GEOLOGICAL SURVEY OF CANADA
DEPARTMENT OF ENERGY, MINES AND RESOURCES, OTTAWA

PAPER 74-47

UPPER PALEOZOIC ROCKS OF THE ATLIN TERRANE, NORTHWESTERN BRITISH COLUMBIA AND SOUTH-CENTRAL YUKON

J.W.H. Monger

1975

ERRATUM

Geological Survey of Canada

Paper 74-47

During the preparation of this report for publication the captions for Figures 4, 7, 11, 12 13 and 14 were inadvertently abbreviated. The full captions are typed in the proper format as follows:

Figure 4. (page 4)

Algalaminate dolomitic limestone of the Teslin Formation from the French Range, near Dease Lake. Note the fine laminations and colour variations on the surface and also the very pale grey weathered surface that contrasts with the dark grey to black fresh surface, visible on fragment above hammer handle. GSC Photo No. 202891-A

Figure 7. (page 8)

Fold in typical thin-bedded, ribbon chert, of the Kedahda Formation in the Kedahda River valley, south of Kedahda Lake. GSC Photo No. 202891-B

Page 13

Figure 11. Carbonate breccia of the Kedahda Formation that locally marks the contact between the Kedahda Formation and the underlying Horsefeed Formation. Exposed on the east side of the valley containing the headwaters of Horsefeed Creek, approximately 9 miles northwest of the west end of Nakina Lake. GSC Photo No. 202891-C

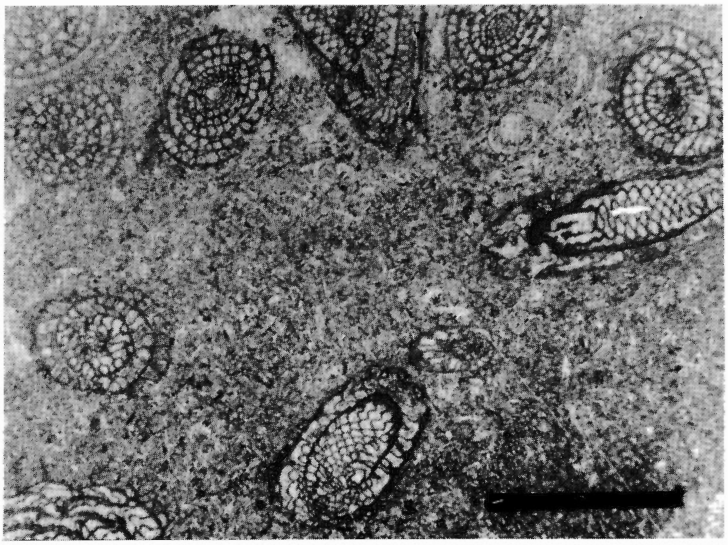
Page 21

Figure 13. Massive Upper Pennsylvanian carbonate of the Horsefeed Formation. The massive bedding of this part of the formation is typically conspicuous. From cirque, northeast side of carbonate ridge approximately 9 miles northwest of Nakina Lake. GSC Photo No. 202891-M

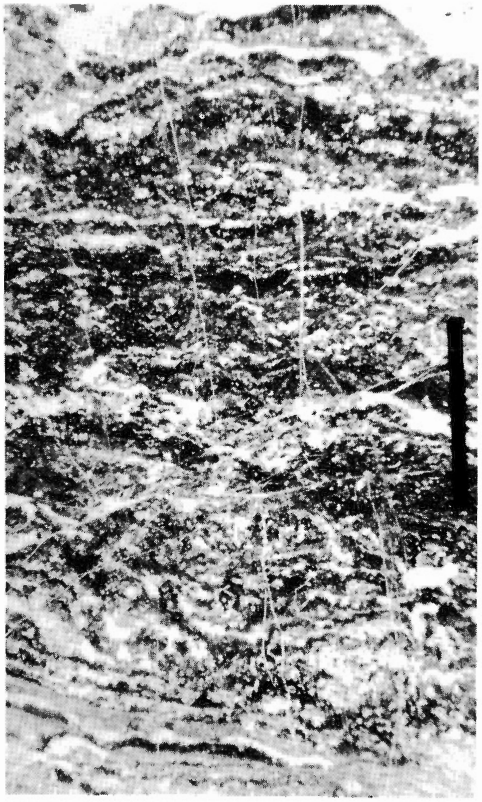
Page 21

Figure 14. Well-bedded mid-Permian aphanitic carbonate on the west side of Sinawa Eddy Mountain, 24 miles northwest of Nakina Lake. GSC Photo No. 202891-N

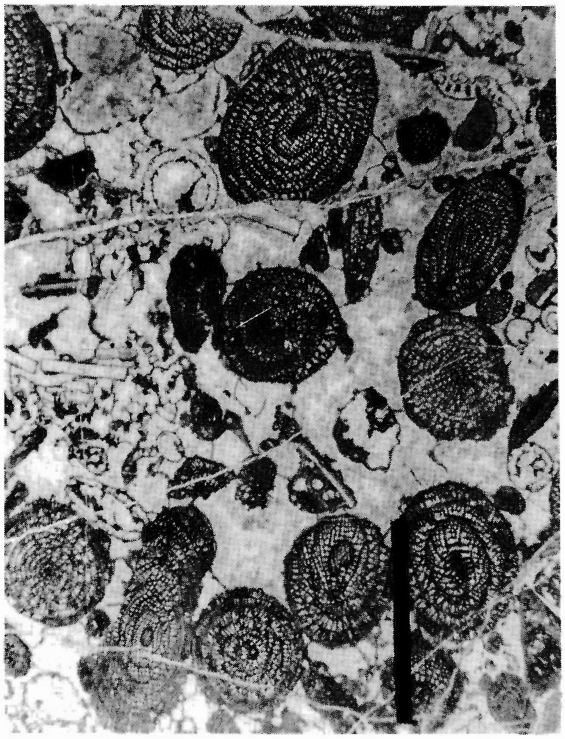
Table 1 (p. 46) — detailed locations are given on Figure 6 (not 7 as in printed text).



12(g) GSC Photo No. 202891-J



12(h) GSC Photo No. 202891-K



12(i) GSC Photo No. 202891-L

12a: Upper Mississippian crinoidal calcarenite, basal Horsefeed Formation.
12b: Middle Pennsylvanian fusulinid and crinoidal calcarenitic limestone.
12c: Upper Pennsylvanian fusulinid and crinoidal calcarenitic limestone.
12d: Lower Permian fusulinid calcarenitic limestone, with large loosely coiled *Pseudochwagerina.*
12e: Lower Permian fusulinid calcarenitic limestone, with algal ball.
12f: Lower Permian oolitic calcarenite.
12g: Mid-Permian fusulinid calcarenitic limestone.
12h: Mid-Permian algalaminate dolomitic limestone.
12i: Upper Permian fusulinid and ammonoid calcarenite, Upper Horsefeed Formation.

Figure 12: Carbonate from the type-area of the Horsefeed Formation showing the variety of textures and fusulinid faunas. Bar of scale is 5 mm long.

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

GEOLOGICAL SURVEY
PAPER 74-47

UPPER PALEOZOIC ROCKS OF THE ATLIN TERRANE, NORTHWESTERN BRITISH COLUMBIA AND SOUTH-CENTRAL YUKON

J.W.H. Monger

1975

Available by mail from *Information Canada*, Ottawa, K1A 0S9

from the Geological Survey of Canada
601 Booth St., Ottawa, K1A 0E8

and

Information Canada bookshops in

HALIFAX — 1683 Barrington Street
MONTREAL — 640 St. Catherine Street W.
OTTAWA — 171 Slater Street
TORONTO — 221 Yonge Street
WINNIPEG — 393 Portage Avenue
VANCOUVER — 800 Granville Street

or through your bookseller

A deposit copy of this publication is also available
for reference in public libraries across Canada

Price - Canada: $3.50
Other Countries: $4.20

Catalogue No. M44-74-47

Price subject to change without notice

Information Canada
Ottawa
1975

CONTENTS

Tables

Illustrations

Abstract

The Upper Paleozoic Cache Creek Group in the Atlin Terrane comprises five formations, in part coeval with one another, and disposed in three facies belts. The northeastern facies belt consists of Permo-Carboniferous chert, pelite and minor sandstone and carbonate of the Kedahda Formation, overlain conformably and gradationally by Permian basic flows and pyroclastic rocks of the French Range Formation, above which lies Permian shallow-water carbonate of the Teslin Formation. The central facies belt is mainly chert and pelite, with local sandstone, altered basalt and limestone all included in the Kedahda Formation. The southwestern facies belt consists of basal, basic Carboniferous volcanic rocks of the Nakina Formation, which is closely associated with alpine-type ultramafic rocks, overlain successively by chert of the Kedahda Formation, thick, Upper Mississippian to Upper Permian shallow-water carbonate of the Horsefeed Formation and, uppermost, chert and pelite, also included in the Kedahda Formation.

These rocks are deformed and commonly of prehnite-pumpellyite metamorphic grade. Much of the deformation probably occurred in late Middle Jurassic time, when the Atlin Terrane was at least in part relatively underthrust from the southwest by Middle Jurassic and older rocks, but there is a possibility that there was an earlier, Permo-Triassic, episode of deformation accompanied by blueschist metamorphism, at least in the southeastern end of the Atlin Terrane.

Résumé

Le groupe de Cache Creek du Paléozoique supérieur, de la série d'Atlin, comprend cinq formations en partie contemporaines et disposées en trois zones de faciès. La zone de faciès du nord-est formée des cherts, de la pélite, d'un peu de grès et des roches carbonatées de la formation de Kedahda du Permo-Carbonifère, recouverte graduellement en concordance par les coulées basiques et les roches pyroclastiques du Permien de la formation de Franch Range sous-jacente aux roches carbonatées de faciès peu profond de la formation de Teslin du Permien. La zone de faciès du centre renferme surtout des cherts et de la pélite, du grès par endroits, du calcaire et du basalte altéré de la formation de Kedahda. La zone de faciès du sud-ouest comprend, à la base, les roches volcaniques basiques de la formation de Nakina du Carbonifère, étroitement associées aux roches ultrabasiques de type alpin; la formation est recouverte successivement par les cherts de la formation de Kedahda, d'épaisses couches de roches carbonatées de faciès peu profond de la formation d'Horsefeed du Mississippien supérieur au Permien supérieur et, au sommet, des cherts et de la pélite, également de la formation de Kedahda.

Ces roches ont été déformées et sont au degré métamorphique de la prehnite et de la lotrite. Les déformations remontent probablement à la fin du Jurassique moyen où la série d'Atlin a été, au moins partiellement, sous-charriée par l'avancée de roches du sud-ouest, du Jurassique moyen ou plus anciennes, mais il est possible qu'antérieurement, au Permo-Trias, ait eu lieu une phase de déformation, accompagnée d'un métamorphisme, dont le faciès atteint celui des micaschistes à glaucophane, au moins à l'extrémité sud-est de la série d'Atlin.

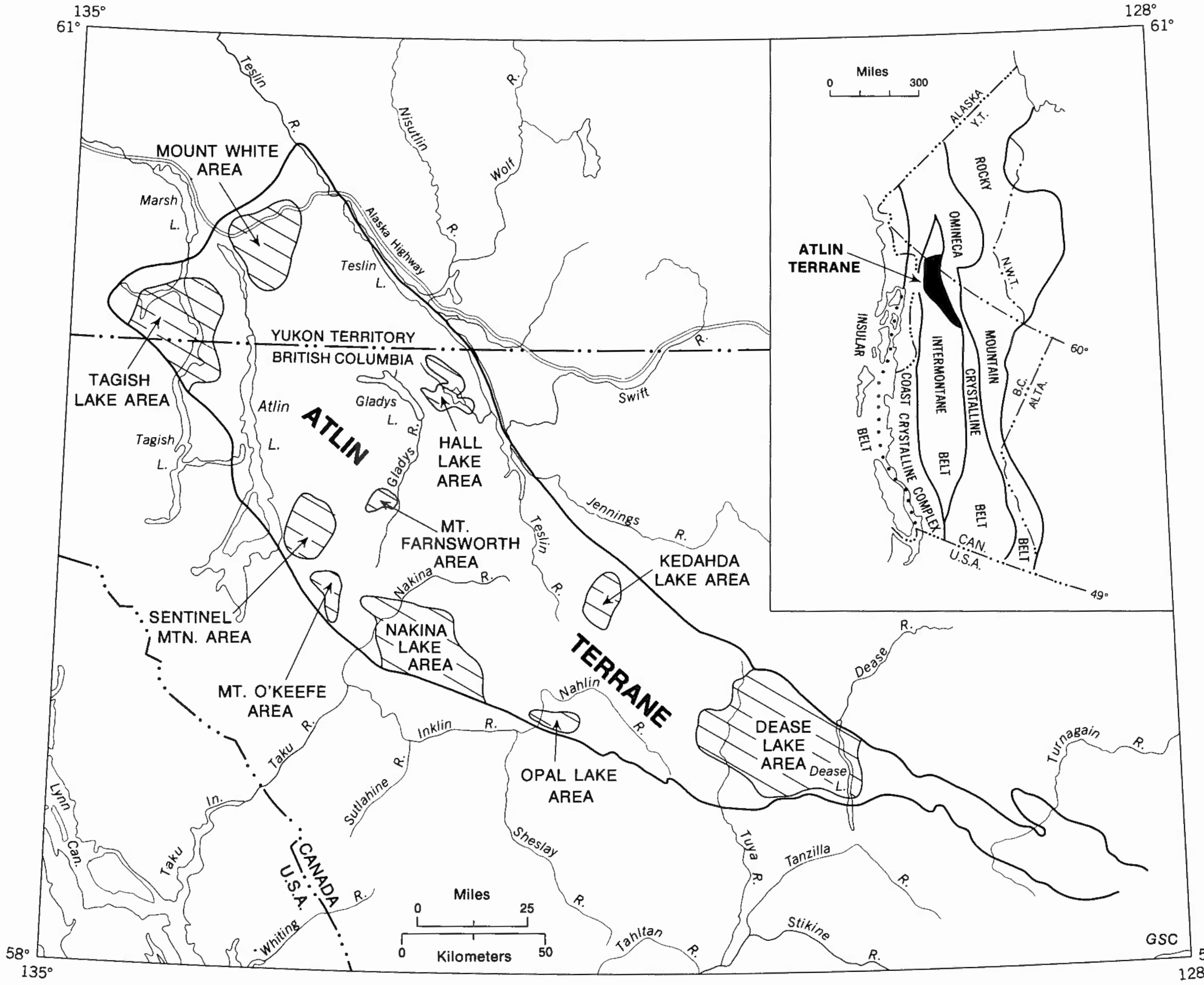


Figure 1. Index maps showing (a) location of the Atlin Terrane within the Canadian Cordillera, and (b) areas studied in detail within the Atlin Terrane.

UPPER PALEOZOIC ROCKS OF THE ATLIN TERRANE, NORTHWESTERN BRITISH COLUMBIA AND SOUTH-CENTRAL YUKON

INTRODUCTION

This report describes upper Paleozoic rocks of the Atlin Terrane of northern British Columbia and south-central Yukon. The terrane represents the largest continuous area of little metamorphosed rocks of this age in the western, eugeosynclinal part of the North American Cordillera and contains the oldest rocks known to date in the Intermontane Belt of the Canadian Cordillera. The results of the study outline the gross stratigraphy of the upper Paleozoic rocks, the possible structure and regional relationships of the Atlin Terrane, and illustrate the environment of deposition during the early stages of evolution of part of the western Canadian Cordillera.

The Atlin Terrane, formerly called the Atlin Horst by Wheeler (1959) and subsequently renamed (Wheeler and Gabrielse, 1972, p. 37) is a northwest-trending fault-bounded area underlain by upper Paleozoic chert, pelite, carbonate, volcanic and ultramafic rocks, Mesozoic granitic intrusives, and in a few places, latest Mesozoic or early Tertiary and Pleistocene volcanic rocks. It lies at the northern end of the Intermontane Belt between latitudes 58° and 60°30', and longitudes 128° and 135°, and is approximately 250 miles long by a maximum of 60 miles wide (Fig. 1).

The first recorded description of upper Paleozoic rocks in this region was given by Dawson in 1889 who dated them, and noted their general similarity to the Cache Creek Series in southern British Columbia. Further brief descriptions were made by Gwillim (1902), Cairnes (1913), Cockfield (1925), and Cockfield and Bell (1926). Watson and Mathews (1944) mapped part of the northeastern terrane on a scale of 1 inch to 4 miles and later the whole region was systematically mapped on this scale and published in a series of maps and reports each covering 1 degree of latitude and 2 degrees of longitude. From northwest to southeast these maps are Whitehorse (105D; Wheeler, 1961); Teslin (105C; Mulligan, 1963); Bennett (104M; Christie, 1957); Atlin (104N; Aitken, 1959); Jennings River (104O; Gabrielse, 1969); Tulsequah (104K; Souther, 1971); Dease Lake (104J; Gabrielse and Souther, 1962); and Cry Lake (104I; Gabrielse, 1962). In addition to these maps, unpublished theses done at the University of Wisconsin under L. R. Laudon by Bain (1964), Link (1965), and Ruedisili (1965), describe sections at the northwestern end of the Atlin Terrane.

During the investigation emphasis was placed on mapping small areas rather than measuring sections in the conventional manner, as stratigraphic sections are rarely obvious in these rocks. The key areas (Fig. 1) were selected initially from the geology shown on the reconnaissance maps and by consultation with the authors of these maps. As work progressed it was guided more and more by the results obtained. The most useful stratigraphic markers are the carbonate units. Non-recrystallized carbonates contain abundant foraminiferal faunas that are used both for correlation within the Atlin Terrane, where the sequence is characterized by rapid facies changes, and also to determine the stratigraphic top of carbonates containing a succession of faunas. In addition, the nature of the contacts between rock-units and especially those between carbonates and other units is critical. In many places these are probably bedding plane faults and are generally undetectable unless the lithologies or faunal successions are dramatically repeated or unless marked by exotic rock-types. These features can only be evaluated by mapping. The schematic sections given in this report are composite sections pieced together and interpreted from the lithological and paleontological data on the accompanying detailed maps.

The study was started in 1966, in the Dease Lake area at the eastern end of the terrane (Monger, 1969) and field work continued in 1967 and 1968. Fossils were identified mainly by C. A. Ross, Western Washington State College, Bellingham (fusulinids), B. L. Mamet, Université de Montréal (small foraminifera), and E. W. Bamber, Geological Survey of Canada's Institute of Sedimentary and Petroleum Geology (corals). The writer made preliminary identifications of fusulinids in the field and these identifications are used where no others are available. Able assistance in the field was provided by D. W. Morrow in 1966, J. Bamburak and C. Glanville in 1967, and B. Calder and P. Tredger in 1968.

