PRE-MISSISSIPPIAN ROCKS IN THE CLARENCE AND MALCOLM RIVERS AREA, ALASKA, AND THE YUKON TERRITORY

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ABSTRACT

Weakly metamorphosed, folded, and thrust-faulted rocks of Proterozoic or Cambrian to Devonian(?) age along the northern border of Alaska and the Yukon Territory make up a stratigraphic succession estimated to be about 850 m thick. The succession consists of lithostratigraphic units containing various combinations of limestone, argillite, volcaniclastic rocks, and chert that grade into one another and are overlain unconformably by strata of Mississippian to Triassic age. Depositional environments are interpreted to have been on slopes at the shelf-slope transition, in basins having freely circulating waters, and in an anoxic basin having restricted circulation.

INTRODUCTION

The stratigraphy of pre-Mississippian rocks in northeastern Alaska and adjacent northwestern Yukon Territory has been poorly known because of the reconnaissance nature of the investigations, sparse fossils, and structural complexity. Recent studies in the Clarence and Malcolm Rivers area show that the rocks belong to a continuous stratigraphic section containing strata as old as Proterozoic or Cambrian and as young as Devonian(?). Although the rocks are weakly metamorphosed, folded, and broken by thrust and high-angle faults, good exposures and gradational contacts permit unraveling of the stratigraphic succession and limited interpretation of depositional environments.

Previous attempts to decipher the stratigraphy of pre-Mississippian rocks in the Clarence and Malcolm Rivers area in Alaska consist of work by Maddren (1912) and maps by Mangus (1953), Brosgé et al. (1962), and Reiser et al. (1980). Although Maddren (1912) did not publish his work on the area, brief summaries of his studies are included in Mangus (1953) and Brosgé et al. (1962). Mangus (1953) indicated the pre-Mississippian rocks to be the Neruokpuk Formation and considered them to be older than Devonian in age. Brosgé et al. (1962) also recognized the Neruokpuk Formation but indicated that the formation was Devonian and older(?) in age. Reiser et al. (1980) show Precambrian to Ordovician unnamed geologic map units, including a number of units of uncertain age and stratigraphic position. They assigned none of the rocks in the Clarence and Malcolm Rivers area to what now is called the Neruokpuk Quartzite (Reiser et al., 1978) in Alaska. The Neruokpuk may be equivalent to the Windermere Supergroup of Late Proterozoic to Cambrian age (Lane, 1991, 1992).

Gabrielse (1957), Martin (1959), Norris et al. (1963), and Norris (1981) constitute the previous work in the Malcolm River area of Yukon Territory. Norris (1981) showed the pre-Mississippian rocks to be of Proterozoic age and to be part of his Neruokpuk Formation. Later, Norris (1986) found Devonian fossils in some of these rocks; and Lane and Cecile (1989) identified Paleozoic strata 60 km southeast of the study area in the same stratigraphic and structural belt.

