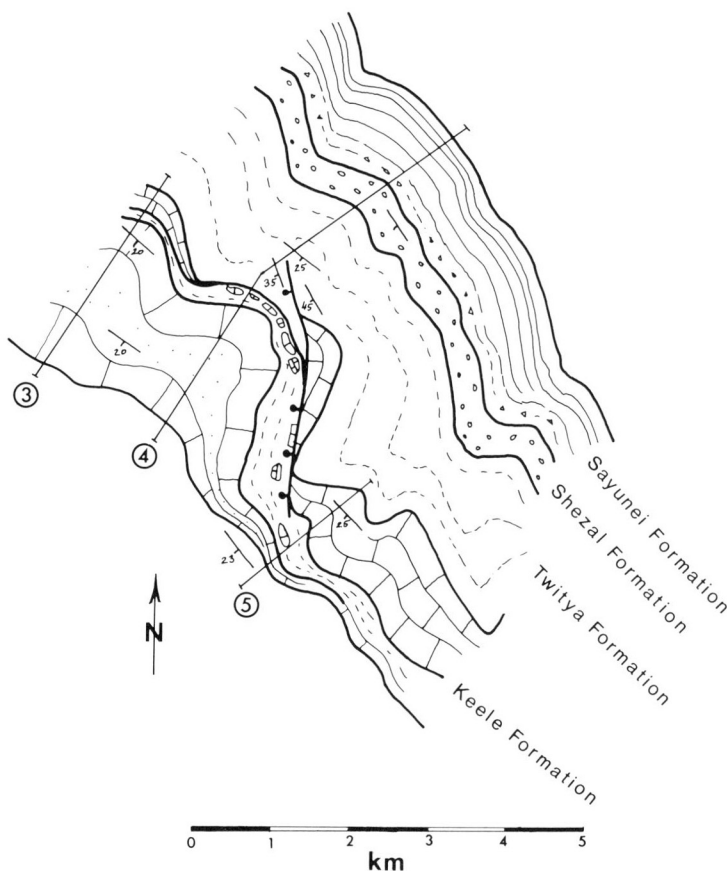


Figure 30. Sketch map of olistostrome in the Keele Formation near synsedimentary scarp along the front of the Keele carbonate platform. Sections shown in Fig. 11 are indicated by numbers. Fig. 11 also serves as regional index map for this sketch map.

Coppercap Formation

The succession of grey weathering carbonates above the Redstone River Formation has been named Coppercap Formation by Gabrielse et al. (1973). The type section is at Coppercap Mountain east of Little Dal (or Coates) Lake. The base of the unit is generally recessive black shale and dolomitic siltstone. This dark grey basal unit is overlain by thin beds of particulate dolomite and limestone commonly laminated or graded. Laminated cherty dolomite and cryptalgal carbonate is common towards the top. In many sections from Redstone River northwards the Coppercap Formation can be divided into two cycles each beginning with dark grey shale or limestone and grading upwards into thick bedded, thrombotic limestone, cherty dolomite or channels of limestone conglomerate. The thin graded beds of the Coppercap Formation commonly display slump folds of various sizes (Eisbacher, 1977). Most of the dark chert layers within dolomite or limestone were also intricately deformed during penecontemporaneous displacements of the semiconsolidated sediment. The Coppercap Formation records a phase of carbonate deposition transgressive over the shallow-water and mudflat setting of the Little Dal and Redstone River formations. Sedimentary structures within the particulate carbonate beds of the Coppercap Formation indicate that turbidity and density currents carried detrital carbonate grains into a basin which developed above the subsiding Redstone River Formation. The cryptalgal laminites and evaporites in the Redstone River Formation represent the initial record of regional transgression and accelerated



Figure 31.

View along the north-south trending synsedimentary scarp in the Keele Formation. Blocks of limestone in the foreground are on the outer edge of the scarp which can be clearly recognized in the background (arrows). View is to the south. (GSC 203219-Y).

subsidence which extended at least 300 km along strike. Although Redstone River and Coppercap strata to date have been found only in four distinct outcrop areas, it is probable that the basin is continuous in the subsurface of the Rapitan Group. The correct sedimentary model for the transgression of the Coppercap sea over the continental deposits of the Redstone River Formation is significant for predicting and understanding the distribution of copper mineralization beneath the Rapitan Group.

Hayhook Lake Area

A number of sections illustrate facies and thickness changes of the Rapitan Group, and Coppercap and Redstone River formations between Redstone River and Hayhook Lake (Fig. 10). They include the type sections of the Sayunei, Shezal, and Twitya formations. The sections measured occur in the hanging wall of the Plateau Fault within which the Proterozoic units were transported eastward over Paleozoic carbonate rocks (Fig. 10). The common stratigraphic base is the Little Dal Formation, a complex succession which in the area discussed consists of varied buff-rusty particulate dolomite, quartzite bands and stromatolitic carbonate buildups. The contact between the Little Dal Formation and the Redstone River Formation is placed at the first distinct conglomerate, pink siltstone or recessive gypsum bed.