SETTING OF THE ATLIN TERRANE

The Atlin Terrane forms the east side of the northern end of the Intermontane Belt of the Canadian Cordillera (Fig. 1), or more precisely, part of the northern end of the Hinterland Belt of the Columbian Orogen of Wheeler and Gabrielse (Wheeler and Gabrielse, 1972, p. 26). It is bounded on the northeast by the Omineca Crystalline Belt of mainly greenschist and higher grade metamorphosed upper Paleozoic strata and Mesozoic granitic rocks, that make up the core of the Cassiar Mountains, and by a narrow strip of lower Mesozoic volcanic and sedimentary rocks. On the southwest it is in contact with Lower Jurassic sedimentary rocks of the Intermontane Belt that overlie, to the west, Upper Triassic and older variably metamorphosed strata on the east side of the Coast Crystalline Complex.

The terrane is bounded nearly everywhere by faults (Fig. 2). On the northeast boundary, north of Dease Lake, the Thibert Creek Fault is nearly vertical, marked by small bodies of serpentinized peridotite, serpentinite and quartz-carbonate rock, and separates upper Paleozoic rocks from generally more deformed and metamorphosed Paleozoic strata and less deformed Mesozoic rocks to the northeast. The extension of this

Original manuscript submitted: February 10, 1974
Final version approved for publication: June 5, 1974

Author's address:
6th Floor, Sun Building,
100 West Pender Street,
Vancouver, B.C. V6B 1R8

fault zone to the northwest is largely obscured by Jurassic and Cretaceous granitic rocks or covered by Teslin Lake, but it is the boundary known as the Teslin Lineament, that separates sub-greenschist metamorphic facies rocks to the west from more metamorphosed rocks to the east. The southwestern boundary of the Atlin Terrane is delineated by a zone of reverse and thrust faults that in many places are associated with large bodies of peridotite and serpentinite. The dips of the fault planes vary; at the southeastern end they dip northerly at about 50 degrees or less (Gabrielse, 1962 and pers. comm.), whereas farther to the northwest the continuation of the same fault zone is known as the Nahlin Fault and dips steeply to the northeast or is vertical (Souther, 1971). The northern end of this fault zone, near Tagish Lake, is largely covered by probable lower Tertiary volcanic rocks. The northern extremity of the Atlin Terrane runs roughly northeasterly from Carcross to the north end of Teslin Lake, and in part is less well defined than the other boundaries. On the west, upper Paleozoic rocks are separated from Lower Jurassic strata by the alluvium-filled Crag Lake valley, interpreted by Wheeler (1961, p. 31) as being underlain by either a fault or an unconformity. To the east between Little Atlin Lake and Teslin Lake, poorly dated ('Permo-Triassic') altered basic volcanic rocks and ultramafic rocks are in contact with Triassic strata. The nature of the contact is not known.

The fault bounded character of this large area of upper Paleozoic rocks surrounded largely by younger rocks, gave rise to the term Atlin Horst (Wheeler, 1959). Subsequently the name was modified to Atlin Terrane by Wheeler and Gabrielse (1972, p. 37), because horsts are associated with normal, block faults, whereas at least the southwest-bounding faults of the terrane are thrust or reverse faults. The internal deformation of the terrane is compressional in nature and compatible in style and trend with the southeast bounding faults. The nature of these faults, the presence of parallel thrust faults in lower Mesozoic strata to the southwest (Souther, 1971, p. 45), and the great differences between upper Paleozoic rocks in the Atlin Terrane and those only 30 miles or more to the southwest on the east side of the Coast Mountains (Monger, 1970), makes it possible to speculate that the Atlin Terrane is, at least in part, a great thrust sheet. Overthrusting was to the southwest in late Middle or early Late Jurassic time, when the Atlin Terrane became a source area supplying detritus to the south (Souther and Armstrong, 1966, p. 177).

STRATIGRAPHY OF UPPER PALEOZOIC ROCKS IN THE ATLIN TERRANE

Stratigraphic Nomenclature

Upper Paleozoic rocks in the Atlin Terrane belong to the Cache Creek Group, a term used in this report for assemblages in the Intermontane Belt of the Canadian Cordillera between latitudes 50°30' and 60°30', composed mainly of chert, pelite, carbonate, basic volcanics and ultramafic rocks. Justification for the use of Cache Creek Group along much of the length of the Canadian Cordillera is given in Appendix B. This section is concerned with the nomenclature of subdivisions of the Cache Creek Group within the Atlin Terrane and some of the problems encountered in applying formal rock-stratigraphic nomenclature to these rocks.

Most rock bodies in the Atlin Terrane are discontinuous and lensoidal, features that are in part primary and depositional in origin and in part due to later deformation (Fig. 2). The lenses are commonly carbonate, or volcanic or ultramafic bodies in a chert and argillite matrix, but all combinations can be found. They range from the enormous carbonate masses near Tagish and Nakina lakes which are approximately 40 miles long and 20 miles wide, with an original thickness of 5,000 feet increased by later deformation, down to small carbonate pods a few feet or less in length. The apparent lack of any natural break in the size range of these bodies and their lack of continuity, makes it difficult to apply formal rock-stratigraphic nomenclature in a natural, as opposed to an arbitrary way, in all places, without great proliferation of stratigraphic names. One somewhat cumbersome solution is to distinguish rock-units solely on the bases of lithology, and where possible, age, as is done on most 1 inch to 4 mile reconnaissance maps. Another solution, adopted here for ease of reference and to emphasize similarities, is to name rock-units of the largest scale as formations. For example, the major carbonate bodies noted above near Tagish and Nakina lakes are clearly of formational status in their lithological uniformity and mappability and can be given the same name as they are homotaxial. This usage has historical precedent both within the Atlin Terrane, where Watson and Methews (1944) named two formations, and elsewhere, in the type area of the Cache Creek Group, where the major limestone body is distinguished as the Marble Canyon Formation (Duffell and McTaggart, 1952; Campbell and Tipper, 1971). Smaller rock bodies occurring as tongues in continuity with the named formations and isolated, internally and externally homotaxial rock bodies are given the same name as the formations. Relatively minor units, such as carbonate pods a few thousand feet long and a few hundred feet thick enclosed by a formation of another lithology such as chert, are considered to be members of the predominantly chert formation, even though they are mappable as discrete units on scales of 1: 25,000 feet or larger, or are coeval with a nearby carbonate formation and <u>may</u> have been a tongue of that formation prior to deformation. If these minor carbonates need to be named at a later date for reference purposes, then they can be regarded as members of the enclosing formation.

Different terms have been applied at different times to rock-units and associations in the various parts of the Atlin Terrane. This report attempts to apply a uniform terminology over the whole area, whilst retaining as much of the original usage as possible. Greenstone, ultramafic rock and slate that form the bedrock of the Atlin placer field were called the Gold Series by Gwillem (1902). Cairnes, in 1913, used Taku Group for Devonian (?) chert and slate below his Carboniferous (?) Braeburn limestone and Perkins Group volcanics near Tagish Lake at the northwestern end of the Atlin Terrane. "Braeburn limestone" was discarded by Cockfield and Bell (1926) and Wheeler (1961) as it is Upper Triassic in the type-locality in Laberge map-area and Permian (and Pennsylvanian) near Tagish Lake, and Wheeler (1961) included limestone, chert and slate in his redefined Taku Group of Permian and Pennsylvanian age. The Perkins Group consists in part of Upper Cretaceous or lower Tertiary volcanic rocks, and in part of volcanic rocks of the Gold Series, and so it is not used here. "Taku Group" is discarded for reasons given near the end of this report, and "Cache Creek Group" is employed instead. This follows both Dawson (1889), who noted the similarity between rocks near Cache Creek in southern British Columbia and those near Tagish Lake, and also Aitken (1959), who used the term in Atlin map-area.

The Cache Creek Group in the Atlin Terrane consists of five formations of sedimentary and volcanic rock, together with ultramafic rocks believed to be genetically related to one of the volcanic formations (Fig. 2). Watson and Mathews (1944) worked in the northeastern part of the terrane and used "Kedahda Formation" for quartzite (metachert), argillite, and chert with small amounts of interbedded volcanic rock and limestone, outcropping near Kedahda Lake, and "Teslin Formation" for Permian limestone, local volcanic rocks, and minor chert and argillite exposed in and near Teslin River valley. Monger (1969) studied the southeastward extension of these rocks in the French Range near Dease Lake, used these formations, introduced a new term "French Range Formation" for Permian volcanic rocks, and included all three formations in the Cache Creek Group. Although these formations, with very minor ultramafic rocks, make up the whole Cache Creek Group in the northeastern part of the terrane, other formations are present in the southwestern part. These are the Nakina Formation, a new term for a thick sequence of Mississippian and Pennsylvanian altered basic volcanic rocks, and the Horsefeed Formation, introduced for Mississippian to Permian carbonate containing minor lenses of volcanic rock, that is in part coeval with the Teslin Formation but not in demonstrable continuity with it. The Nakina Formation is defined on page 25 of this report and the Horsefeed Formation on page 31. In addition, there are extensive ultramafic rocks spatially associated with the Nakina Formation and perhaps genetically related to it, that are known in places as the Atlin intrusions (Aitken, 1959) and elsewhere as the Nahlin ultramafic body (Souther, 1971).

Facies Belts

The five formations and the ultramafic rocks are distributed in three facies belts, each running roughly parallel with the regional trend and probably grading laterally into one another (Fig. 2). The northeastern facies belt consists of carbonates of the Permian Teslin Formation, generally intercalated with and overlying volcanic rock of the French Range Formation, that in turn overlies Kedahda Formation chert and pelite. The central belt comprises mainly chert, pelite and minor volcanic sandstone of the Kedahda Formation and includes local pods and beds of lowest Permian limestone. The southwestern facies belt is dominated by locally very thick Mississippian to Permian carbonate of the Horsefeed Formation. This forms enormous lenses largely surrounded by chert and pelite of the Kedahda Formation. The oldest rocks, intercalated with the base of the Kedahda Formation, are Mississippian and Pennsylvanian basic volcanic rocks of the Nakina Formation, that in many places contain bodies of ultramafic rock.

Northeastern Facies Belt

The northeastern facies belt of the Atlin Terrane extends at least 150 miles from the east side of Dease Lake to the northern end of Teslin Lake and is up to 25 miles wide. The oldest unit, the Kedahda Formation, is generally poorly exposed and comprises thin-bedded chert, pelitic chert and siliceous pelite, in places metamorphosed to quartzite or quartzose phyllite, local intercalated volcanic sandstone, and minor carbonate. Fossils from the top of the formation are of mid-to Late Permian age, but the basal part is probably pre-Permian (Fig. 3-1, -2, -3). The base of the unit is nowhere exposed but commonly the top is gradational with the French Range Formation, an assemblage of altered basic flow rocks and pyroclasts. In turn, the Kedahda Formation underlies, grades into, and intertongues with the Teslin Formation, a carbonate of mainly Late and mid Permian age, but locally as old as Early Permian. The Teslin Formation is generally the most prominent of the three formations, and in areas of little relief such as the Teslin Valley, may be the only one exposed. Even though formation boundaries may be markedly disachronous (within the Permian), and the French Range Formation is strongly lensoidal and absent in places, yet the lithologies, general relationships and ages are similar along the 150-mile-length of the northwestern facies belt. The Permian rocks are cut by Mesozoic and Tertiary plutons and are overlain by Upper Cretaceous or lower Tertiary intermediate to acidic volcanic rocks near Hall Lake and by Pleistocene basalt west of the French Range.

The stratigraphy was studied near Dease Lake (area 1, Fig. 1), Kedahda Lake (area 2), and Hall Lake (area 3). Isolated traverses were made between these areas to ensure that there was continuity along the belt.

1. Dease Lake Area

Stratigraphy of upper Paleozoic rocks in the Dease Lake area has been previously described (Monger, 1969), and only a summary is included herein. Schematic stratigraphic sections (Fig. 3-1), show the relationships of the formations and the diachroneity of the unit boundaries even within this small area.

Figure 4.

Algalaminate dolomitic limestone. GSC Photo No. 202891-A.

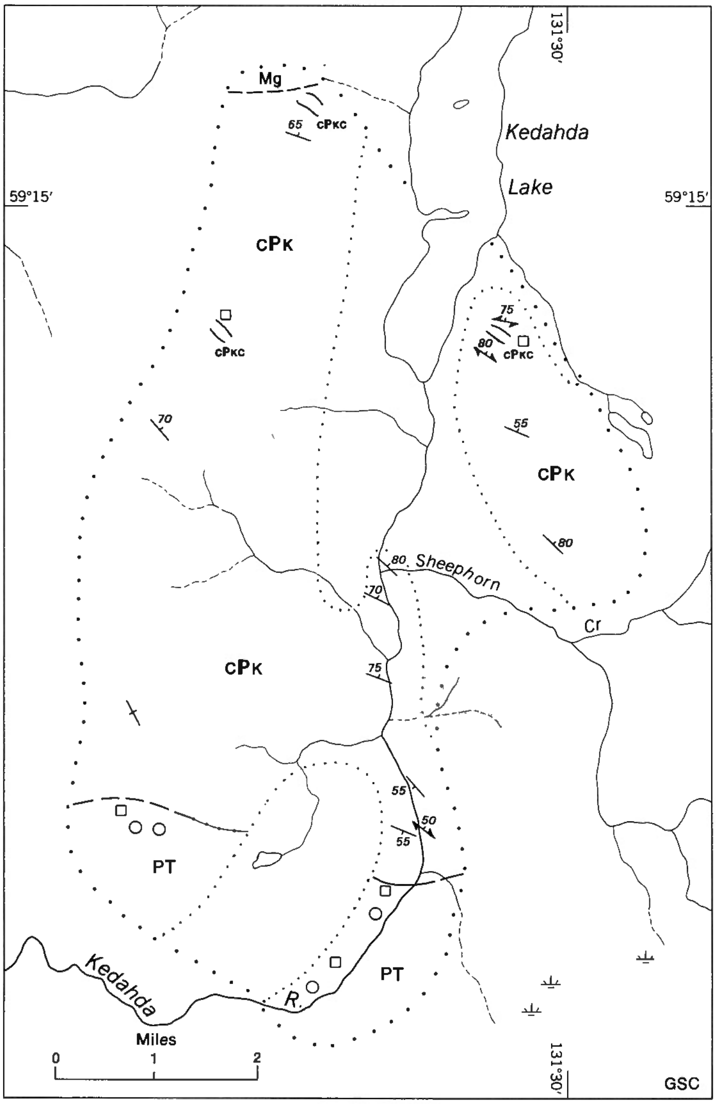


Figure 5.

Upper Paleozoic rocks near Kedahda Lake, southwestern Teslin map-area.

JURASSIC

Mg — *CHRISTMAS CREEK BATHOLITH; hornblende quartz diorite, granodiorite*

PERMIAN AND (?) OLDER

CACHE CREEK GROUP

PT — *TESLIN FORMATION: limestone*

cPκ — *KEDAHDA FORMATION: argillite, cherty argillite, bedded chert, minor intercalated silicified tuff and metabasalt;* **cPκc** *carbonate*

Bedding (inclined, vertical)

Cleavage (inclined)

Geological boundary (directly observed, approximate, assumed)

Limit of geological mapping (this report)

Limit of little or no outcrop

FUSULINID LOCALITIES

Late Permian (mid Guadalupian)

Early to Late Permian (later Leonardian-early Guadalupian)

Deformation and regional metamorphism are more intense in the Dease Lake area than farther northwest in the Atlin Terrane. There appear to have been two phases of deformation, with metamorphism related to the older one. The older phase, manifested by penetrative foliation and probably related isoclinal folds in the Kedahda Formation and in pyroclastic rocks of the French Range Formation, does not show up on the map-pattern unless as slides or thrust faults parallel to bedding (Fig. 2). The younger phase, shown mainly by crumpling associated with strain slip cleavage, appears to largely govern the map-pattern of the Paleozoic rocks. The regional metamorphic grade, characterized by mineral assemblages in the French Range Formation, is that of the pumpellyite-chlorite facies of Seki (1961, p. 421), transitional to the glaucophane schist facies, and is related to the early phase, as shown by parallelism of metamorphic minerals with the early foliation. This is a higher grade than revealed by most of the upper Paleozoic rocks in the Atlin Terrane, with the exception of some thermally metamorphosed rocks near Mesozoic plutons and greenschist grade volcanics near Tagish Lake.

i. Kedahda Formation. The Kedahda Formation has a minimum apparent thickness of 5,000 feet, but its base was not seen. It consists mainly of thin-bedded, pelitic chert and cherty pelite, interbedded in the northern part of the area with poorly foliated volcanic sandstones composed of abundant volcanic fragments and lesser amounts of plagioclase, mafic minerals, argillite chips and quartz. In the eastern and lower parts of the area, along Dease Lake, where the rocks are more metamorphosed than in the French Range, the typical lithology is a phyllitic quartzite or quartzose phyllite. Small limestone, dolomitic limestone and dolomite lenses, in places thin-bedded and fine-grained and elsewhere breccia, are locally interbedded with the pelitic chert and occur particularly at the top of the formation near and southwest of Mount Rath in the French Range, approximately 24 miles north-northwest of the settlement of Dease Lake.

The upper contact of the Kedahda Formation is conformable and locally gradational with the French Range Formation. In places, flow rocks overlie cherts and the contact is sharp, but elsewhere cherty tuff grades up into chert.

Fusulinids in the small carbonate bodies at the top of the formation indicate that the age of the upper part of the Kedahda Formation is mid to Late Permian. The only other fossils known are brachiopods and corals from some of these bodies and probable radiolaria in bedded chert at about the same horizon.

ii. French Range Formation. The term French Range Formation was proposed by Monger (1969, p. 10), to replace the McLeod series of Kerr (1925, p. 86a) as the latter contained two unrelated lithologically distinct units, one of Permian and one of lower Mesozoic age. The formation has an apparent thickness range from possibly 200 feet to more than 3,000 feet. On an areal basis, it consists of about equal parts of altered flow rocks and pyroclastic rocks, with minor intrusive equivalents, and intercalated chert and argillite. The flow rocks are typically grey-green metabasalt with local pillows but also include rare feldspar porphyries and highly altered siliceous flow rocks. Chemical analyses of the basalts are given in Table 1. The pyroclastic rocks range from agglomerates to more typical lithic tuffs. They are commonly well foliated and original textures range from agglomerates containing blocks more than three feet long to lapilli tuffs. Metamorphism has generally obliterated finer textures, and many originally very fine grained tuffs are now chlorite-muscovite-albite schists with no primary texture remaining.