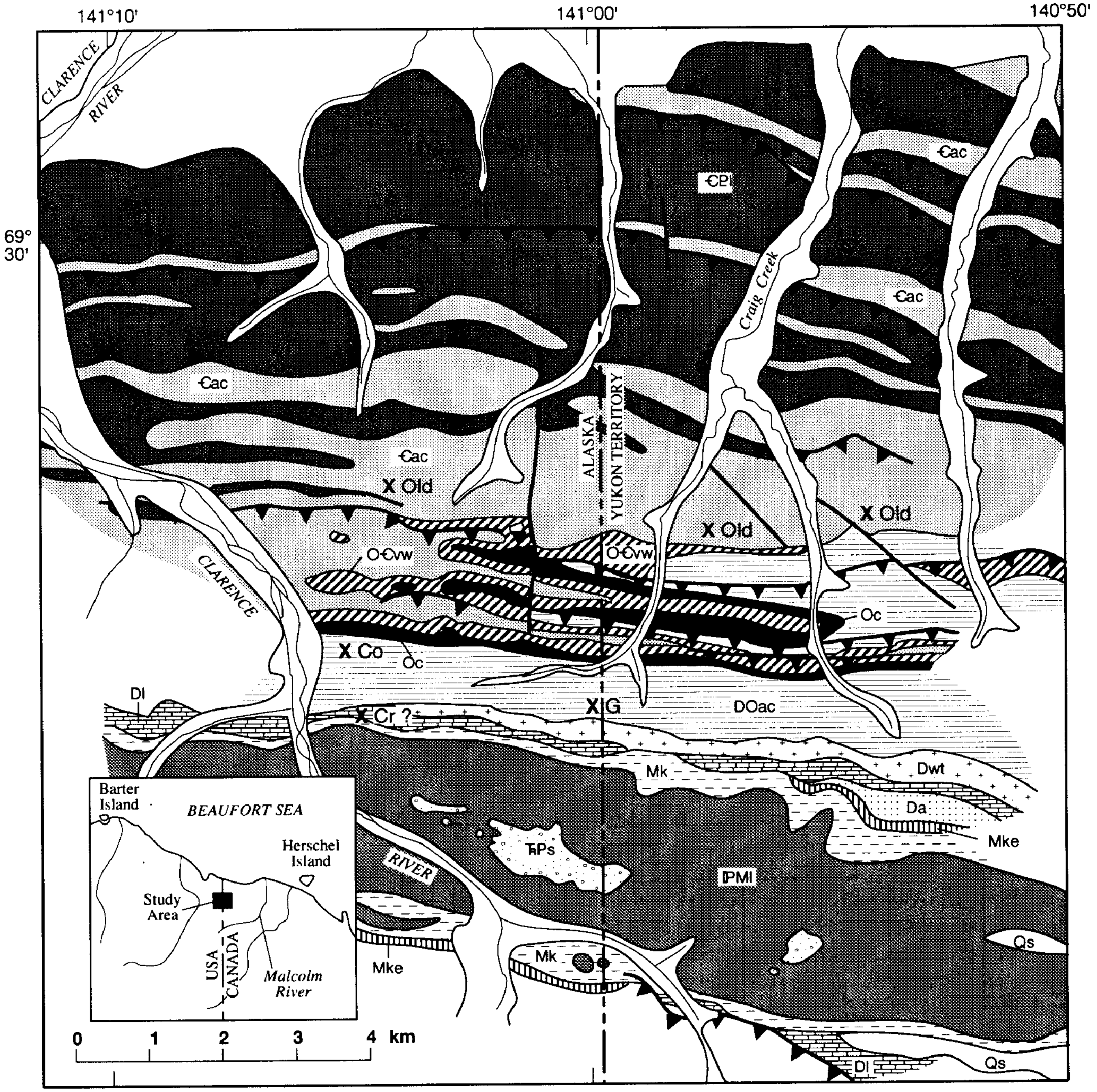
To provide more comprehensive knowledge and continuity in the understanding of the geology spanning the international boundary, the Geological Survey of Canada and the U.S. Geological Survey began a cooperative study in 1990. The results of the first field season are a detailed geologic map (Fig.1) and an improved knowledge of the stratigraphy of the Clarence and Malcolm Rivers area. A brief summary of the 1990 field season is included in Lane et al. (1991). The stratigraphic aspects of that study are expanded here.

STRATIGRAPHY

The pre-Mississippian rocks in the Clarence and Malcolm Rivers area are Proterozoic or Cambrian to Devonian(?) in age. They are oldest in the north and become progressively younger to the south, where they are overlapped by Mississippian strata. Despite structural and metamorphic overprints, sufficient stratigraphic detail remains so that the succession can be deciphered. The generally well-exposed section along the Clarence River in Alaska (Fig.1) is used here as the basis for interpreting the layered sequence, which is about 850 m thick (Fig.2).

Proterozoic or Cambrian Rocks

The oldest stratigraphic unit consists of dark-gray limestone and rare chert, sandstone, argillite, and limestone conglomerate. Limestone beds are mostly 1 to 3 cm thick but range to as much as 10 cm thick. Matrix calcite is mostly medium- to coarse-grained and has vague concentric structures suggestive of ooids. Some exposures have oncolites as large as 4.5 cm across. A conspicuous and distinctive feature of many limestone beds is coarse sand- to grit-size, matrix-supported, rounded quartz grains that make up 10 percent or more of the rock. As seen in thin section,



EXPLANATION

Qs	Surficial deposits and thick tundra, undivided (Quaternary)
TrPs	Sadlerochit Group (Triassic and Permian)
IPMl	Lisburne Group (Pennsylvanian and Mississippian)
Mk	Kayak Shale (Mississippian)
Mke	Kekiktuk Conglomerate (Mississippian)
Da	Argillite (Devonian?)
Dl	Limestone (Devonian?)
Dwt	Wacke and tuff (Devonian?)
DOac	Argillite and chert (Devonian?, Silurian, and Ordovician)
Oc	Chert (Ordovician)
O-Ꞓvw	Volcaniclastic rocks (Ordovician or Cambrian)
Ꞓac	Argillite and chert (Cambrian)
ꞒPl	Limestone (Cambrian or Proterozoic)
(thrust symbol)	Thrust fault, teeth on upper plate
X Co	Fossil locality. Co, conodont; Cr ?, crinoid ?; G, graptolite; Old, *Oldhamia*

Fig.1. Geologic map of the Clarence and Malcolm Rivers area.