Thickness and facies of the Redstone River Formation vary dramatically along strike. From 150 m of coarse fluvial conglomerate in Section 2 it changes to about 250 m of gypsiferous siltstone in Section 4 and thins to zero south of Section 8. The astonishing fact is that the distance between the conglomeratic Section 2 and the siltstone of Section 4 is only 6 km. Paleocurrents, as determined from imbricated cobble layers in the conglomerate, flowed to the southwest. The clasts of the conglomerate are almost entirely dolomite with sporadic components of quartzite. The poorly cemented pink siltstones of Sections 3 to 8 are commonly cross-laminated and the mean paleocurrent vector in the area points to the west-northwest.

The Coppercap Formation is about 100 to 150 m thick and thickness changes along the outcrop belt mimic those in the underlying Redstone River Formation. Two sedimentary cycles can be correlated throughout the area. Each cycle begins with thinly laminated or internally graded particulate carbonates and grades upwards into cherty dolomite or thick bedded limestone.

In the Sayunei Formation of the Rapitan Group changes of thickness and rock colour also are pronounced; from 320 m of maroon siltstone-argillite at Section 1 the formation thins to 165 m in the type locality (Section 2), and is only a few metres thick in Section 3. In the same direction green siltstone at the top of the Sayunei Formation thickens from a few metres in Section 2 to 60 m in Section 3.

Thickness and facies variations in the Shezal Formation are less pronounced. Clast size of extrabasinal components in the diamictites increases upwards in all sections.

In the Twitya Formation slump folding is prominent in the lowest parts of the section and renders detailed work difficult. Analysis of slump folds indicates that intra-formational mass transport was directed to the southwest. Apparent thickness of the formation varies between 400 and 700 m. In order to obtain greater precision measured sections must be supplemented by detailed mapping. Many angularities within the section are due to extensive slumping involving packets up to 50 m thick.

In the Keele Formation of the Hayhook Lake area clastic facies predominate over carbonate facies, and paleocurrents measured in cross-bedded sandstones indicate a southwest dipping paleoslope during deposition of the unit.

The abrupt changes between the northern and southern sections of the Hayhook Lake area are probably partly due to movement along a contemporaneous fault zone trending obliquely to the later regional structures of the Mackenzie Mountains. The evolution of the area, considering fault movement between Sections 2 and 3 is shown schematically in Figure 32. It can be appreciated from this diagram that sense of vertical displacement along the fault reversed itself. Dislocation on the fault was much less significant after deposition of the Sayunei Formation. The location of the postulated contemporaneous fault must be coincident with a narrow drift covered valley west of Hayhook Lake. Mapping in this area has revealed several structural complications along the Plateau Fault which might be related to the old transverse break within the rocks composing the sections west of the Plateau Fault. The significance of contemporaneous faults in understanding subtle or abrupt facies changes has been pointed out for other parts of the Rapitan Basin (Eisbacher, 1977), and needs further careful documentation, particularly since many of the older breaks