The upper contact of the French Range Formation is conformable, gradational, and probably intertongues with carbonate of the Teslin Formation. The carbonate at the contact is typically of mid to Late Permian age (late Leonardian to early Guadalupian), but in places is as old as Early Permian (probably Leonardian, but could be Wolfcampian). The upper contact of the French Range Formation is thus markedly diachronous.

iii. Teslin Formation. The Teslin Formation ranges from 2,000 feet in thickness to less than 1,000 feet, although the upper contact is either a fault or the Recent erosion surface. It is commonly massive, with bedding rarely visible and contains several distinctive carbonate lithologies, although in perhaps 50 per cent of the formation these have been destroyed by recrystallization. At its base, near the contact with the French Range Formation, the carbonate is brown or tan weathering and tuffaceous. Higher in the formation carbonate breccias, containing angular lithic carbonate clasts and minor black chert fragments, are associated with the most typical carbonate lithology in the formation, a hard splintery, fetid, very fine grained to aphanitic, pale grey weathering, dark grey to black limestone and dolomitic limestone*. In a few places the rock contains fine laminations, probably of algal origin (Fig. 4), and 'injection structures' associated with features resembling mudcracks (Morrow, 1972). This lithology contains the youngest fossils in the formation, which are of late Guadalupian age. Similar lithologies are common in rocks of this age in the Teslin Formation of the northeastern facies belt.

The age of the Teslin Formation ranges from late Guadalupian to possibly Wolfcampian. Parts of it are thus contemporaneous with the upper part of the Kedahda Formation and the French Range Formation.

iv. Ultramafic Rocks. Ultramafic rocks, mainly serpentinite or talc-carbonate, occur along the Thibert Creek Fault, which bounds the upper Paleozoic rocks to the north. The largest ultramafic body at the north end of Dease Lake, consists of serpentinized peridote, altered gabbro and minor diabase. These rocks are in probable fault contact with enclosing cherts.

*Carbonate terminology used in this report follows the classification of Powers, 1962, unless otherwise stated.

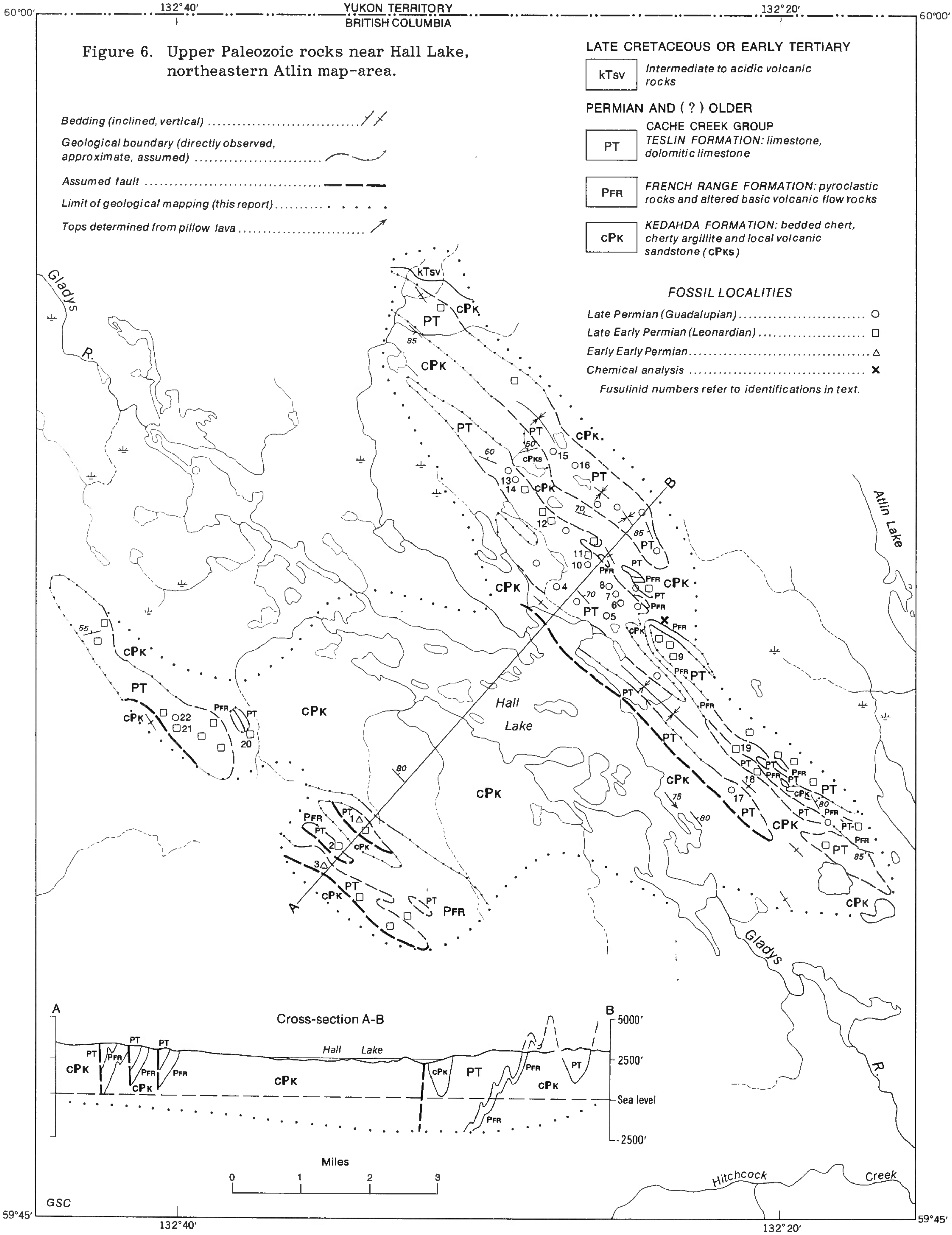


Figure 6. Upper Paleozoic rocks near Hall Lake, northeastern Atlin map-area.

West of the French Range is mainly a high rolling upland of elevation about 4,500 feet known as the Kawdy Plateau (Holland, 1964, p. 51), with much of the local relief provided by Pleistocene basalt and agglomerate centres built up above the general level of the plateau. Paleozoic rocks underlying this terrain are generally very poorly exposed and occur mainly as outcrops along incised creek valleys.

Metabasalt, pyroclastic rock, carbonate and, locally, isoclinally folded chert and pelitic chert are exposed in the valleys of the headwaters of Kawdy Creek, approximately 4 miles south-southeast of Kawdy Mountain. In places where the carbonate is little recrystallized, a common lithology is the very pale grey weathering, dark grey, fetid, aphanitic limestone and dolomitic limestone characteristic of the younger part of the Teslin Formation in the French Range. Large poorly preserved fusulinids (probably *Yabeina* of Late Permian age) were found at two localities. Elsewhere, near the contacts with volcanic rocks, the carbonate is tuffaceous. The degree of deformation of the cherts, and the development of foliation in the tuffs, is similar to that in the French Range. Blue amphibole, probably crossite, is known from volcanic rocks at two localities in Metahag Creek, which is only 12 miles southeast of Kawdy Mountain (Monger, 1969). It seems likely, therefore, that rocks of similar stratigraphy and metamorphic grade extend northwestwards from the French Range at least as far as Kawdy Mountain, which is 45 miles west-northwest of Dease Lake.

Northwest of Kawdy Mountain exposures are generally poor, being limited to higher ground on the southwest flank of the Atsula Range, whose core consists of mainly Mesozoic granitic plutons, and to scattered outcrops in the broad, open valleys of the Teslin and Kedahda rivers and Glundebery Creek. Most exposures near the Atsula Range are chert, metaquartzite and pelite with local metabasalt of the Kedahda Formation. Exposures in the valleys are small, isolated ridges of limestone, correlated with the Teslin Formation (Watson and Mathews, 1944; Gabrielse, 1969). Dark grey, fetid carbonates, 4.8 miles southwest of Metah Mountain, contains Guadalupian neoschwagerinid fusulinids (H. Gabrielse, pers. comm.).

2. Kedahda Lake Area

The succession near Kedahda Lake, which is located about 27 miles southeast of the southern end of Teslin Lake (Fig. 2), differs from that in the French Range and near Hall Lake, as the French Range Formation is absent or is represented only by minor tuff and metabasalt within the Kedahda Formation (Fig. 3-2). The upper part of the Kedahda River valley, between 2 and 6 miles below the outflow of Kedahda Lake, contains good exposures of these rocks and the higher areas on both sides of this valley contain scattered exposures (Fig. 5).

i. Kedahda Formation. The Kedahda Formation, in its type-area near the south end of Kedahda Lake, is dark grey to black argillite, in places with a marked slaty cleavage. Farther south, pale to medium grey or brownish grey, thin-bedded chert with argillaceous partings and cherty argillite is the predominant rock-type and is more typical of the formation elsewhere in this belt (Fig. 7).

Volcanic rocks within the Kedahda Formation are thin bedded, greenish silicified tuffs, exposed in the Kedahda valley about 4 miles south of the outflow of the lake. Small exposures of tuff, volcanic sandstone and amygdaloidal metabasalt containing limestone fragments occur near the confluence of Sheephorn Creek and Kedahda River.

Dark grey weathering, dark grey, argillaceous aphanitic limestone, in places sheared and recrystallized and elsewhere massive and pale grey weathering, forms isolated units up to 100 feet thick on the high areas on both sides of the south end of Kedahda Lake. This limestone contains probable late Leonardian or early Guadalupian neoschwagerinid and schwagerinid fusulines and small crinoid columnals. Its argillaceous character and occurrence within the Kedahda Formation suggests that it is interbedded with this formation. However, the contacts were not seen and it is of similar lithology and contains similar fossils as the basal part of the Teslin Formation to the south. Thus it may equally well represent the basal part of the Teslin Formation, folded or faulted into the Kedahda Formation.

The Kedahda Formation in the type area appears to be far less deformed than in the French Range. In more pelitic parts a fracture or slaty cleavage prevails, and the argillaceous laminae in bedded cherts contain a fracture cleavage, in contrast with the phyllitic cleavage seen elsewhere. In many places bedding is little deformed, and deformation appears to be mainly kinking and crumpling associated with crenulation cleavages, concentrated in a few zones. The crumples show a predominant sense of overturning to the southeast.

The formation is in probable stratigraphic contact with the basal part of the Teslin Formation. The contact is visible to within 30 feet on the plateau 2.5 miles west of the Kedahda River valley, and appears to be gradational with the Teslin Formation as the carbonate contains shaly beds near the contact. Elsewhere, in the Kedahda River valley, the contact is marked by a breccia composed of carbonate clasts in a pelitic matrix.

The Kedahda Formation is at least in part of mid to Late Permian age as it is in probable gradational contact with basal Teslin limestone of this age, and possibly contains coeval interbeds of carbonate elsewhere.

ii. Teslin Formation. The formation forms the walls of Kedahda River valley where it turns and debouches into the broad Teslin Valley and forms the north side of the Teslin Valley for about 3 miles farther west. This is the type area of the formation (Watson and Mathews, 1944, p. 17).

Thicknesses are not known. Bedding is generally massive so that attitudes cannot be measured and

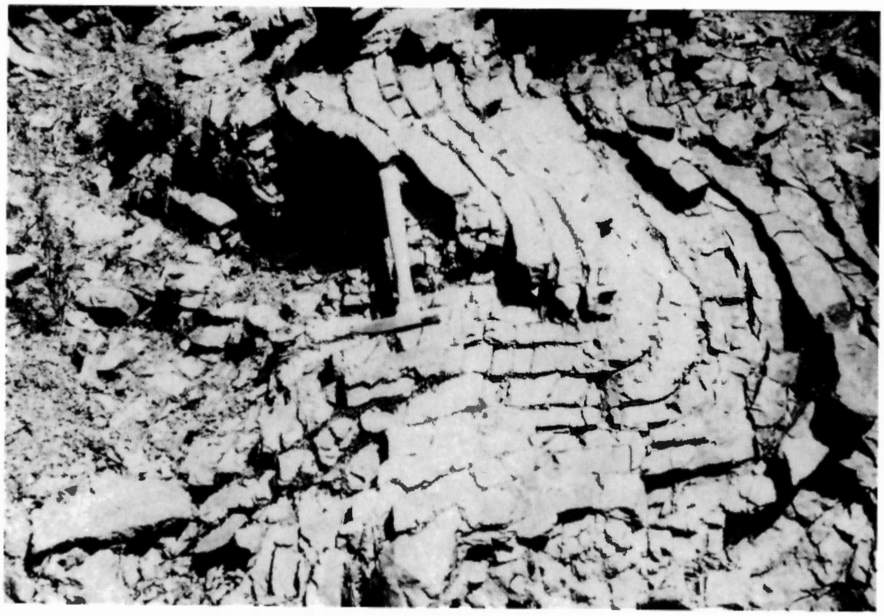


Figure 7.

Open fold in bedded chert of the Kedahda Formation. GSC Photo No. 202891-B.

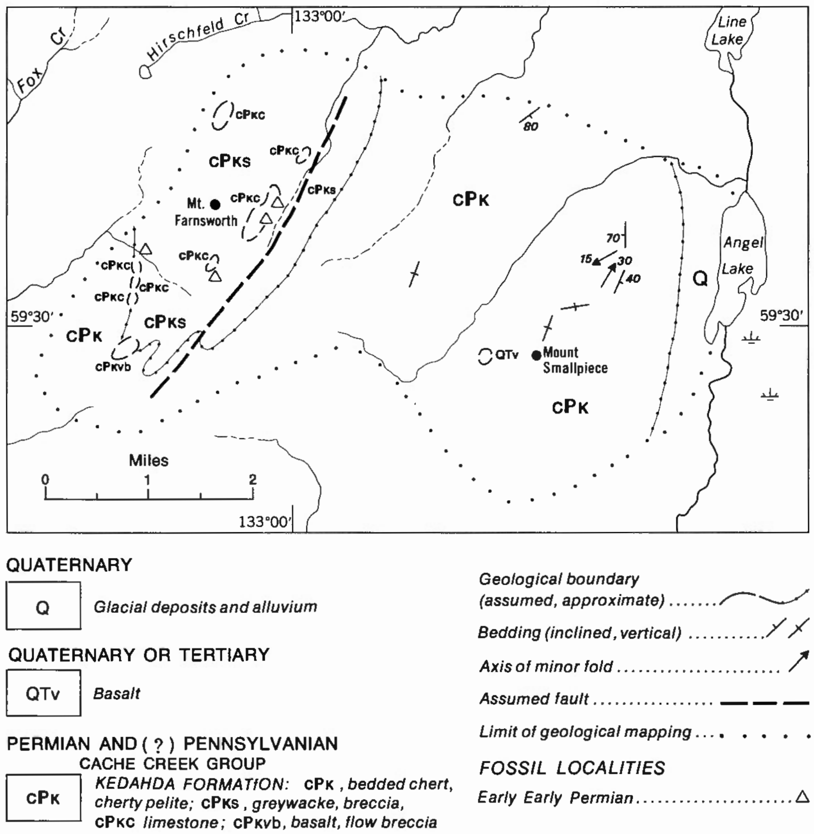


Figure 8. Upper Paleozoic rocks near Mount Farnsworth, central Atlin map-area.

not enough fossils have been collected to demonstrate repetitions.

The basal part of the limestone is argillaceous, and is overlain by a massive medium grey limestone coquina, with abundant schwagerinid and neoschwagerinid fusulinids, similar lithologically and faunally to coquinas in the lower part of the Teslin Formation near Hall Lake. Above is a medium to pale grey weathering, dark grey to black aphanitic limestone, with abundant fusulinids concentrated in certain horizons. The upper contact of the carbonate is not known.

The age of the formation is Guadalupian, although the basal part may be as old as Leonardian. Fossils found well within the limestone about 6 miles below the outflow of Kedahda Lake are of probable mid Guadalupian age (H. Gabrielse, pers. comm.).

To the northwest, the Teslin Formation strikes into the broad Teslin valley, outcrops as small ridges on the flat valley floor and contains lenses of volcanic rock. Fossils collected by Watson and Mathews (1944, p. 17) include crinoid stems, corals and both schwagerinid and neoschwagerinid fusulinids (*Yabeina*?) and leave little doubt that these rocks are the equivalent of the unit south of Kedahda Lake. In addition, Watson and Mathews (1944, p. 17) reported that the Teslin Formation apparently lies conformably on the Kedahda Formation about 20 miles northwest of Kedahda Lake. From there to the Hall Lake area, a distance of 20 miles, exposures of upper Paleozoic rocks are extremely sparse.

3. Hall Lake Area

Upper Paleozoic rocks in the Hall Lake area (Fig. 3-3) are similar to those near Dease Lake. Primary features are better preserved than near Dease Lake because the amount of deformation and metamorphism is less. Unfortunately, the rocks are not so well exposed. The average elevation near Hall Lake is between 3,000 and 3,500 feet, about 1,500 feet less than the French Range near Dease Lake. Prominent ridges of carbonate of the Teslin Formation strike northwesterly, their relief enhanced by differential erosion during glaciation, but chert and minor amounts of volcanic rock between the ridges are commonly poorly exposed and contacts have only been seen at a few localities (Fig. 6).

The general structure of the area is believed to be a series of synclines and anticlines with near vertical axial surfaces, as first suggested by Aitken (1959), but with a sense generally reversed from his interpretation, as the younger rocks, mainly carbonates, occupy the cores of the synclines (Fig. 6). Only those faults necessary to make a sensible interpretation of the structure are shown, but the possibility cannot be discounted that there are numerous faults parallel or subparallel with bedding.

i. Kedahda Formation. Areally this is the most extensive unit but is generally seen only as small scattered outcrops in lower areas. The predominant lithology is pale grey to brown weathering, pale grey to greenish grey ribbon chert occurring in beds 1 to 3 inches thick, separated by argillaceous partings that in places are phyllitic. There seems to be less argillaceous material in this area than near Dease Lake, although this could be partly a function of exposure.