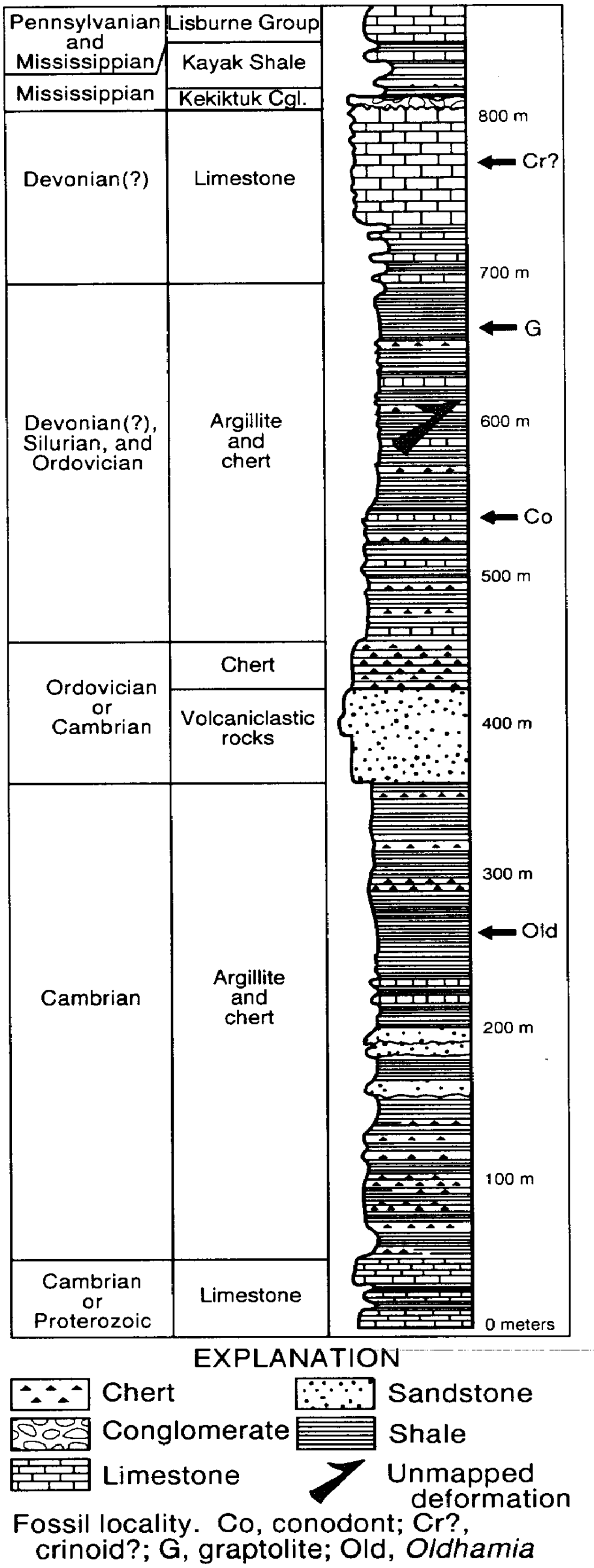


Fig.2. Stratigraphic column of rocks in the Clarence and Malcolm Rivers area.

the quartz is strained; and some grains consist of a mosaic of sutured grains--features indicative of a metamorphic provenance that contained quartzite. Local quartz arenite beds are composed of similar sand grains. The limestone includes ripple cross-laminations associated with channel deposits 15 to 60 cm thick that have cut-and-fill structures and trough-type cross-beds. Hummocky cross-bedding has been identified at one locality. Flute casts are present locally where limestone is interbedded with argillite. Slumps are found locally. The Proterozoic or Cambrian limestone unit is at least 50 m thick; but unmapped folds, bedding thickness modified by deformation, and the absence of an exposed basal contact limit the estimation of its original thickness.