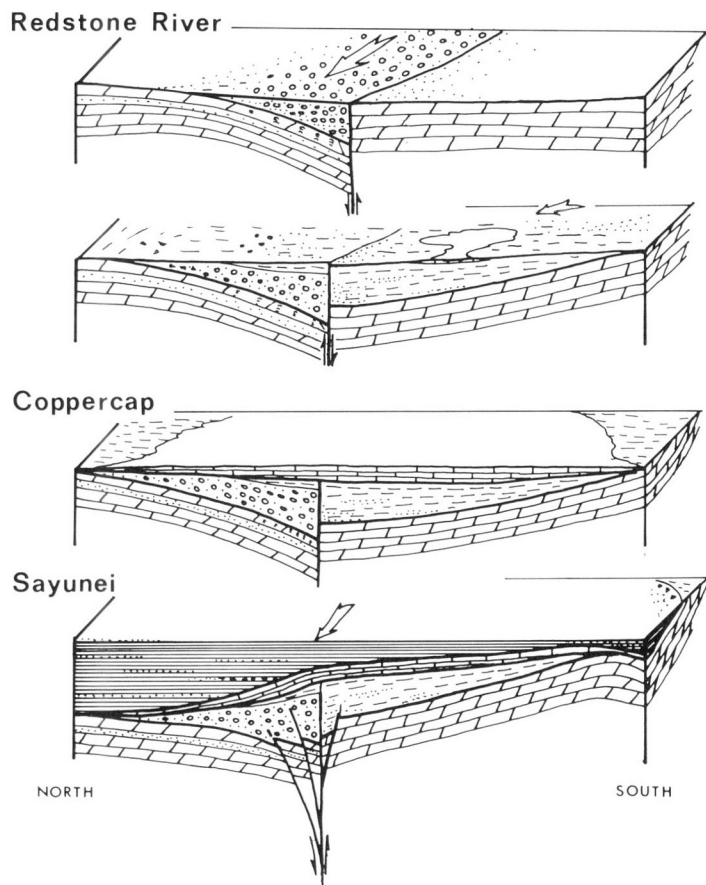


Figure 32. Sketch showing the development of a fault contemporaneous with the deposition of Redstone River, Coppercap and Sayunei Formation between Sections 2 and 3 near Hayhook Lake (Fig. 10). Arrows indicate paleocurrents.

were reactivated during later folding and thrust faulting (Aitken and Cook, 1974). Exploration for copper also has to consider possible influence of deep faults on the migration of ore-bearing fluids in this region.

Palmer Lake Area

Sections northeast of Palmer Lake illustrate similar complexities as those of the Hayhook Lake area (Fig. 11). The Redstone River Formation changes facies abruptly and consists of evaporites, siltstones, conglomeratic sandstone, and conglomerate. The formation as a whole pinches and swells from zero to about 100 m over short distances. The Redstone River Formation is generally overlain by thinly bedded particulate limestone and dolomite of the Coppercap Formation. These graded particulate carbonates change upwards into laminated cherty dolomite.

The Sayunei Formation of the Rapitan Group increases rapidly from zero in Section 1 to 400 m in Section 2. Measurements of cross-lamination suggest southeasterly flowing paleocurrents, compatible with the direction of increasing thickness of the Sayunei Formation. Between Sections 1 and 2 there are distinct channels of angular carbonate clasts interbedded within the finer grained

siltstone-argillite succession (Fig. 9). These channelized deposits demonstrate a situation that could have led to the emplacement of sharpclasts as dispersed slurries in deeper parts of the basin. It is probable that a contemporaneous fault separated Section 1 from Section 2.

The Shezal Formation of the area is partly brick-red and partly buff in colour. The bulk of the Shezal Formation in Section 2 is red. Red coloration could possibly signify that maroon siltstone and argillite of the Sayunei Formation were eroded in the source area of the Shezal Formation and redeposited as matrix of the Shezal diamictite. The buff colour of the Shezal Formation in most sections of the area, particularly towards the top of the unit, reflects the brownish grey colour of the calcareous and dolomitic matrix.

During deposition of the Twitya Formation the basin margin was tilted progressively toward the southwest, although it is worthy to note that the basal laminated limestone thickens to the northwest.

The Keele Formation is composed of southwestward prograded carbonates and sandstones. Debris flows such as those discussed above were launched at the outer margin of the platform and make up the distal facies of the Keele Formation.

CONCLUSIONS AND OUTLOOK

This preliminary report focusses on the four formations which compose the redefined Rapitan Group (Windermere Supergroup) of the Mackenzie Mountains. The basal Sayunei Formation is a predominantly fine grained, rhythmically bedded siltstone-argillite succession with sharpclast-siltstone units deposited within a basin bounded by active faults. The Shezal Formation is composed of diamictites of glacialmarine origin which are interbedded with sandstone and siltstone. The Twitya Formation is a shale-sandstone-siltstone assemblage which was laid down on a rapidly subsiding shelf and slope. The Keele Formation is a highly variable suite of carbonates and clastics deposited on a shallow shelf.

It is fully recognized that in many areas the boundaries between these formations may not be as sharp as might be desirable for a formalized nomenclature and that towards the margins of the basin, facies changes may render this subdivision impracticable and necessitate a more detailed subdivision. However, such difficulties are normal in all sedimentary basins and should not be the cause for major correlation problems throughout most of the Mackenzie Mountains. Some of the units proposed in this report have been recognized for over 500 km and might continue or disappear beyond this distance. Windermere strata immediately west and south of the Mackenzie Mountains are preserved as outliers or in structurally complicated patterns. They will be investigated one by one and probably will ultimately be correlated with the stratigraphic units of the central Mackenzie Mountains proposed in this report. From present knowledge it is evident that facies changes, particularly within the Sayunei Formation and underlying Redstone River and Coppercap formations, can be related to fault tectonics contemporaneous with deposition of these units. In terms of tectonic framework the carbonate formations immediately beneath the Windermere Supergroup were therefore deposited in a setting similar to that of the basal clastic Windermere strata, a point of considerable significance in the exploration for stratabound copper deposits in the northern Cordillera.

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