Volcanic sandstone is exposed about 2¼ miles north of the northernmost part of Hall Lake. In outcrop the rock is massive, hard, grey-green with dark argillite chips and feldspars, and grades locally into pale greenish grey siltstone, argillite and cherty argillite. The sandstone is unsheared, in contrast with comparable rocks near Dease Lake that have a penetrative foliation. It consists mainly of angular rock fragments altered to semiopaque, optically irresolvable material, in some of which are volcanic textures, chert and argillite fragments, and minor angular and rounded quartz grains mainly as unstrained single crystals, albitic feldspar, hornblende and epidote. In composition it is very similar to sandstone from the Dease Lake area (Monger, 1969, Table 1).

Commonly, bedding is vertical or very steep and the only deformational structures seen are warps and open angular folds within the cherts, although small scale folds occur at a few localities, as on the small peninsula 1 mile north-northeast of the outlet of Hall Lake. The fold style is very irregular and ranges from small isoclinal folds to open crumples and the fold axes show a wide variation even within one small area.

Contacts between the Kedahda Formation and other Paleozoic rocks have only been observed directly in a few places. Two miles north of the outlet of Hall Lake, greenish grey bedded chert grades into fine-grained grey green cherty tuff. The volcanic rocks are in gradational contact with basal, mid Permian limestone (fossil locality 18). About 2 miles northwest of the northernmost part of Hall Lake, the basal limestone, of Late Permian age (similar fossils to those at locality 15), contains chert nodules, and is separated by a covered interval of a few feet from conformable, bedded chert. In both localities, the chert is older than the carbonate, and the upper contact is thus diachronous. Near the northernmost part of Hall Lake, chert is in apparent contact with the youngest part of the limestone in the area (near fossil locality 4). It is not known if the contact is a fault or is stratigraphic, but for structural simplicity the latter is assumed, this making chert the youngest Paleozoic lithology in the area, as well as the oldest. It is overlain unconformably only by Late Cretaceous or early Tertiary volcanic rocks near Dawson Peaks. Cherts of the Kedahda Formation are both older and younger than carbonate of the Teslin Formation elsewhere. They conformably underlie Upper Mississippian carbonate of the Horseteed Formation and unconformably overlie Upper Permian carbonate of the same formation in the Nakina Lake area.

No fossils are known from the Kedahda Formation in the Hall Lake area, and it cannot be dated directly. Judging from its relationship to the limestone, however, it is at least partly Permian.

ii. French Range Formation. The French Range Formation is closely associated with basal Permian

TABLE I

Chemical Analyses* of Volcanic Rocks from the Atlin Terrane

Specimen No.	Anal. No.	Location: Area	Location: Fig. No.	Unit	Mode of Occurrence	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	CO_2	H_2O	Total
MV66-25	1870	Dease Lake		French Range Fm.	Massive Flow Rock	44.8	13.1	0.7	11.2	6.1	8.9	4.3	<0.01	2.31	0.22	0.19	2.5	3.7	98.1
MV66-99a	1871	Dease Lake		French Range Fm.	Massive Flow Rock	46.3	15.2	3.8	7.0	8.5	8.8	3.4	0.7	1.65	0.14	0.18	0.1	4.2	100.0
MV66-159	1872	Dease Lake		French Range Fm.	Massive Flow Rock	46.6	16.2	2.3	7.9	6.8	11.4	2.1	2.4	1.35	0.12	0.22	0.2	0.6	98.2
MV66-216a	1874	Dease Lake		French Range Fm.	Massive Flow Rock	42.8	14.7	3.1	9.2	8.8	9.7	2.9	0.2	1.62	0.12	0.18	<0.01	5.1	98.4
MV66-221	1875	Dease Lake		French Range Fm.	Massive Flow Rock	47.0	15.4	0.5	10.1	7.6	4.8	3.3	1.0	4.47	0.73	0.15	0.3	5.4	100.8
MV66-251	1876	Dease Lake		French Range Fm.	Pillowed Flow Rock	49.6	16.4	0.6	8.8	4.8	8.6	4.0	0.9	1.35	0.10	0.14	<0.01	3.0	98.3
MV67-585a	2808	Opal Lake	9	Nakina Fm.	Massive Flow Rock	50.0	17.1	2.7	7.5	5.6	8.4	4.1	0.2	1.12	0.09	0.18	0.1	3.5	100.6
MV67-590	2809	Nakina Lake	10:1	Nakina Fm.	Massive Flow Rock	46.3	16.9	3.0	6.8	5.0	11.0	2.5	1.4	1.16	0.13	0.16	1.4	4.5	100.3
MV67-603	2810	Nakina Lake	10:2	Nakina Fm.	Massive Flow Rock	51.4	16.9	4.6	5.5	3.7	9.5	3.8	0.6	1.86	0.18	0.19	0.4	4.0	102.6
MV67-617	2811	Nakina Lake	10:3	Nakina Fm.	Pillowed(?)Flow Rock	50.4	19.1	2.9	7.5	4.2	5.8	3.8	1.1	1.26	0.10	0.18	0.5	5.5	102.3
MV68-804	2821	Nakina Lake	10:4	Nakina Fm.	Massive Flow Rock	48.8	15.3	2.4	8.9	6.8	8.7	2.7	0.7	1.61	0.13	0.19	0.1	4.3	100.6
MV68-815a	2822	Nakina Lake	10:5	Nakina Fm.	Massive Flow Rock	50.7	15.6	2.6	8.3	6.6	7.7	3.4	1.1	1.46	0.11	0.20	0.1	3.0	100.9
MV67-641	2812	Mt. O'Keefe	15	Nakina (?) Fm.	Massive Flow Rock	48.1	18.2	8.4	4.7	2.7	10.9	3.0	0.9	2.01	0.24	0.19	<0.01	2.6	101.9
MV67-654c	2813	Hall Lake	7	French Range Fm.	Massive Flow Rock	44.4	16.0	2.0	12.6	7.2	6.5	1.9	0.7	3.80	0.34	0.16	0.2	6.4	102.2
MV68-759b	2815	Sentinel Mtn.	16:1	Nakina (?) Fm.	Diabase Sill	47.9	17.3	1.4	6.5	5.4	8.7	4.5	1.0	2.64	0.52	0.15	2.5	3.7	102.1
MV68-759c	2816	Sentinel Mtn.	16:2	Nakina (?) Fm.	Diabase Sill	53.9	15.2	3.0	6.8	6.7	6.5	3.5	0.3	1.12	0.10	0.22	0.1	4.5	101.9
MV68-759e	2817	Sentinel Mtn.	16:3	Nakina (?) Fm.	Flow Breccia	48.1	17.0	2.8	9.5	7.2	5.8	4.0	0.1	1.82	0.14	0.16	0.1	5.0	101.7
MV68-761	2818	Sentinel Mtn.	16:4	Nakina (?) Fm.	Diabase Sill (?)	48.8	15.7	1.4	9.1	8.7	8.0	2.6	1.7	0.89	0.05	0.14	0.6	4.2	101.9
MV68-761b	2819	Sentinel Mtn.	16:5	Nakina (?) Fm.	Diabase Sill (?)	50.1	13.8	1.5	8.8	8.0	10.6	2.6	0.3	0.96	0.06	0.17	<0.01	3.5	100.4
MV68-767	2820	Sentinel Mtn.	16:6	Nakina (?) Fm.	Massive Flow Rock	45.8	18.4	1.3	9.6	6.9	5.3	2.5	3.2	2.93	0.37	0.18	0.6	4.6	101.7
MV68-821	2823	Sentinel Mtn.	16:7	Nakina (?) Fm.	Diabasic Sill	48.6	14.0	1.9	9.2	8.5	11.9	1.5	0.3	1.15	0.08	0.18	0.1	3.8	101.2
MV68-821b	2824	Sentinel Mtn.	16:8	Nakina (?) Fm.	Pillowed Flow Rock	49.4	15.4	1.5	6.7	5.6	13.8	2.1	<0.01	0.85	0.06	0.14	0.6	4.1	100.3
MV68-847	2826	Tagish Lake	18:11	Flow in Horsefeed Fm.	Massive Flow Rock	46.3	15.4	3.9	4.5	10.3	9.1	2.3	0.1	1.85	0.34	0.17	0.6	4.6	99.5
MV68-873b	2827	Tagish Lake	18:2	Flow in Horsefeed Fm.	Massive Flow Rock	44.0	15.1	5.1	4.3	11.2	10.0	1.1	1.0	0.90	0.13	0.15	1.1	4.9	99.0
MV68-880	2828	Tagish Lake	18:3	Nakina Formation?	Massive Flow (?)	46.5	16.3	1.0	10.1	8.1	9.5	3.0	0.2	1.63	0.14	0.18	1.0	3.1	100.7
MV68-880b	2829	Tagish Lake	18:4	Nakina Formation?	Massive Flow (?)	48.2	14.9	2.0	8.9	8.5	7.8	2.3	<0.01	1.40	0.11	0.20	1.2	5.1	100.6
Average 26 Analyses						47.9	15.9	2.6	8.1	6.9	8.8	3.0	0.8	1.73	0.18	0.17	0.55	4.1	

* Analyses done by the rapid method by S. Courville in the laboratories of the Geological Survey of Canada.
Localities for Dease Lake area analyses in G.S.C. Paper 68-48, Table III.

TABLE II

Comparison of the Chemistry of Average Basalt from the Atlin Terrane, with Average Spilite, Normal Tholeiitic and Alkaline Basalt and Ocean Floor Basalts

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	CO_2	H_2O
Average, 26 analyses, basalt and diabase, Atlin Terrane	47.9	15.9	2.6	8.1	6.9	8.8	3.0	0.8	1.73	0.18	0.17	0.55	4.11
Average, 92 analyses, reported 'spilite' (Vallance, 1960)	49.65	16.00	3.85	6.08	5.10	6.62	4.29	1.28	1.57	0.26	0.15	1.63	3.49
Average, 137 analyses, normal tholeiitic basalt and diabase (Nockolds, 1954)	50.83	14.07	2.88	9.00	6.34	10.42	2.23	0.82	2.03	0.23	0.18	---	0.81
Average, 96 analyses, normal alkali basalt and diabase (Nockolds, 1954)	45.78	14.64	3.16	8.73	9.39	10.74	2.63	0.95	2.63	0.39	0.20	---	0.76
Average, 94 analyses, selected ocean floor basalts (Cann, 1971)	49.61	16.01	---	11.49	7.84	11.32	2.76	0.22	1.43	0.14	0.18	---	---

carbonate, and outcrops mainly east and southwest of Hall Lake, just below or on the summits of the carbonate ridges. It probably nowhere reaches more than 1,000 feet in thickness.

The formation consists of two lithologies, pyroclastic rocks and metabaslat, with the former probably the more abundant. The pyroclastic rocks are green, yellow green or maroon, and range from very fine grained, chert-like rocks, through common lithic tuffs to agglomerate, with clasts generally up to three inches in diameter but ranging up to 2 feet. The fragments typically have vesicular or scoriaceous textures, which in thin sections are highly altered, semiopaque material. Other fragments are typical, fine grained metabasalt (see below), or else a prominent feldspar porphyry with green altered feldspar phenocrysts up to about ½ inch long in a maroon matrix. In thin section, the phenocrysts, originally zoned, are largely albite, sericite and calcite. The matrix is trachytic. A very similar rock occurs as fragments in pyroclastic rocks in the Dease Lake area (Monger, 1969, p. 14).

In several places the pyroclastic rocks contain abundant carbonate clasts, particularly near or at the contact with the overlying carbonate. Two miles southwest of Hall Lake (fossil locality 1), is a breccia consisting of about 70 per cent angular dolomitic limestone boulders up to two feet long, that are a fusulinid and crinoidal coquina with a dolomitic limestone matrix, and about 20 per cent maroon weathering, fine-grained and vesicular volcanic fragments in a calcareous tuff matrix. The carbonate blocks contain the oldest fossils in the area, of Wolfcampian age (earliest Permian), and in their general lithology resemble some of the carbonates near the top of the Kedahda Formation in Dease Lake area.

Many of the pyroclastic rocks are completely unsheared, in contrast with rocks of similar primary lithology in the French Range Formation near Dease Lake that are typically semischists or schists.

Metabasalt is a less prominent part of the formation and is typically massive, fine-grained rock locally with chlorite amygdales. No pillows were seen. In thin section it consists of a mesh of randomly oriented feldspar ghosts, now mainly albite, epidote and chlorite with interstitial chlorite, opaque minerals and local stilpnomelane and albite, calcite and chlorite veins and amygdales. Chemically, this rock is a basalt (Table 1).

The formation is in gradational and probably interfingering contact with the Teslin and Kedahda formations. Leonardian (mid Permian) carbonate east of Hall Lake is commonly buff weathering and tuffaceous near contacts with the volcanic rock, and lenses of carbonate occur within the volcanic sequence. In a few places, the volcanic rocks grade into bedded cherts of the Kedahda Formation.

The French Range Formation in the Hall Lake area is of Leonardian age, as it is in gradational contact with fossiliferous limestone (Fig. 3). It is not present in places where the lower contact of the limestone is of Guadalupian age.

iii. Teslin Formation. The Teslin Formation is the best exposed, most prominent unit in the area, forming most of the ridges. It consists entirely of carbonate and contains an abundant, readily dateable, fusulinid fauna (Appendix A, Table 1). It has an apparent maximum thickness in the order of 1,000 feet, but in places is probably lenticular.

The formation contains several distinctive primary carbonate lithologies, but in many places is recrystallized, although the amount of recrystallization is less than in the Teslin Formation near Dease Lake. The basal part commonly consists of brown to buff weathering tuffaceous calcarenite to calcarenitic limestone, with abundant schwagerinid fusulinids, small crinoid columnals and rare small rhomboporoid bryozoa. A second, distinctive lithology is a dark calcarenitic limestone composed of a fine lime mud matrix containing small shell fragments, probably ostracods, foraminifera, and fragments of sparry calcite. Included are beds up to about 2 feet thick with small neoschwagerinid fusulinids so abundant that in places the rock is a coquina. The limestone contains characteristic laminations of sparry calcite best displayed on the ridge 2 miles north of the northernmost part of Hall Lake (fossil locality 14). In thin section, the laminations consist of calcite crystals with their 'C' axes oriented normal to the lamination plane at the margins and a randomly oriented mosaic of sparry calcite in the interior. These laminations are possibly traces of seaweed fronds (*see* Horowitz and Potter, 1971, p. 59, fig. 4). Laterally this lithology seemingly grades into a pale grey massive coquina of crinoidal and neoschwagerinid fusulinid fragments, scattered through a finely crystalline matrix with local chert nodules. The carbonate containing the youngest fossils in the area is pale grey weathering, dark grey to black, fetid, hard, splintery aphanitic limestone or dolomitic limestone with local fine laminations probably of algal origin. Fossils are large neoschwagerinid fusulinids which may be rare or abundant. This lithology is very similar to that of the same age in the French Range near Dease Lake from near Kedahda Lake and elsewhere in the Teslin Valley, and is the most characteristic carbonate lithology in the northeastern belt of the Atlin Terrane.

The older part of the unit in the Hall Lake area, of Leonardian age, is gradational with the French Range Formation, whereas the younger part of Guadalupian age overlies chert of the Kedahda Formation. It also seems probable that bedded chert overlies the whole formation, although this is based largely on the assumption that no faults occur between the Teslin and Kedahda formations.

Central Facies Belt

The central facies belt of the Atlin Terrane consists mainly of bedded chert and cherty pelite, locally interbedded volcanic sandstone and greywacke, and minor pods and lenses of volcanic rock and carbonate, all of which are included in the Kedahda Formation. The carbonates contain Mississippian fossils in places, and elsewhere, Lower Permian fossils. The latter are coeval with the oldest part of the Teslin Formation to the north, and parts of the thick Permo-Carboniferous Horsefeed Formation to the southwest. The Mount Farnsworth area (4) provides a typical range of lithologies for this belt and the Sentinel Mountain area (8) marks the transition from the southwestern facies belt to the central one.

4. Mount Farnsworth Area

Lithologies in the Mount Farnsworth area included in the Kedahda Formation are, in order of decreasing abundance, bedded chert, greywacke, limestone and altered basalt (Fig. 8).

Chert underlies the high ridge west of Angel Lake and typically is rusty weathering, pale grey, relatively pure with little pelitic material, and forms beds 2 to 3 inches thick. In places it is brecciated and elsewhere is folded into tight but generally irregular folds.

Greywacke, distinguished from volcanic sandstone by its high content of chert and carbonate clasts, underlies much of the area near Mount Farnsworth. It is predominantly grey green, very fine grained and hard, with locally abundant chert fragments. Interbedded with it are rare brown weathering cherty carbonate lenticles. Coarse breccia with clasts up to 4 inches in diameter outcrops in the creek south-southwest of Mount Farnsworth. It contains clasts of up to 30 per cent pale grey green, pale grey chert fragments, some of which contain radiolaria, and lesser amounts of dark grey cherty pelite, green basic to intermediate volcanic rock and rare, angular, clear quartz grains in a locally calcitized finer matrix of similar composition. These sandstones are undeformed internally but the grain boundaries in many of them are indistinct.

Limestone forms prominent outcrops surrounded by greywacke or chert that vary in size from small isolated pods up to massive limestone bodies one half mile long and several hundred feet thick. The limestone is largely pale grey or brownish weathering, pale to medium grey and is mainly finely recrystallized or porcelaneous. Preserved primary textures are of pelletal, fusulinid calcarenitic limestone.

An outcrop of altered basalt southwest of Mount Farnsworth appears to be a small pod in the enclosing greywacke and has a breccia texture.

The age of all fossils found in the limestone pods is probably Early Permian although the possibility exists that some may be latest Pennsylvanian (Aitken, 1959, Fossil Locality 6). Presumably the age of the enclosing greywacke and chert is similar.

Southwestern Facies Belt

The southwestern facies belt of the Atlin Terrane is about 140 miles long and up to 30 miles wide, and contains the most complete sections in the Cache Creek Group (Fig. 2). Oldest rocks are the Nakina Formation of mainly massive metabasalt of Mississippian and Pennsylvanian age which is closely associated spatially with peridotite, serpentinite and local gabbroic rock. It is overlain, apparently conformably, by bedded chert, pelite and minor sandstone of the Kedahda Formation that in places contains carbonate pods with Mississippian and Pennsylvanian fossils. Above, conformable with, and laterally equivalent to parts of the Kedahda Formation is the Horsefeed Formation, comprising mainly carbonate of Late Mississippian, Pennsylvanian and Permian ages. Finally, chert, pelite, and volcanic sandstone of the Kedahda Formation unconformably overlies the Horsefeed Formation locally. Northeastwards this assemblage grades laterally into the dominantly chert, argillite and sandstone sequence of the central facies belt. Southeastwards it is either in fault contact with lower Mesozoic greywacke or else is overlain by probable Upper Cretaceous or lower Tertiary volcanic rock.