No clearly identifiable fossils have been found in the limestone unit. A few calcite fragments vaguely resemble crinoid ossicles. However, a search for conodonts from one sample yielded no microfossils or mineralized organic material (A.G. Harris, USGS, written commun., 1990). A Proterozoic or Cambrian age is based on the position of the limestone unit below and gradational into beds containing Early Cambrian fossils.

Cambrian Rocks

Overlying the Proterozoic or Cambrian limestone unit is a sequence dominated by red and green argillite. This probably is the same marker unit recognized by Lane and Cecile (1989) southeast of the Clarence and Malcolm Rivers area. Reddish hues dominate over greenish ones at most outcrops. Cleavage is so abundant that identification of original bedding is possible only at rare outcrops where bedding and cleavage cross at high angles. The argillite and chert unit includes minor amounts of pale-green- and white-weathering siliceous argillite. Limestone interbeds resembling the underlying strata are found in the lower one-quarter of the argillite and chert unit, whereas minor amounts of interbedded sandstone and chert are found throughout the unit. The interbedded sandstone is composed of well-rounded medium and coarse quartz grains in a finer-grained matrix in beds 2 to 30 cm thick. Some beds are obscurely graded, and others comprise Bouma sequences with the A layer missing. Flute and groove casts are found in some beds.

The argillite and chert unit is estimated to be about 320 m thick, but no accurate determination of thickness is possible because of the abundant cleavage and numerous isoclinal folds. The contact with the overlying volcaniclastic-rocks unit is gradational.

An Early Cambrian age for the argillite and chert unit is based on the presence of the trace fossil *Oldhamia* (Hofmann and Cecile, 1981) at several localities (Fig.1). *Oldhamia* is widely known east and southeast of the study area (Hofmann and Cecile, 1981).

Cambrian or Ordovician Rocks

A sequence of volcaniclastic rocks with lesser amounts of argillite and chert defines a distinctive unit above the red and green argillite. The volcaniclastic rocks are coarse-grained to gritty and consist of tuffs, wackes, and volcanic conglomerates in beds 2 cm to 2 m thick. The tuffs are composed of lenticular fragments of altered volcanic glass--some of which are vesicular, angular pieces of basalt, and variable amounts of clastic calcite. Wacke beds, because they are composed of the same materials as the tuffs, may represent resedimented tuffaceous debris as well as material derived from the weathering of other volcanic rocks. Thin-section examination of wackes shows clasts of distinctive red biotite. Some beds have slump structures, soft-sediment deformation, graded beds, and a few scour and fill channels 15 cm deep. Conglomerate beds consist of matrix-supported, angular to subrounded, small pebbles to cobbles of basalt, basalt scoria, and rare clasts of recrystallized limestone as much as 25 cm in size. A gabbro sill too small to be shown in Fig.1 and about 10 m thick is present adjacent to the Clarence River low in the volcaniclastic section. The sill is sufficiently altered to suggest that it may have intruded wet sediments. The volcaniclastic-rocks unit is estimated to be about 65 m thick at Clarence River but thins to the east. It grades into the overlying chert unit.

A Cambrian or Ordovician age for the volcaniclastic-rocks unit is based on its gradation into underlying beds of Cambrian age and overlying beds of assumed Ordovician age, and on the presence of rare red basaltic cobbles that resemble rocks from the Whale Mountain section 25 km to the south, where a Late Cambrian trilobite fauna has been found (Dutro et al., 1971).

Ordovician Rocks

Ridge-forming ribbon chert lies above the volcani-clastic rocks unit. The chert is dark gray, rhythmically interlayered with thin, dark-gray, shaly argillite partings. Chert beds are between 3 and 20 cm thick. A conspicuous local feature of the chert is that it is strongly bioturbated. About 40 percent of the chert unit is interbedded dark-gray and olive-gray bioturbated argillite. As seen in thin section, some beds, especially beds of cherty argillite, contain abundant round bodies of microcrystalline quartz that resemble recrystallized radiolarian tests. The chert unit is about 35 m thick and interbedded with the overlying argillite and chert unit of Ordovician to Devonian(?) age.

An Ordovician age for the chert unit is based on its probable correlation with similar chert containing graptolites of Early Ordovician age (Lane and Cecile, 1989) southeast of the Clarence and Malcolm Rivers area. Chert southeast of the Clarence and Malcolm Rivers area lies on red and green argillite rather than on volcaniclastic rocks.