The stratigraphy was studied near Opal Lake (area 5, Fig. 1), Nakina Lake (area 6), Mount O'Keefe (area 7), Sentinel Mountain (area 8), Tagish Lake (area 9) and Mount White (area 10).

5. Opal Lake Area

Rocks correlated with the Nakina, Kedahda and Horsefeed formations, together with ultramafic rocks, are exposed at "Opal Lake"*, 5 miles east of Tedideech Lake and 6 miles southeast of the confluence of Chastot Creek and Nahlin River in northeast Dease Lake map-area (Fig. 9). Exposure in this area is generally not good and contacts between the various units are probably mainly faults, as shown by Gabrielse and Souther (1962). The area is significant from the point of view of this report only in that it appears to be the southeastern limit of the southwestern facies belt in the Atlin Terrane. Rocks in this area are briefly described below, from south to north.

The ultramafic rock is serpentinite in vertical or steeply dipping fault contact with Lower Permian carbonate. Along the fault the serpentinite is highly fractured, glassy (opalized) and at Opal Lake contains the nickel mineral millerite (Ann. Rept., B.C. Dept. Mines, 1957, p. 5). Two miles west of Opal Lake the serpentinite contains a probable fault slice of unsheared metabasalt. These ultramafic rocks are physically continuous with the Nahlin ultramafic body in Tulsequah map-area (Souther, 1971).

Carbonate of the Horsefeed Formation underlies two ridges northwest of Opal Lake, separated by a low area containing scattered outcrops and boulders of chert correlated with the Kedahda Formation. In places the carbonate is recrystallized and heavily veined with calcite, but elsewhere primary textures are well preserved. The rock commonly is a pale grey weathering, pale to medium grey unsorted, massive limestone breccia. The fragments are angular, up to 5 cm in length, have sutured borders in many places, and include a variety of carbonate types. These are, pale brownish grey, porcelaneous, very finely crystalline limestone, medium grey calcarenitic limestone containing pellets, fusulinids and oncoliths, and black,

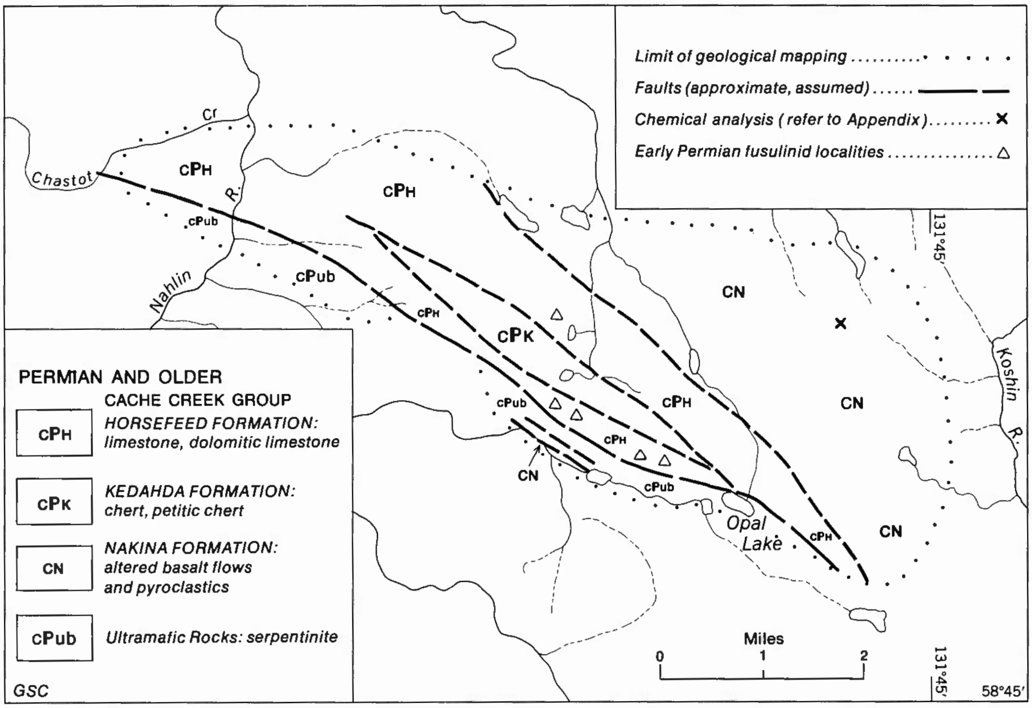


Figure 9. Upper Paleozoic rocks near Opal Lake, northeastern Dease Lake map-area.

Figure 11. Carbonate breccia at the base of the upper part of the Kedahda Formation. GSC Photo No. 202891-C.

fine-grained limestone. "Free" crinoid columnals and fusulinids occur between these lithic fragments. In a few places there is massive non-brecciated limestone, very similar texturally to the porcealneous fragments. The fusulinids are fusiform schwagerinids up to about 6 mm long and largely loosely coiled spherical forms about 6-7 mm diameter that belong to the genus *Pseudoschwagerina*. Both the lithology and these fossils are common in the Teslin Formation, 25 miles to the northwest near Nakina Lake, and there is little doubt that this is the same formation. The age of all fossils seen is probably Early Permian.

Volcanic rocks exposed north of the carbonates are dark grey green massive metabasalt (Table 1) and unsheared basaltic lithic and crystal tuff that are very difficult to distinguish in the field from the flow rocks. One example of crystal tuff contained abundant pyroxene, fairly fresh albitic feldspar, epidote, skeletal ilmenite and altered lithic fragments. In most respects these rocks resemble the Nakina Formation in the vicinity of Nakina Lake. They are locally interbedded with chert.

6. Nakina Lake Area

Rocks in the Nakina Lake area range in known age from Mississippian to Permian and provide perhaps the most complete stratigraphic section in the Atlin Terrane (Fig. 3-6). They are well exposed over an area more than 30 miles long and 20 miles wide, much of which is above treeline, with a local relief as great as 4,000 feet. Most prominent topographically are the extensive, rolling upland areas about 5,000 feet in elevation, underlain by carbonate and cut by steep-sided canyons containing Nakina River and Horsefeed Creek, and the bare, red-brown summits of the Menatatuline Range composed of ultramafic rock of the Nahlin body that bounds the upper Paleozoic strata on the southwest.

Structurally the area consists of large faulted folds of wave length in the order of 4 miles and amplitude at least 2 miles, with vertical and steeply dipping limbs (Fig. 10). There is little evidence of penetrative deformation associated with these folds. Pyroclastic rocks and volcanic sandstones are rarely foliated and minor folds tend to be irregular crumples rather than regular, repetitive structures. Probably much deformation took place by faulting, particularly along contacts between incompetent and competent units such as bedded chert/argillite sequences and massive metabasalts, and internally in competent successions of basalt and carbonate. This faulting is demonstrable within the carbonate in places where there is good fossil control (cross-section, Fig. 10). Elsewhere it is inferred by the presence of small, sheared serpentinite bodies, in places containing blocks of amphibolite and rodingite, found particularly within the metabasalt and at contacts between it and other rocks.

i. Ultramafic rocks of the Nahlin ultramafic body. Ultramafic rocks flank the upper Paleozoic rocks on the southwest and separate them from Lower Jurassic strata. They form the Nahlin ultramafic body, which is 65 miles long and up to 5 miles wide, the largest alpine-type ultramafic body in the Canadian Cordillera. Only the contacts of this body were examined by the writer, but reconnaissance mapping has been carried out by Aitken (1959) and Souther (1971). The data given below are summarized mainly from the latter report.

Dark green to black, tan weathering, variably serpentinized peridotite is the most common rock. It consists of partly serpentinized olivine, 10 to 20 per cent orthopyroxene, minor augite, and traces of chrome spinel. In places, pyroxene-rich layers occur within the peridotite, and dip steeply northeastward. In general, the peridotite becomes increasingly serpentinized towards the contacts. Subordinate tabular bodies of fine- to medium-grained gabbro and basic diorite, composed of labradorite, diopisidic augite and hornblende occur particularly near the southwestern margin of the ultramafic body. They form dyke swarms and elongate stocks subparallel with the margins of the main body. The general character, composition and relationships of the Nahlin body suggest that it is of the alpine-type (Benson, 1926, p. 6).

The Nahlin ultramafic body is bounded by faults. On the southwestern side the Nahlin fault zone varying in width from a few feet to several thousand feet, contains steep, northeasterly-dipping or vertical fault planes and appears to be a high angle reverse fault. This fault zone forms the southern boundary of the Atlin Terrane for a distance of over 200 miles and juxtaposes ultramafic and upper Paleozoic rocks with Jurassic rocks over most of its length (Fig. 2). The northeastern contact is covered, but is probably a near-vertical fault which brings ultramafic rocks into contact with bedded chert, argillite and siltstone of the Kedahda Formation.

The age of the Nahlin ultramafic body is possibly Mississippian. It was emplaced in its present position in late Middle Jurassic time along the Nahlin Fault (Souther, 1971, p. 47). Other ultramafic rocks in this region are generally spatially associated with Mississippian metabasalt of the Nakina Formation, as, for example, on both sides of Nakina Lake (Fig. 10), and near Sentinel Mountain (area 8). Aitken (1959, p. 38) remarked on this association and suggested that the ultramafic Atlin intrusions were contemporaneous with Cache Creek volcanism, then thought to be of Pennsylvanian or Permian age. He noted as well the similar degree of alteration in basic intrusive rocks within the ultramafics and the volcanic rocks. The basalt-basic intrusive-ultramafic assemblage or ophiolite suite is common in many mountain chains, and has been the focus of considerable attention in recent years (e.g. Coleman, 1971). Apart from the Cache Creek volcanic rocks, no other volcanic rocks in the region have the characteristics necessary for this association. However, the Nahlin ultramafic body is separated by faults and in places slivers of sedimentary rocks from the Cache Creek volcanics. All that can be said is that if this body is of the same age as other lithologically similar ultramafic rocks in the region, then its most probable age is Mississippian.

ii. Nakina Formation. Massive altered basalt of probable Mississippian age is designated Nakina Formation in this report. The type area is near Nakina Lake, which lies within the western margin of the largest area of such basalt in the Atlin Terrane (Fig. 2). The formation is exposed elsewhere in the southwestern facies belt near Mount O'Keefe (area 7), Sentinel Mountain (area 8) and Tagish Lake (area 9).

The thickness of the formation is not known but is probably in the order of several thousand feet. Contacts of the formation appear to be faults. The formation is faulted internally and no marker horizons have been distinguished. Yet the area underlain by the formation is extensive and the attitude of bedding in surrounding formations is steep, suggesting that the original thickness is great.

The topographic expression is variable. Although the rock is intrinsically fairly hard and resistant to erosion, in many places it is highly fractured and weathered and less resistant. North and south of Nakina Lake and southeast of Victoria Lake it underlies fairly rugged ridges, but elsewhere forms rounded knolls, such as east of Nakina Lake.

The lithology is very uniform. Commonly it is tan or brown to green weathering, grey green or rarely maroon, very fine grained altered basalt, in places with small chlorite amygdales and calcite veins. The rocks are generally massive and the only planar structures recognizable are fractures and faults with slickensided surfaces. No definite pillow lavas are known from this area, but possible pillows, manifested as rounded blocks of altered basalt surrounded by sheared selvages, occur on the divide between Horsefeed Creek and Nakina River and east of Horsefeed Creek. Chemically, these rocks are basalts (Table 1).

Other less common rock types are diabase and fine-grained basalt porphyry with small feldspar phenocrysts and very rarely, fine-grained gabbro, basaltic flow breccia and tuff. Locally within the formation are small dykes of serpentinite, typically slickensided and presumably marking faults, as on the divide between Nakina and Victoria lakes. In many places these serpentinite dykes contain blocks of amphibolite with either a well developed lineation or randomly oriented grains, or its bleached equivalent.

Primary textures in these volcanic rocks are commonly preserved even though the mineralogy is partly or entirely secondary. Moderately fine grained varieties consist mainly of a mesh of randomly oriented "ghosts" of small feldspar laths composed of semiopaque, greyish saussurite (albite and epidote minerals are invariably prominent on whole-roch diffractograms), intergranular diopsidic augite and interstitial chlorite, with opaque minerals altered in part or wholly to "leucoxene". Amygdales are commonly calcite and chlorite, and veins are commonly calcite, chlorite, albite and rarely pumpellyite. In still finer grained varieties the rock consists largely of brownish grey, optically irresolvable material, presumably altered basic glass, with small porphyritic laths of altered feldspar and small pyroxene grains. In some coarser grained diabasic varieties the feldspar is clear in places, but is invariably albite. Conversely, in such rocks the pyroxene is altered to greenish uralitic hornblende, whereas it is generally fresh in the fine grained examples. The amphibolite associated with the formation consists in large part of hornblende with green to brownish green pleochroism and minor intergranular, semiopaque, low birefringent material and irregular opaque minerals in the matrix.

Contacts of the Nakina Formation appear to be faults, but in general the formation is in contact with the oldest fossiliferous rocks in the area. South of Victoria Lake, west of Nakina Lake, and on the divide between Horsefeed Creek and Nakina River, serpentinite and amphibolite blocks occur at the contact between the Nakina and Kedahda formations. However, near the contact, the Kedahda Formation is commonly tuffaceous, contains horizons of metabasalt identical in lithology and metamorphic grade to those of the Nakina Formation, beds of carbonate with Upper Mississippian fossils, and grades away from the contact into bedded chert. Thus the possibility exists that this is a faulted, gradational contact, with mainly bedding plane slip between the incompetent Kedahda Formation and the competent Nakina Formation and no great stratigraphic displacement. This interpretation is shown in section (Fig. 3-6). Other contacts are with chert and Lower Permian limestone west of Nakina Lake, with sheared serpentinite separating the two, and serpentinite or serpentinized peridotite, northeast of Nakina Lake and southeast of Victoria Lake.

The Nakina Formation is probably older than the other formations with the possible exception of the ultramafic rock. Most contacts are with the oldest dated rocks. The only dykes of greenstone that cut the other formations are very rare ones that feed minor volcanic lenses in the Teslin Formation. If largely coeval with the greenstone in the Kedahda Formation, its age is Late Mississippian. However, fossiliferous rocks as old as Early Mississippian occur with similar basalt near Sentinel Mountain (area 8), so it may be somewhat older.

iii. Kedahda Formation. The Kedahda Formation comprises two parts, one of Late Mississippian age that conformably underlies the Horsefeed Formation, the other, of post-Late Permian age that unconformably lies on the Horsefeed Formation (Fig. 3-6). These two parts are so lithologically similar that remote from the Horsefeed Formation it is not possible to differentiate them. To the north, in the central facies belt, where the thick Horsefeed Formation is equivalent to a series of relatively small carbonate lenses in the Kedahda Formation, these two parts presumably coalesce.

The formation consists in large part of bedded chert and cherty argillite, with minor argillite, siltstone and volcanic sandstone, rare horizons of carbonate, tuff and greenstone, and, immediately above the Horsefeed Formation, a breccia with limestone clasts. Its total thickness is not known, but is apparently well in excess of 5,000 feet.

Bedded chert and cherty argillite are grey-to-rusty weathering, medium grey and form beds 1 to 4 inches thick which pinch and swell within these limits and are separated by more pelitic horizons. The latter are rarely phyllitic in this area, in contrast with those, for example, near Dease Lake.

Volcanic sandstone and siltstone interbedded with cherty argillite occur mainly south of the outcrop of Horsefeed Formation 4 miles south of Victoria Lake. They are typically fine grained, thinly laminated, graded and poorly sorted, and consist predominantly of angular semi-opaque, fine-grained aggregates of albite, calcite and chlorite, originally probably mainly feldspar, but in part volcanic fragments, minor (<3 per cent) grains of quartz, argillite chips and scattered epidote grains. Calcite forms patches in the groundmass and also veins. Grain boundaries are blurred, but no foliation is developed.

Volcanic rocks in the Kedahda Formation occur near the contact with the Nakina Formation, north and south of Victoria Lake, and three miles northwest of Nakina Lake. Six miles northwest of Nakina Lake they are found near the base of the Horsefeed Formation. They range from massive grey green altered basalt lenses, tens to a few hundred feet thick, that are lithologically identical with those of the Nakina Formation, and grade through scoriaceous basalts with calcite filled amygdales to well-bedded lithic tuffs in many places containing carbonate fragments. These volcanic rocks are interbedded in part with chert and argillite, but also are invariably closely associated with and grade into carbonate pods.

The distribution of carbonate pods in the Kedahda Formation is similar to that of the volcanics. They occur as beds 20 to 100 feet thick, conformable and in contact with bedded chert and lithic tuff and are well exposed on the ridges northeast and southwest of Victoria Lake. Typically they are brownish grey to pale grey weathering, massively bedded, partly tuffaceous or argillaceous, relatively fine-grained crinoidal calcarenitic limestone, or, less commonly, calcarenite. In places horn and colonial corals and small gastropods are common. Brachiopod fragments, oolites, calcispheres, small foraminifera and probable dasyclad algal fragments occur between the crinoid ossicles. The tuffaceous carbonates grade from crinoidal calcarenite containing minor volcanic fragments and interstital chlorite into calcareous lithic tuff with scattered crinoid fragments. In places, such as on the ridge 2 miles west of the southwest end of Nakina Lake, the carbonate is tightly folded, brown weathering dolomitic limestone, with up to 50 per cent of the whole consisting of intercalated secondary (?) chert bands.

A very distinctive carbonate breccia occurs at many places between the upper contact of the Horsefeed Formation and the Kedahda Formation. It consists typically of grey angular carbonate fragments of predominantly aphanitic limestone (common in the mid-Permian part of the Horsefeed Formation) but also other carbonate lithologies, in a tan weathering, partly dolomitized matrix. Grain size ranges from boulder to sand sizes, although generally the clasts are cobbles or smaller. The nature and relationships of this conglomerate can be understood from outcrops along the contact between the Kedahda and Horsefeed formations on the east side of the valley containing the head-waters of Horsefeed Creek, 9 miles west-northwest of the west end of Nakina Lake. At the southern end of the contact the breccia is a tan-buff weathering, crossbedded, predominantly granule-sized carbonate breccia about 2 feet thick. A clast from it contains an Upper Permian fusulinid, although the breccia is in contact with massive Upper Pannsylvanian carbonate of the Horsefeed Formation. The breccia passes gradationally upwards into conformable siltstones, argillites and cherts, typical of the Kedahda Formation. One and one quarter miles to the north-northwest on the same contact, the breccia is about 300 feet thick, contains blocks up to 1 foot in diameter and is in contact with Lower to mid-Permian limestone (Fig. 11). There also Upper Permian fossils occur in the blocks. About one mile farther to the northeast, volcanic greywacke and chert overlie Upper Permian limestone. The breccia was not present although the carbonate of the Horsefeed Formation contains limestone fragments. Thus, over a distance of about two miles the breccia cuts down from Upper Permian to Upper Pennsylvanian limestone, possibly removing more than 2,000 feet of carbonate. Carbonate breccia present at the northern contact of the Teslin Formation south of Victoria Lake contains Upper Permian fossils and rests on both Upper and Lower Permian limestone. There, the upper Kedahda sequence must be faulted against the lower sequence, because away from this contact in the Kedahda sequence is carbonate correlated with the Mississippian carbonate elsewhere. Similar carbonate breccia is infolded into Lower Permian limestone three miles northwest of the western end of Nakina Lake and also is found within the carbonate mass on Sinawa Eddy Mountain and west of Dry Lake.

The contacts of the upper and lower parts of the Kedahda Formation contrast markedly. The lower contact of the upper part, as deduced from the relationships of the breccia, is an angular unconformity on the Horsefeed Formation. The upper contact of the upper part of Kedahda Formation is not known. A small outlier of possible lower Mesozoic laminated argillite and siltstone sits on the lower part of the Kedahda Formation, 2½ miles northwest of Nakina Lake and may indicate an unconformity. The upper contact of the lower part of the Kedahda Formation is known definitely from 9 miles northwest of the western end of Nakina Lake. There the formation consists of chert that passes up into bedded tuff and scoriaceous greenstone containing lenses of dark grey, brownish weathering, Upper Mississippian carbonate. This sequence in turn is overlain conformably by massive, crinoidal carbonate of the basal Horsefeed Formation of similar age. The lower contact is not known. The oldest fossils are of mid to Upper Mississippian age, and occur in limestone pods associated with volcanic rocks. Possibly these rocks were originally gradational with the Nakina Formation but are now in fault contact with it.

The age of the Kedahda Formation in the Nakina Lake area is (1) middle to Late Mississippian, and (2) post-Late Permian.

iv. Horsefeed Formation. This area is the type-area of the Horsefeed Formation, herein named from Horsefeed Creek, which heads in the valley 9 miles west-northwest of the southwest end of Nakina Lake. This unit consists of about 5,000 feet of carbonate with minor intercalations of basic volcanic rocks, and contains Upper Mississippian, Middle and Upper Pennsylvanian, Lower, mid, and Upper Permian fossils. It is the most important unit in this area both for determining stratigraphy and structure, because it is highly fossiliferous so that unequivocal tops can bd determined and contiguous but unfossiliferous units can be related to it where stratigraphic contacts occur, and also for interpretation of the environment of deposition.

The base of the Horsefeed Formation, which is visible 9 miles northwest of Nakina Lake, consists of massive, white to pale grey weathering crinoidal calcarenite to calcarenitic limestone (Fig. 12a). The crinoid columnals are up to one half inch in diameter and in places are articulated. Between them is a matrix consisting of small crinoid fragments, endothyrid foraminifers, calcispheres and calcareous spicules. These rocks apparently grade up into the next dominant carbonate lithology.

The most characteristic lithology of the Teslin Formation in the Nakina Lake area (and elsewhere in the southwestern facies belt) spans Middle Pennsylvanian to mid-Permian time and includes more than 3,000 feet of the total 5,000 feet of the formation. It is pale grey to white weathering, pale grey to pale buff-grey, porcelaneous crinoidal and foraminiferal calcarenitic limestone (or wackestone of Dunham, 1962) (Figs. 12b, c, d, e). Commonly the rock is so massive that bedding is not apparent, and is only rarely visible from a distance as faint colour variations in cliff faces (Fig. 13). Typically it consists of crinoidal detritus and/or fusulinids scattered through a finer grained matrix containing smaller crinoidal and fusulinid material, brachiopod shell fragments, smaller foraminifera, calcispheres, algal fragments and rarely, oolites. In places such as in the Permian limestone 2 miles west-northwest of Nakina Lake, some grains have a laminated algal coating and algal laminae may bind several grains together. Oolitic calcarenite is relatively rare, but has been observed on the east side of the valley 8 miles west-northwest of Nakina Lake (Fig. 12f). The oolites are nucleated on echinoderm fragments, calcareous algal, rarely small foraminifera and enclosed by sparry calcite. Colonial and horn corals are extremely rare, but have been found in this lithology.

Many of the rocks are recrystallized but are typically very fine grained, with the internal structure and boundaries of clasts blurred. The original texture is still perserved, and the rock retains its porcelaneous appearance. Foraminifera are white, very fine grained crystalline calcite, whereas many of the crinoid fragments have a dark grey colour, the two giving a characteristic, speckled appearance to the rock. The ultimate product of recrystallization is a finely crystalline, fragmental limestone in which no internal details of the fragments can be determined.

Other alteration is relatively minor. Dolomitization is commonly restricted to a few scattered rhombs. Secondary silicification in the form of chert nodules parallel with bedding is very rare, but occurs south of Victoria Lake.

This predominant lithology grades upward through dark grey, very fine grained detrital limestone and dolomitic limestone with scattered beds containing large mid-Permian fusulinids (Fig. 12g) into algalaminate aphanitic dolomitic limestone and dolomite (Fig. 12h). This aphanitic carbonate is about 600 feet thick and is readily recotnizable in the field from its excellent bedding (Fig. 14). It is pale grey to cream weathering, pale grey to dark grey, with generally planar but slightly irregular and locally domed laminations revealed by slight variations of colour and dolomitic content. Typically the rock consists of very fine grained, dense micrite with scattered calcispheres and (?) ostracodes, with the laminae delineated by darker, denser micrite. Some examples contain anastomosing patches of sparry calcite ("birdseye" texture). These rocks are lithologically very similar to the somewhat younger, Upper Permian algalaminate carbonates of the northeastern facies belt.

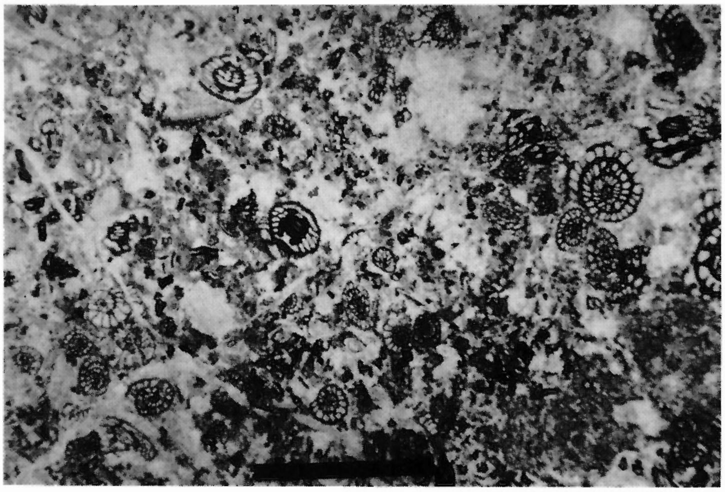
The youngest, Upper Permian, part of the Horsefeed Formation consists of aggregate and foraminiferal calcarenitic limestone and minor foraminiferal calcarenite. The former contains abundant fragments of carbonate together with large fusulinids, in a matrix of small fragments, crinoidal detritus, smaller foraminifera and calcispheres. It appears to grade, in several places, such as at the northern contact of the limestone south of Victoria Lake, into the breccia that characterizes the base of the upper part of Kedahda Formation. The foraminiferal calcarenite is relatively rare but consists of large foraminifera and other fossil fragments, including cephalopods, in a sparry matrix (Fig. 12i).

Altered basic volcanic rocks and minor tuff locally form small lenses within the formation. The small lens in Lower Permian limestone 2 miles northwest of Nakina Lake is pillowed, brown weathering, grye to purple basalt completely surrounded by and conformable with the carbonate. Four miles west of Dry Lake, in the northern part of the area, the carbonate encloses a bed of maroon to green lithic tuff.

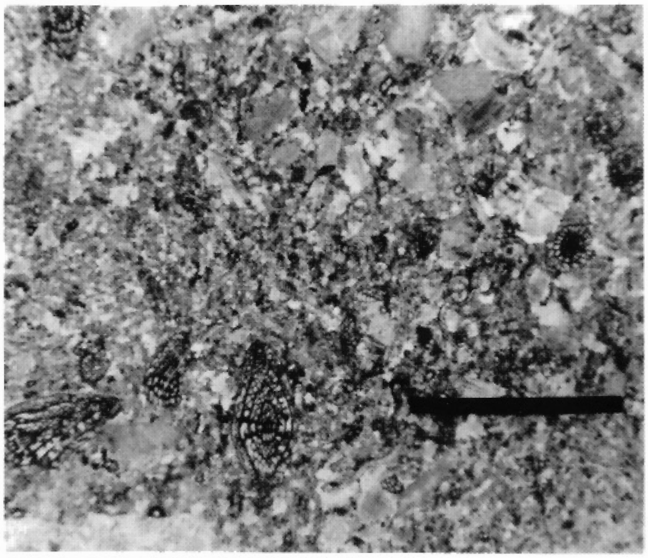
The contacts of the formation have been described under the Kedahda Formation. The top is locally overlain unconformably by breccia at the base of the upper part of the Kedahda Formation but elsewhere this breccia is missing. The base of the Horsefeed Formation is conformable on Upper Mississippian tuff, argillite and chert containing limestone pods.

The age of the Horsefeed Formation ranges from Late Mississippian to Late Permian. No Early Pennsylvanian fossils are known from the Nakina Lake area, but this is possibly due to incomplete collecting rather than to a major hiatus, as Early Pennsylvanian fossils occur in the basal part of the formation near

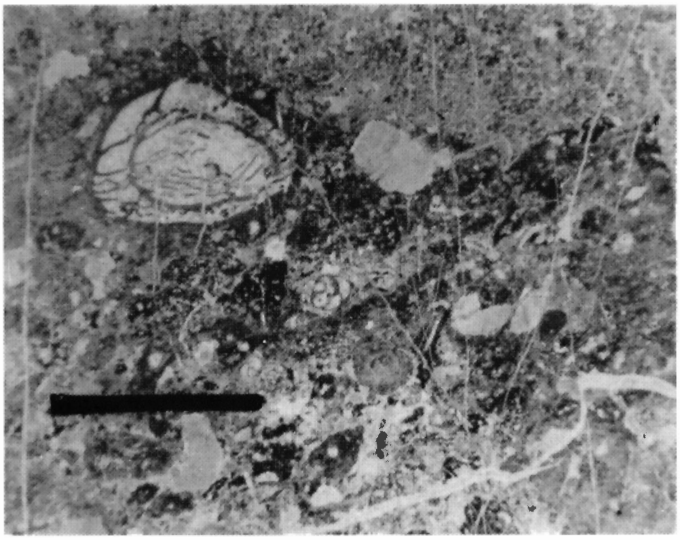
12(a) GSC Photo No. 202891-D



12(b) GSC Photo No. 202891-E

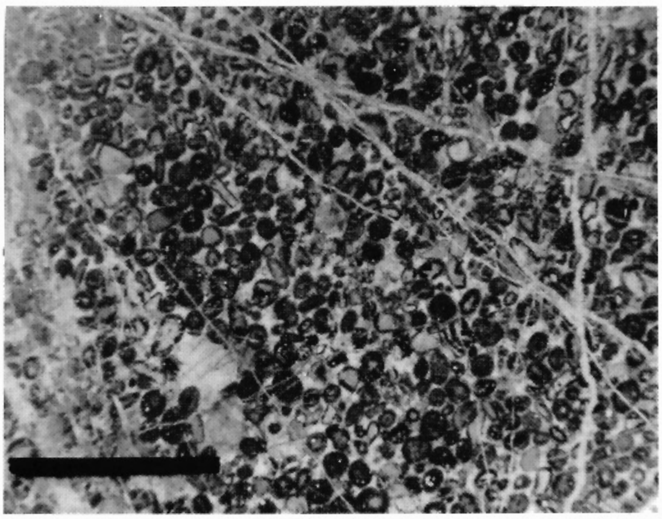


12(c) GSC Photo No. 202891-F

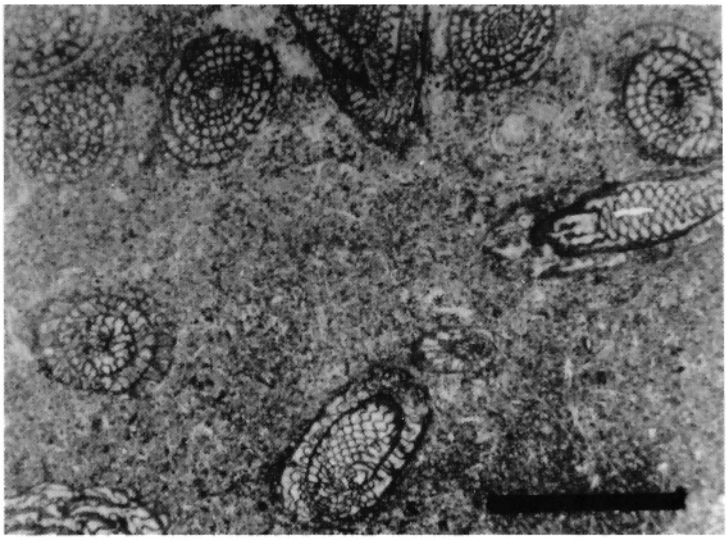


12(d) GSC Photo No. 202891-G

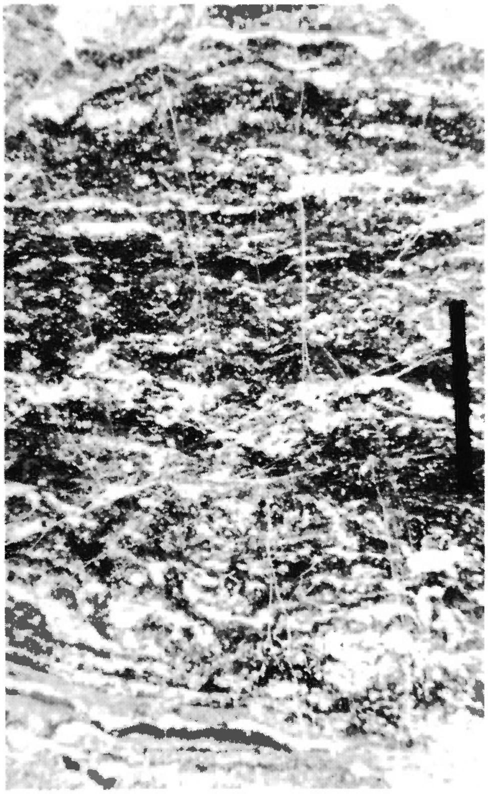
12(e) GSC Photo No. 202891-H



12(f) GSC Photo No. 202891-I



12(g) GSC Photo No. 202891-J



12(h) GSC Photo No. 202891-K

12(i) GSC Photo No. 202891-L

Figure 12. Textures in carbonate of the Horsefeed Formation.

Tagish Lake. From the distribution of fossils, it seems that Lower Permian limestone is the most extensive.

v. Triassic(?). A small area of dark grey to greyish green calcareous argillite and siltstone outcrop $2\frac{1}{2}$ miles northwest of the western end of Nakina Lake. These rocks resemble no known upper Paleozoic rocks in the Atlin Terrane, but look similar to the Upper Triassic - Lower Jurassic Nazcha Formation that bounds the northeastern side of the Atlin Terrane, northwest of Dease Lake. The rocks northwest of Nakina Lake are separated by a probable fault from Lower Permian limestone and possibly lie on chert of the Kedahda Formation. These rocks and others on Sentinel Mountain are the only known occurrences of possible lower Mesozoic strata in the Atlin Terrane, although it may be that the upper part of the Kedahda Formation is of Lower or even Middle Triassic age.

7. Mount O'Keefe Area

The rocks near Mount O'Keefe are predominantly basic volcanics and chert or pelitic chert with small lenses of Permian carbonate. The area is significant in that it lies southwest of the belt of thick Permo-Carboniferous carbonate of the Horsefeed Formation passing through Nakina Lake area, the southern end of Sentinel Mountain area and Tagish Lake (Fig. 2). It reveals that the thick carbonate thins out to the southwest as well as to the northeast. The area is highly faulted (Fig. 15), and the stratigraphic section given in Figure 3-7 is very tentative.

Pale grey green, green and maroon, hard, altered basalt (Table I) forms most topographic highs. It is commonly massive but in places is pillowed and brecciated and is lithologically similar to the Nakina Formation. The basalt is conformably overlain by bedded chert and pelite. The contact 3 miles northeast of Mount O'Keefe seems gradational in that pillow lavas younging to the north grade into about 10 feet of pillow breccia and aquagene tuff and then bedded chert. West-northwest of Kuthai Lake, mid-Permian carbonate, fairly typical of thick carbonate of the southwestern facies belt, overlies altered basalt. The contact is possibly a fault. The lower contact of the main mass of basalt is not known.

Bedded chert, cherty pelite and pelite, typical of the Kedahda Formation, is well exposed in the southwestern part of the area. It contains rare lenses of volcanic greywacke and altered basalt and pods and beds of two types of carbonate. Large schwagerinid fusulinids of mid-Permian age (Aitken, 1959, p. 31), are in medium grey fusulinid pelletal calcarenitic limestone and dolomitic limestone. This limestone mainly forms fault slices along the prominent northwest-trending fault running through the area, but similar limestone appears to be interbedded with pelitic chert one mile northeast of the fault zone. In addition, one fossiliferous fault block is brecciated and contains fusulinids in a tuffaceous matrix, indicating the contemporaneity of at least some volcanism with the fossiliferous limestone. The other carbonate forms small pods unequivocally interbedded with chert and cherty pelite, and is buff or orange weathering, light to dark grey crinoidal limestone and dolomictic limestone, that in many places is largely recrystallized and contains chert nodules. Apart from crinoid columnals, which may be up to $\frac{1}{2}$ inch diameter, no fossils have been found in the limestone.

Limestone north and northeast of Kuthai Lake is massive, pale grey weathering, medium grey, fusulinid, pelletal calcarenitic limestone. The fusulinids are large, mid-Permian forms similar to those on Mount O'Keefe. However, the limestone is more massive than that on Mount O'Keefe, and is more similar in lithology and mode of occurrence to coeval carbonate of the Horsefeed Formation in the Nakina Lake area and the southern part of Sentinel Mountain area.