Ordovician, Silurian, and Devonian(?) Rocks

A section of argillite with thin interbeds of chert overlies the chert unit. Light-olive-gray argillite dominates the lower half of the argillite and chert unit and dark-gray argillite the upper half. Resistant white porcelaneous-weathering beds in sets 15 cm to 1 m thick may be tuffaceous. A few beds of brown-weathering limestone are present in the lower one-quarter of the unit. Beds in the lower few meters of the unit have prominent manganese coatings on fracture surfaces. The unit is gradationally overlain by limestone along the Clarence River and by a section of volcaniclastic rocks and argillite in Canada and for a short distance in Alaska.

The age of the argillite and chert unit is known from fossil collections at two localities. One collection made near the contact with the overlying map unit in Alaska barely west of the international border (Fig.1) consists of a single graptolite identified as Late Ordovician in age (Dutro et al., 1971). The other collection, from one of the brown-weathering limestone beds near the contact with the underlying map unit close to the Clarence River (Fig.1), contains conodonts that indicate a latest Silurian or earliest Devonian age (A.G. Harris, USGS, written commun., 1990).

Age determinations from fossils are incompatible with a simple homoclinal stratigraphic sequence as shown on the geologic map because the position of the graptolite locality appears to be stratigraphically higher than the conodont locality. Clearly this cannot be, and the problem is not resolved. Unmapped structural complications exist in the section comprising the argillite and chert unit. Isoclinal folds observed in outcrop and one or more inferred thrust faults may explain the problem.

The depositional thickness of the argillite and chert unit is unknown. The thickness shown in Fig.2, about 240 m, is the apparent thickness in outcrop and does not take into account structural repetition implied by the apparent superimposition of older fossils on younger fossils and structural complications not shown in Fig.1.

Devonian(?) Rocks

Overlying the Ordovician, Silurian, and Devonian(?) argillite and chert unit are map units that wedge out in and near the map area. The lowest of these units is composed of Devonian(?) volcaniclastic wacke and tuff, which wedge out about 2.7 km west of the international border (Fig.1). Overlying this volcaniclastic unit is a Devonian(?) limestone unit that extends across the map area, wedges out a few kilometers west of the area, and is in depositional contact with the underlying Ordovician, Silurian, and Devonian(?) argillite and chert unit along the Clarence River. An argillite unit resting above this Devonian(?) limestone unit in Canada wedges out before reaching the Alaska border. The wedge-out of the wacke and tuff unit is likely a distal margin of the unit, whereas the wedge-out of the argillite unit that overlies the Devonian(?) limestone unit is likely caused by truncation along the unconformity at the base of the Mississippian section (Fig.1). Of the three Devonian(?) map units, only the Devonian(?) limestone unit is present in the traverse section shown in Fig.2 and has been closely examined.

The wacke and tuff unit consists of tuffs, lithic sandstone, and conglomerate, all composed of fragments of basalt and dark-colored former glass, and is interlayered with argillite and minor amounts of chert and limestone. In contrast to the volcaniclastic rocks of Cambrian or Ordovician age lower in the Clarence River section, no red biotite was found in thin sections of these Devonian(?) rocks. This section appears to grade into the overlying limestone unit and has a maximum thickness of about 25 m.

The overlying limestone unit consists of dark-gray and probably completely recrystallized limestone. Relict structures in this unit include cross-bedding, scour and fill structures, and possible hummocky cross-bedding. The unit is about 130 m thick. A distinctive feature of the limestone is a weak petroliferous odor on fresh breaks. Rare, coarse, single-crystal calcite grains resemble crinoid columnals; but their identity as fossil fragments is uncertain.

Argillite lying above the limestone unit in Canada was not closely examined, and rocks that make up the argillite unit are poorly exposed. The argillite is pale green, in part silty, as much as 150 m thick, and has a slaty appearance.