Numerous small bodies of serpentinite occur throughout the area and may mark fault zones.

The main problem in the Mount O'Keefe area is the age of the volcanic rocks. They appear to be almost continuous with basalt of probable Mississippian age of the Nakina Formation in the Nakina Lake area, yet the only fossils obtained from the area are of mid-Permian age. Furthermore, some fossiliferous limestones are tuffaceous. Possibly two ages of volcanic rock are represented as in the Nakina Lake area, where the bulk of the volcanic rock appears to be Mississippian yet small pods of Permian volcanics occur in the limestone. Further examination for fossils in the crinoidal calcarenitic limestone unequivocally interbedded with chert that in turn conformably overlies basalt may resolve this problem, but until then any solution will remain speculative.

8. Sentinel Mountain Area

The stratigraphy of the Sentinel Mountain area is complex and spans the boundary between the southwestern and central facies belts. It includes three differing although partly coeval stratigraphic sections separated by faults (Fig. 3-8). Southernmost is thick Permian and uppermost Pennsylvanian carbonate of the Horsefeed Formation, typical of the southwestern facies belt (Fig. 16). It is overlain on the south and underlain on the north by the Kedahda Formation, which to the south is mainly bedded chert, but to the north is chert, pelite, minor volcanic sandstone and lithic tuff with Middle Pennsylvanian carbonate pods. The central part of the Sentinel Mountain area is dominated by altered basalt, diabase and lithic tuff included in the Nakina Formation and ultramafic rock. The volcanic and ultramafic assemblage in part intrudes and in part grades into bedded chert, pelite, and Mississippian and Pennsylvanian carbonate pods of the Kedahda Formation. The northeastern part consists mainly of chert, pelite, minor volcanic sandstone, and carbonate pods of Mississippian and possibly Permian age all included in the Kedahda Formation.

The overall structure appears to be a faulted east-west trending anticlinorium, but this hypothesis is probably too simplistic, and it is difficult to say

Figure 13. Massive Upper Pennsylvanian carbonate of the Horsefeed Formation. GSC Photo No. 202891-M.

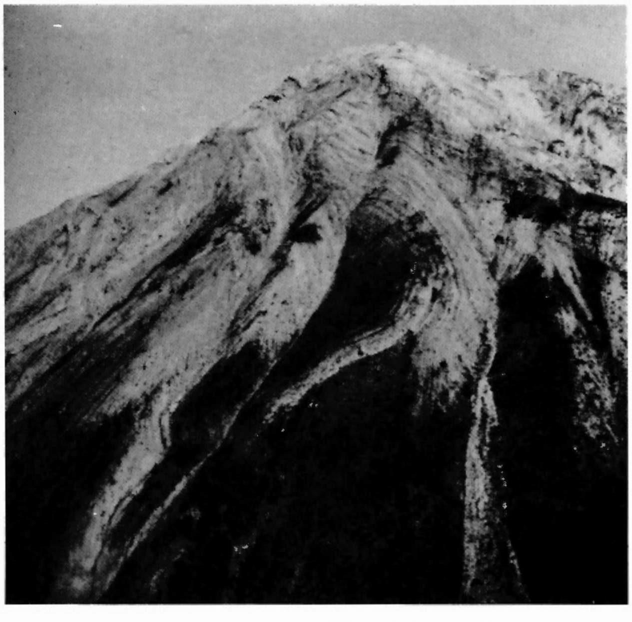


Figure 14. Well bedded mid-Permian carbonate of the Horsefeed Formation. GSC Photo No. 202891-N.

whether faulting or folding plays the dominant role in the structure (Fig. 16). The simple interpretation is made from (1) the generally older age of rocks in the central part of the area, in comparison with those to the south and some from the north, (2) the increasing age of rocks in the southern part of the area from south to north, and (3) probable faults delineated by serpentinite pods that bound the central part of the area on the south and north. Because bedding in this area is generally steep or vertical, and minor folds are limited to irregular crumples in chert, these features are of little use in interpreting structure. Stratigraphic tops obtained from pillow lavas and differentiated diabase sills indicate that the central part alone is probably synclinal.

i. Ultramafic rocks (Atlin intrusions). The term Atlin intrusions was applied by Aitken (1953, 1959) to small ultramafic bodies closely associated with Cache Creek volcanic rocks. The largest area of these rocks is north-northwest of the summit of Sentinel Mountain, where they are largely red to tan weathering serpentinized peridotite containing bastite pseudomorphs. In a few places within this body are lenses or discontinuous dykes of diabase or microgabbro, with stubby albite laths, yellow green uralitic hornblende and skeletal ilmenite. Other exposures of ultramafic rocks are small serpentinite pods within lithic tuff about 3 miles south of the summit of Sentinel Mountain, chert east of Wilson Creek and probably related orange quartz-carbonate rock separating volcanic rock and carbonate north of McKee Creek.

Contacts of the ultramafic rocks are probably mainly faults. Contacts with enclosing altered basalts and cherts are commonly sheared. The basal part of the volcanic succession 2½ miles northwest of the summit is mylonitized above the contact with serpentinite.

The age of the ultramafic rocks is unknown but as they contain lenses of diabasic rock in places that may well be related to Pennsylvanian and Mississippian rocks of the Nakina Formation, they are considered to be Mississippian or older.

ii. Nakina Formation. The Nakina Formation contains three main lithologies - basalt, diabase and lithic tuff. The basalt is conformable with bedded chert of the Kedahda Formation, the diabase locally intrudes it, and the lithic tuff is gradational with it, so the separation between the two formations shown in Figure 3-8 is somewhat arbitrary.

The basalt is typically greenish grey or yellowish green-grey but locally maroon, and commonly is very fine grained or aphanitic. In places it contains pillows, pillow breccia and aquagene tuff, excellent examples of which can be seen on the north-south ridge one mile west of the summit of Sentinel Mountain, and on the lower spur of this ridge, west of Eldorado Creek (Fig. 17). In thin section, these rocks typically consist of a matrix of felted small saussuritic feldspar laths that are albite where determinable, variable amounts of intersertal diopsidic augite, interstitial chlorite, and opaque minerals. Some examples contain scattered, greenish albitic feldspar phenocrysts. Vesicles typically contain chlorite and carbonate, with local clinozoisite, and veins contain carbonate, albite, clinozoisite, and, rarely, pumpellyite. Near the ultramafic body north of the peak of Sentinel Mountain, some of these volcanic rocks form fine-grained, very hard, grey-green actinolite-bearing greenstones, more altered than the common basalts. The pillow breccia and aquagene tuff contain brown altered glassy fragments, some of which are pumiceous. Silica in the basalts ranges from about 45 to 50 per cent, but they are anomalous in that they have a highly variable potassium content, even between rocks that are texturally and mineralogically similar (Table I).

Rocks included under diabase are closely associated with the basalt and may grade into it. They form sills or possibly flows as much as 1,000 feet thick generally concordant with the enclosing chert and basalt. One of the diabase bodies forms the main east-west ridge of Sentinel Mountain, west of the summit, and at least four cross the intersecting north-south ridge to the west. The typical diabase is tan weathering, greenish grey and texturally more uniform than the basalt. Commonly it is possible to see individual crystals without the aid of a hand lens. Feldspars are randomly oriented laths up to 4 mm but generally about 1 mm in length. They are partly saussuritized but in most cases are much fresher than those in the basalts and although commonly albite, in some examples are andesine or rarely, labradorite. The feldspars are in subophitic relationship with clinopyroxene, or, rarely, uralitic hornblende. Chlorite and clinozoisite occur interstitially, the opaque mineral is commonly skeletal ilmenite altered partly to leucoxene, and rare veins contain prehnite and, in one example, pumpellyite. Variations occur near the margins of some of the sill-like bodies on the north-south ridge west of Sentinel Mountain. The northern margin of the narrow sill 2 miles west-southwest of the summit is red- to buff-weathering grey green diabase composed of small, relatively equant, saussuritic feldspar crystals, corroded, partly uralitized intergranular and somewhat porphyritic clinopyroxene, abundant epidote, opaque minerals and very small amounts of quartz in the groundmass. The silica content of one of these rocks is 53.9 per cent, compared with about 48 per cent for the 'normal' diabase. The bulk of the sill is 'normal' diabase, but the southern margin is tan weathering, very dark grey-green diabase that contains large clinopyroxenes about 3 mm in diameter in ophitic relationship with small, lath-like, saussuritic albite. Some lithologically similar rocks contain scattered patches of antigorite, suggesting that olivine originally may have been present. Variations seen at several localities suggest that some sill-like bodies are partly gravity differentiated, and thus indicate the original top and bottom of the sills.

Alteration of diabasic rocks is less than that of any other volcanic upper Paleozoic rocks in the Atlin Terrane. The presence of relict pyrogenic calcic feldspars is particularly unusual. The presence of prehnite and rare pumpellyite indicates that these

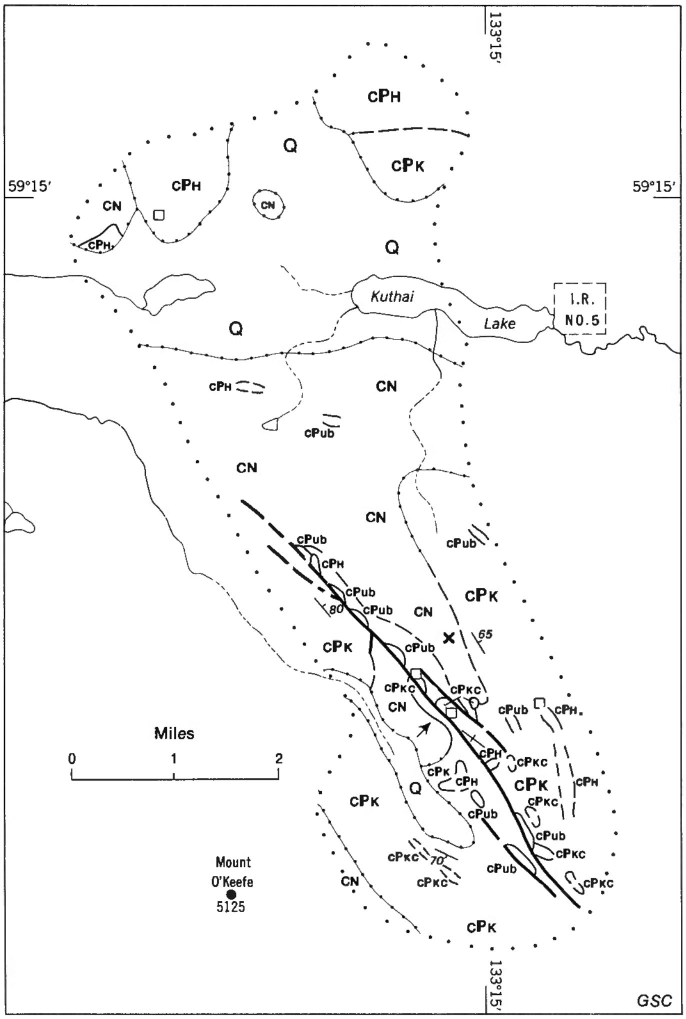


Figure 15.

Upper Paleozoic rocks near Mount O'Keefe, south central Atlin map-area.

QUATERNARY

Q — *Alluvium*

UPPER PALEOZOIC

CACHE CREEK GROUP

CPH — *HORSEFEED FORMATION?: carbonate*

CPK — *KEDAHDA FORMATION: bedded chert, cherty pelite, pelite;* CPKC *; carbonate pods*

CN — *NAKINA FORMATION?: basic volcanic rocks, local pillow lavas, volcanic breccia*

CPub — *Serpentinite*

Bedding (inclined, vertical)

Geological Boundary (defined, approximate, assumed)

Limit of geological mapping

Fault (defined, approximate)

Tops determined from pillow lava

Mid Permian fusulinid localities

Chemical analysis

Figure 17. Pillow lavas of the Nakina Formation on Sentinal Mountain. GSC Photo No. 202891-O.

rocks belong to the prehnite-pumpellyite metamorphic facies.

Pyroclastic rocks exposed near the southern limits of the central, volcanic part of the Sentinel Mountain area are typically yellow-green to grey-green, lithic lapilli tuff, with unfoliated clasts composed mainly of semiopaque, pumiceous altered volcanic glass, basalt fragments, and individual feldspar crystals. Many tuffs are calcareous, with calcite forming patches in the groundmass. They are particularly important because they grade into chert, pelite and fossiliferous limestone and thus give an indication of the age of the volcanic sequence.

The volcanic rocks appear to be of Mississippian and Pennsylvanian ages. Diabase clearly intrudes chert of the Kedahda Formation west of the summit of Sentinel Mountain. Northeast of the summit Upper Pennsylvanian (Moscovian) limestone (Fossil locality 4; Fig. 16) grades into tuff that appears to be continuous with the main mass of volcanic rocks on Sentinel Mountain. Southeast of the summit (Fossil locality 1; Fig. 16), Lower Mississippian limestone, the oldest fossiliferous rock known in the Atlin Terrane, passes northwards through partly foliated lithic tuff into massive amygdaloidal basalt that appears to be the western end of the predominantly diabasic body underlying the summit of Sentinel Mountain. Pillow lavas near the western end of this body indicate that the top is to the north and thus the Mississippian limestone underlies it.

iii. Kedahda Formation. The Kedahda Formation consists in large part of thinly bedded chert grading in places into cherty pelite or pelite, interbedded volcanic sandstones and limestone pods. It both underlies and overlies the Teslin Formation. The maximum apparent thickness of 4,000 feet is reached in the southern part of the area, between the base of the overlying Teslin Formation and the fault zone with ultramafic rocks forming the southern boundary of the central part of the area.

The cherts are typically tan weathering, grey, and form beds 1 to 3 inches thick, separated by more pelitic layers. Near the volcanic rocks the chert varies in colour from the normal grey to buff, orange, maroon and red, and where recrystallized near diabase, to white. Probable radiolaria are abundant in the chert in several localities, particularly on the ridge 3 miles west-northwest of the summit of Sentinel Mountain. In thin sections these are circular patches up to 3 mm diameter of a fine quartz mosaic that represents recrystallized radiolarian tests and their silica infilling. The chert grades through cherty argillite into dark grey argillite, that, at best, has only a poorly developed cleavage. Monor folds in these rocks are localized crumples with sharp hinges, but these are seen at relatively few localities.

Volcanic sandstone or greywacke forms massive beds and is generally hard, greenish grey and typically fine grained, although pebble conglomerates containing chert, limestone and volcanic clasts occur locally. The sandstone is poorly sorted below a certain size limit and consists of mainly volcanic fragments, with basaltic, pumiceous and variolitic textures, plagioclase - commonly saussuritic and locally prehnitized - flakes of argillite and chert and minor quartz, in a chloritic matrix. The greywacke locally contains lenses of chert, and on the ridge 2 miles east-southeast of Warm Bay, grades from sandstone, through siltstone into cherty argillite to chert. Thus it seems possible that some of the cherts are silicified fine-grained clastic rocks. Deformation in the sandstone seems to take place largely by movement along fracture and, although grain boundaries in some sandstones are indistinct, grains are never flattened and the rock does not develop a penetrative cleavage.

Limestone forms pod-like bodies in this sequence. One of the largest, of Middle Pennsylvanian age, outcrops on the ridge 2 miles east of Warm Bay, where it is largely surrounded by chert. It is dark to medium grey, calcarenitic limestone containing abundant crinoid columnals, scattered small fusulinids and calcispheres in a matrix of small calcareous fragments and lime-mud. Other limestones occur along the boundary between pyroclastic rocks of the Nakina Formation and chert and pelite. Lower Mississippian limestone, southeast of Sentinel Mountain, ranges from pale grey crinoidal calcarenite containing brachiopods and crinoids up to ¾ inch in diameter, to medium grey calcarenitic limestone with crinoid fragments, oolites, fragmental dasyclad algal and small foraminifera. Other bodies, such as the Upper Pennsylvanian body 1½ miles north-northeast of the summit of Sentinel Mountain are tuffaceous, and contain abundant bryozoan fragments, along with crinoids and small foraminifera. Limestone north and south of McKee Creek forms a series of pods in the predominant chert and pelite. It is mainly grey to brown weathering, dark grey to black, aphanitic limestone and dolomitic limestone. Commonly it is massive, but in places is thin bedded, graphitic and contains chert nodules aligned parallel to the bedding plane. Most common fossils are very small, scattered crinoid columnals, many of which are articulated, and in places, such as towards the base of the outcrop on McKee Creek, they increase in abundance and size and the rock becomes a crinoidal calcarenitic limestone, with white and grey crinoid columnals in a dense grey matrix. Other fossils are locally silicified tabulate and horn corals, small cephalopods and small foraminifera. Mid-Mississippian (Viséan) foraminifera were found in place in two localities. However, Permian fusulinids were found in a float block, lying on dark carbonate on the other side of a fault from the Mississippian carbonate on McKee Creek, so the possibility exists that there are lithologically similar carbonates of two or more ages.

Contacts between the Kedahda Formation and the intercalated Nakina Formation are gradational and interfingering, but those between it and the Horsefeed Formation are sharp. Bedded cherts of the Kedahda Formation are in contact with both older and younger parts of the Horsefeed Formation and so they appear to both underlie and overlie it. Although the contact between carbonate of the Teslin Formation and chert can be located to within a few feet in several places in the south and southeastern parts of the area and near McKee Creek, only in a few places can the actual contact be directly observed. In the saddle at the south end of the ridge west of Wilson Creek, massive finely crystalline limestone is separated from bedded argillaceous chert by a zone of fragmented chert 2 to 6 inches wide, perhaps indicative of shearing along the contact. A small infold of chert on the east side of Wilson Creek is separated from the limestone by a bed of breccia 1 to 8 feet thick composed of limestone and dolomitic limestone clasts up to 1 inch long. This closely resembles the breccia marking the unconformity separating the Kedahda Formation and the underlying Teslin Formation in the Nakina Lake area.