The only direct evidence of the age of these sections is that they lie on strata containing fossils possibly as young as earliest Devonian and are overlain unconformably by Mississippian about 100 km southwest of the study area. The Mangaqtaaq Formation of Anderson and Watts (1992), which crops out about 90 km southwest of the study area, is Late Devonian to Early Mississippian in age and consists largely of interbedded black limestone and shale. Rocks described by Anderson et al. (1992) and Anderson and Watts (1992) are Endicott Group and younger than pre-Mississippian rocks in the Clarence and Malcolm Rivers area. The volcanic rocks described by Anderson et al. (1992) and the Mangaqtaaq Formation are part of a thick depositional sequence consisting mostly of Middle and Upper Devonian clastic rocks that are not penetratively deformed to the degree that pre-Mississippian rocks in the Clarence and Malcolm Rivers area are deformed. Although dead oil in the Mangaqtaaq and the petroliferous odor in the Devonian(?) limestone unit, and the fact that the same Mississippian rocks that unconformably overlie the Mangaqtaaq Formation also unconformably overlie the Devonian(?) limestone unit in the Clarence and Malcolm Rivers area, imply a possible stratigraphic connection, this correlation is unlikely. The Mangaqtaaq lies on a regionally extensive and thick section of nonmarine Middle and Upper(?) Devonian rocks that are not present in the Clarence and Malcolm Rivers area. Additionally, the Mangaqtaaq is unmetamor-phosed and is considered by Anderson and Watts to be lacustrine(?) and part of the Endicott Group; in contrast, the Devonian(?) limestone unit is recrystallized, and Harris (written commun., 1990) reports finding pelmatozoan debris that indicate a post-Early Cambrian age and a marine depositional environment. In the Clarence and Malcolm Rivers area, the Endicott Group consists of the Kekiktuk Conglomerate and Kayak Shale; and the thick sequence of clastic rocks that make up the lower part of the Endicott Group is not present. These relations do, however, imply that the youngest pre-Mississippian rocks in the Clarence and Malcolm Rivers area are no older than early Devonian in age.

Carboniferous, Permian, and Triassic Rocks

A section of Mississippian and younger sedimentary rocks, not investigated in detail, rests unconformably on the pre-Mississippian rocks. From oldest to youngest, these rocks consist of the Kekiktuk Conglomerate, the Kayak Shale, the Lisburne Group, and the Sadlerochit Group. The Kekiktuk is Mississippian in age (Reiser et al., 1980) and is the basal unit to the rocks that unconformably overlie pre-Mississippian rocks in the northeastern Brooks Range. The Kekiktuk is not present everywhere in the Clarence and Malcolm Rivers area. The Kayak Shale, also of Mississippian age (Reiser et al., 1980), and the Kekiktuk Conglomerate make up the Endicott Group in the Clarence and Malcolm Rivers area. The Lisburne Group consists of platform carbonate rocks of Late Mississippian to Middle Pennsylvanian age (Reiser et al., 1980). Only small remnants of the Sadlerochit Group are present in the core of a syncline composed largely of the Lisburne Group.

DEPOSITIONAL ENVIRONMENTS

The strata of the Clarence and Malcolm Rivers area provide a depositional record of sedimentary transport by traction currents and submarine gravity flows as well as accumulation under calmer hemipelagic conditions. Shelf-slope transitions and basin plains are depositional environments where these processes could operate in response to changes in water depth or changes in adjacent source areas. The Proterozoic or Cambrian limestone at the base of the section was deposited in part by the action of traction currents, as indicated by trough-type cross-bedding, cut-and-fill structures, and hummocky cross-bedding, which generally are considered to reflect conditions of high wave energy or storm conditions (Reinick and Singh, 1980, p. 100). Further, oncolites in these beds indicate generation of carbonate clasts in shallow, agitated water in the photic zone. Limestone conglomerates and slump structures reflect gravity-flow conditions and at least moderate slopes. The red and green argillite records deposition in quiet and deeper water, below wave base, where the bottom-dwelling fauna that produced *Oldhamia* could graze but where turbidites also could accumulate. Volcaniclastic beds and the mafic sill in the Cambrian or Ordovician rocks imply down-slope transportation proximal to and concurrent with basaltic volcanism. The overlying chert and succeeding section of shale and interbedded chert indicate hemipelagic sedimentation before accumulation once again of volcanic debris on slopes. Devonian(?) limestone at the top of the section along the Clarence River developed in a marine environment. The weak petroliferous odor reflects a reducing environment, possibly an anoxic basin, a basin with restricted circulation, or in anoxic sediments.

The contrasting lithofacies in gradational transitions to one another could indicate alternating relatively deeper-water and shallower-water conditions in an area undergoing sea level changes but not necessarily near shore. Alternatively, contrasting lithofacies in much of the section could reflect changes in source areas not necessarily related to sea level changes, especially the volcaniclastic deposition. Abundant down-slope deposition implies accumulation on the outer continental shelf or slope. The unconformity at the base of the Mississippian section marks a change to nearshore shallow-water accumulation.

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