The age of the formation ranges from Late Permian to Early Mississippian. Middle and possibly Late Pennsylvanian fossils occur in carbonate pods in the Kedahda Formation. It appears to overlie the Horsefeed Formation, the youngest part of which is early Late Permian.

iv. Horsefeed Formation. The Horsefeed Formation consists mainly of pale grey, clean limestone of Late Pennsylvanian to Late Permian age, approximately 3,000 feet thick. The limestone is commonly massive with no markers to indicate bedding, and in part it is recrystallized so that primary textures are obliterated. Where primary textures are discernible the Lower Permian and Upper Pennsylvanian part is seen to be crinoidal foraminiferal calcarenitic limestone, in places with a speckled sppearance and very similar lithologically to coeval carbonate near Nakina Lake. The mid- and probable Upper Permian part ranges from medium and dark grey aphanitic limestone and calcarenitic limestone containing scattered large schwagerinid fusulinids and crinoid columnals to white weathering, pale grey, hard, splintery, largely unfossiliferous aphanitic limestone and dolomitic limestone. Interstratified with these sparsely fossiliferous rocks are rare layers containing either abundant large schwagerinid or small neoschwagerinid fusulinids. These beds resemble strata transitional to the algalaminate carbonate in the Nakina Lake area, although no algal laminations have been noted in the Sentinel Mountain area. The strata are included in the southwestern facies belt because of their general similarity to the Horsefeed Formation in the Nakina Lake area, even though a shorter time span is represented.

The Horsefeed Formation in this area is dated by fusulinids which are of Late Pennsylvanian, Early, mid- and Late Permian age (Fig. 3-8).

v. Mesozoic (?) clastic rocks. Clastic rocks that are considerably fresher than volcanic sandstones in the Kedahda Formation and are thus thought to be of Mesozoic age, outcrop at two localities. One locality 3 miles west-southwest of the summit of Sentinel Mountain, consists of pale grey laminated siltstone, sandstone, conglomerate and some lenses of very fine grained limestone. In section, the coarse sandstone consists of carbonate grains, felsic volcanic rocks containing quartz phenocrysts, quartz grains, basic volcanic rocks and feldspar. It is probably in fault contact with volcanic rocks of the Nakina Formation that surround it, because serpentine float occurs near the western end. Lithologically, it is similar to rocks of the Upper Triassic - Lower Jurassic Nazcha Formation northwest of Dease Lake described by Watson and Mathews (1944) and Monger (1969), and in part to calcareous argillite and siltstone in the Nakina Lake area. The other locality, situated 2½ miles north of the summit, consists of pale grey weathering sandstones composed largely of fine-grained felsic volcanic rocks, quartz and epidote, that are cut by pink to buff weathering quartzofeldspathic dykes. These rocks resemble probable Late Cretaceous to Early Tertiary sandstones in volcanic rocks that overlie the upper Paleozoic north of the Hall Lake area.

9. Tagish Lake Area

Upper Paleozoic rocks in the Tagish Lake area include the Horsefeed Formation, mainly carbonate with intercalated basic flows and minor tuff that ranges in age from Early Pennsylvanian to Late Permian, with overlying and possibly underlying chert correlated with the Kedahda Formation and variably metamorphosed basic volcanic rock. The Horsefeed Formation is particularly well exposed, highly fossiliferous and easily accessible from Tagish Lake (Fig. 18).

The rocks were mapped by Christie (1957) and Wheeler (1959) with detailed local studies made subsequently by Bain (1964) and Ruedesili (1965) of the University of Wisconsin. Bain measured composite sections in (1) mainly altered volcanic rocks on the south side of Nares Mountain, (2) carbonate and chert northwest of Ten Mile Range on Tagish Lake, and (3) mainly carbonate southwest of Jubilee Mountain. Ruedesili studied predominantly carbonate sections on (1) Bove Island in Tagish Lake and on the shore, (2) west, and (3) southeast of this island. Both reports contain useful lithological descriptions. Although this writer is not completely in agreement with the composite section southeast of Bove Island given by Ruedesili, that report contains valuable paleontological information, particularly on fusulinids, and, as a direct result of the paleontology, the suggestion by Ruedesili (1965, p. 11) that the rocks southeast of Bove Island are thrust blocks separated by bedding plane faults.

Structures shown by Wheeler (1961) are a series of anticlines and synclines with steeply dipping limbs, whose axial traces trend northwesterly between Windy Arm and Taku Arm of Tagish Lake and more open folds with roughly east-west trends on the east side of Taku Arm. Whereas east of Taku Arm folds associated with faults appear to be the dominant style (Section B - B1, Fig. 18), it seems probable that the area between Windy and Taku arms is underlain by imbricated slices of mainly Middle Pennsylvanian to Early Permian carbonate and minor volcanic rock, with each slice 'younging' to the northeast and separated by near vertical bedding plane thrust faults (Section A - A1, Fig. 18). No repetitive mesoscopic

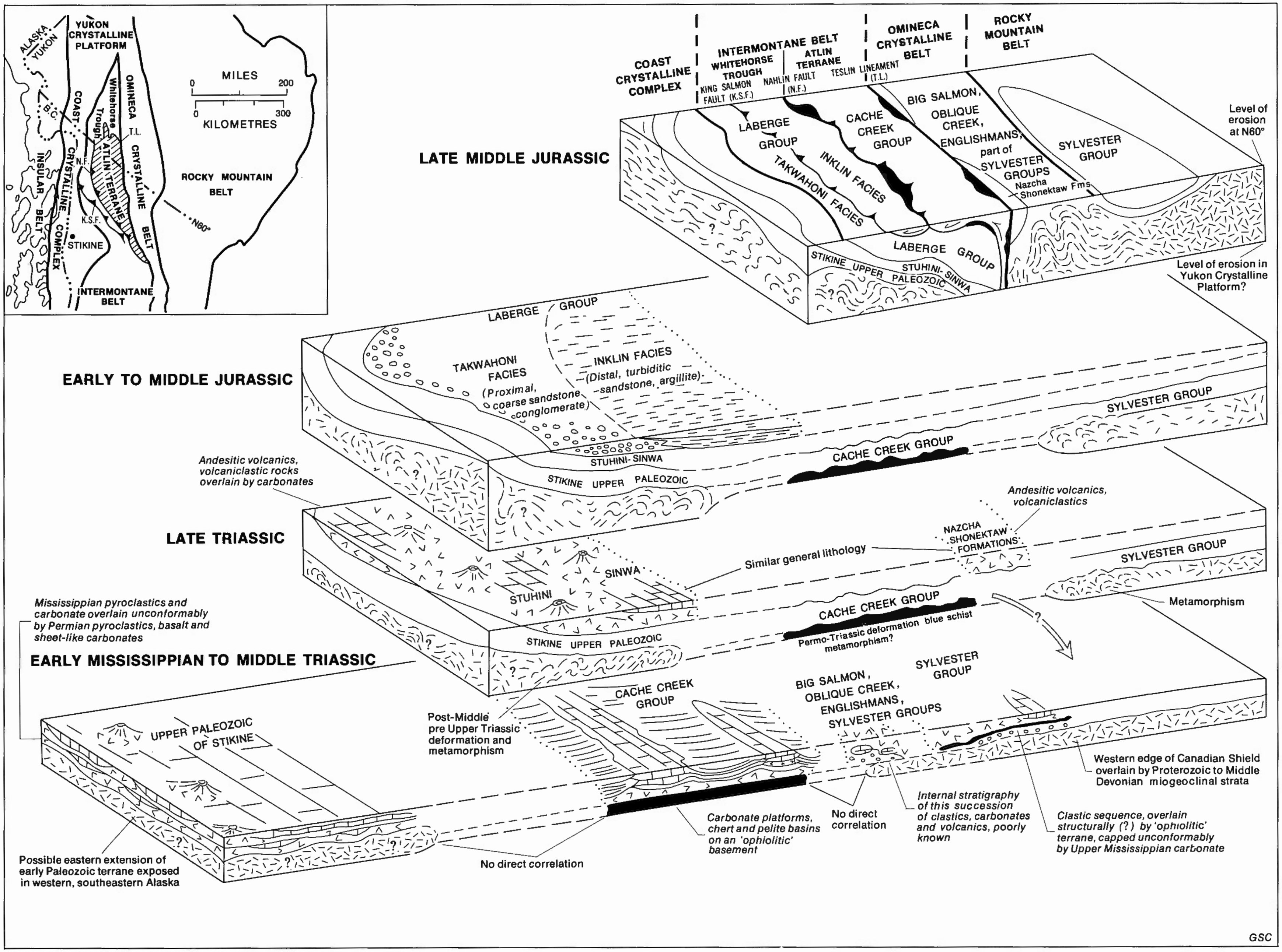


Figure 19. Possible evolution of the Atlin Terrane and its relationship with adjacent areas.

folds have been seen even though bedding is uncommonly well displayed, as might be expected if tight folding were the deformational style, and fossil control and mylonitization of cherty argillites demonstrates faulting southeast of Bove Island. However, paleontological and lithological correlation is not good enough over the whole area to locate these faults with any confidence and they have been omitted from the map in Figure 18.

i. Horsefeed Formation. The Horsefeed Formation in this area consists mainly of carbonate that ranges in thickness from 3,000 to 5,000 feet and includes local bodies of basic flow rock, diabase and lithic tuff, that in places may be as much as 3,000 feet thick, but do not appear to have any great lateral extent.

At least five fusulinid faunas are readily recognizable in the field (Table 4, Appendix A), and a sixth identifiable only in thin section has been described by Ruedesili (1965, p. 92). These faunas range in age from Early Pennsylvanian to Late Permian with Middle Pennsylvanian to Early Permian fusulinids being the most widespread.

Carbonate is divisible lithologically into a predominant Lower Permian and older part and a mid- to Late Permian part. Most extensive is commonly variably recrystallized massive, medium to pale grey bioclastic limestone with a faint brownish tinge, of mainly Middle to Late Pennsylvanian age. Bedding is commonly hard to identify in outcrop but may be visible at a distance (or on air photographs), although in some areas, as on Alfred Butte, bedding is clearly visible. Locally bedding directions may be outlined by layers of black nodular chert. The rock is typically crinoidal, fusulinid calcarenitic limestone or less commonly calcarenite with ubiquitous small crinoid columanls, common fusulinids and small foraminifera, local rhomboporoid bryozoa and rare corals, in a matrix of finer grained biogenic material and pellets. In places the fragments have what appear to be algal coatings. Oolites are not common except near some intercalated volcanic bodies, such as those on Alfred Butte. Alteration of these rocks is generally recrystallization that produces a fine-grained porcelaneous appearance, or else the whole rock becomes finely crystalline and mottled dark and light grey, with the darker patches containing black fractures which Ruedesili (1965, p. 27) suggested are filled with carbon expelled during recrystallization. Older parts of the formation, exposed southeast of Bove Island, are dark grey, fine grained and argillaceous in places, but other parts are pale grey and are carbonate breccia or else are bioclastic, and locally contain abundant chert nodules and large crinoid columnals up to 1 inch in diameter.

Commonly the limestone grades stratigraphically upwards into a sequence consisting mainly of chert correlated with the Kedahda Formation, but on the ridge northwest of Alfred Butte there is a transition upwards through Lower Permian carbonate to the mid and Upper Permian carbonate that forms Stovel Peak, the higher parts of the mountains north of Alfred Butte and a fault slice southeast of Bove Island. This carbonate is massive, locally thick- to medium-bedded, dark brownish grey or rarely pale grey weathering, dark grey to black, fetid aphanitic limestone. Scattered through certain beds are small crinoid columnals, calcispheres, and large schwagerinid or medium sized neoschwagerinid fusulinids. In places these fossils are so closely packed as to form a coquina. Texturally, the carbonate resembles the mid- to Upper Permian algalaminate aphanitic dolomitic limestone in the Nakina Lake area and northeastern facies belt. It differs in that it is rarely dolomitic, sparry calcite 'birdseyes' have not been seen and laminations were recognized only on the headland forming the south side of the entrance to Talaha Bay on Taku Arm. The common absence of recognizable laminations may be because these rocks are limestone, whereas elsewhere differences in degree of dolomitization accentuates the bedding laminations on weathered surfaces. The upper stratigraphic limit of aphanitic limestone has nowhere been recognized.

North of Turtle Lake and west of Charlie Peak, Lower Permian and Upper Pennsylvanian limestone is stratigraphically overlain by chert with dolomitic limestone breccias developed near the contact. The contact is gradational to some extent from predominantly bioclastic limestone through brecciated limestone containing dark grey chert layers, and finally to chert or cherty argillite containing only a few medium or thin beds of carbonate. Carbonate at the top of the limestone and in the thin beds is commonly a buff weathering breccia with angular fragments of limestone, crinoid columnals and broken fusulinids as a finer grained partly dolomitized matrix. Fragments are commonly less than 1 inch in diameter, but may range up to 18 inches in length. On the shoreline west of Cloutier Peak the limestones and interbedded cherts are folded into large irregular, tight to isoclinal folds that are intrafolial in that they are contained between undeformed beds above and below. Possibly these folds are slump structures.

Fossils in the breccias are generally of comparable age to those in the contiguous main limestone mass, unlike the similar carbonate breccias near Nakina Lake where clasts in the breccias contain Upper Permian fossils and locally lie on Upper Pennsylvanian carbonate. However, the chert and included breccias appear to be in unconformable relationship with the carbonate, at least in places, because the carbonate in contact with the chert and breccia horizons near Charley Peak ranges in age from Lower Permian to Upper Pennsylvanian over a distance of about half a mile.

Volcanic rocks in the Horsefeed Formation intercalated with or cutting mainly Middle Pennsylvanian and Lower Permian carbonate are altered basalt, diabase and less commonly basic lithic tuff. The flow rocks and diabase are typically yellow green although they vary from grey green to maroon. They are rarely pillowed, aphanitic and amygdaloidal in hand specimen and consist of small randomly oriented, strongly saussuritized semiopaque feldspar laths, intergranular clear pyroxenes, and opaque minerals, interstitial chlorite, and vesicles filled with chlorite, albite, calcite and/or epidote. Veins are calcite, chlorite and, rarely, prehnite. The diabase is texturally and compositionally similar, but individual crystals are commonly visible in hand specimens. In a few varieties, such as southeast of Bove Island, the metamorphic grade is slightly higher and actinolite, and locally clear albite are developed. Chemical analyses indicate basaltic composition (Table 1). The tuffs are yellow green or maroon, locally crossbedded, composed of altered volcanic fragments, and show all gradations with the enclosing carbonate.

Individual bodies of volcanic flow or intrusive rocks are of limited lateral extent, with the largest, southeast of Bove Island, being just over 3 miles long, and they vary in thickness from a few hundred to over 3,000 feet. Most appear to be conformable with bedding in the limestone and some show a thin tuffaceous transition zone to the enclosing carbonate. By contrast the tuff beds are relatively far more continuous, one horizon on Alfred Butte being a few tens of feet thick, but extending laterally for 3 miles.

The upper contact of the Horsefeed Formation has not been recognized where the formation is of Upper Permian age. Elsewhere, Lower Permian and older carbonate is overlain unconformably, at least locally, by a sequence composed mainly of chert. Southwest of Bove Island, the oldest part of the Horsefeed Formation, dated by Ruedesili (1965, p. 92) as Early Pennsylvanian, is underlain, apparently gradationally, by calcareous chert and bedded chert. The relationship here is ambiguous as these cherts pass gradationally into altered basic volcanic rocks and the southeastern extension of this chert and volcanic sequence appears to overlie Upper Permian limestone on Charlie Peak. Middle Pennsylvanian limestone is in contact with chert on the south side of Alfred Butte, but it is not known whether this contact is stratigraphic or structural.

ii. Kedahda Formation. Bedded chert, cherty pelite and pelite, typical of the Kedahda Formation elsewhere, mainly overlies Lower Permian or Upper Pennsylvanian carbonate of the Horsefeed Formation, but may locally underlie the formation as noted above. No fossils are known from this sequence with the exception of the recrystallized radiolaria reported by Wheeler (1961, p. 29) and fossils in carbonate breccias at the contact with the Horsefeed Formation. Southeast of Bove Island cherty pelite and pelite forms a fault slice that encloses Upper Permian carbonate and is locally mylonitized.

Other bedded cherts are intimately associated with the basic volcanic sequence that surrounds Windy Arm of Tagish Lake, on Nares Mountain northwest of Bove Island (Bain, 1964) and on Jubilee Mountain north of Alfred Butte. These cherts are of unknown age, for as noted above, the evidence of age from southeast of Bove Island and near Charlie Peak is contradictory.

iii. Altered basic volcanic rocks, possibly correlative with the Nakina Formation. These are the "altered volcanic rocks probably belonging to the Taku Group" of Wheeler (1961, p. 29) that are exposed around Windy Arm, on Nares Mountain and on Jubilee Mountain. These rocks were only briefly studied by the writer, although Bain (1964) gave a detailed section from the south side of Nares Mountain.

The metamorphic grade is generally higher than that of chemically similar (Table 1) basaltic rock in the Horsefeed Formation and elsewhere in the Cache Creek Group, although the degree of metamorphism is variable. Common rocks are massive, very hard, dark grey green, fine-grained amphibolite that locally grades into metadiorite. In thin section these rocks rarely retain any primary texture and consist of a dense mesh of actinolite or blue-green hornblende crystals, interstitial albite, opaque minerals, some relict pyroxene grains with variably developed clinozoisite, biotite and minor quartz. Less altered rocks retain some primary texture and a few rocks are comparable in grade to those elsewhere in the Horsefeed Formation. For example, gabbro from Windy Arm of Tagish Lake consists of uralitic hornblende, in part in poikilitic relationship with relatively fresh andesine, and finer grained altered basalt is comparable with that in the Horsefeed Formation, but contains abundant prehnite. Bain (1964, p. 12) reported that these less altered "andesites and dacites" intrude and intertongue with the more altered volcanics, but this relationship was not seen by the writer. Other rocks in this predominantly volcanic sequence are bedded chert, and minor carbonate and serpentinite.

The age of the sequence is not known. The higher grade of metamorphism than comparable basic volcanics in the Horsefeed Formation suggests that it may be older, and if the relationship reported by Bain is correct, this is almost certainly true. However, there is some possibility that this metamorphism could be related to the granitic intrusions on Jubilee Mountain, east of Windy Arm and southwest of Nares Mountain and the question of age of this sequence remains open.

iv. Late Cretaceous - Early Tertiary volcanic rocks. Volcanic rocks correlated with the Late Cretaceous - Early Tertiary Sloko Group (Aitken, 1959, p. 66) and including rocks called Hutshi Group by Wheeler (1959, p. 74) unconformably overlie the Cache Creek Group along the southwestern boundary of the Atlin Terrane in Tagish Lake area. These rocks are andesitic porphyries and porphyry breccias with phenocrysts of plagioclase feldspar, biotite and less commonly, pyroxene. They form flows, well displayed on the knoll on the north side of Tutshi Lake and 3 miles south-southeast of Charlie Peak, that appear to have been laid down on irregular topography developed on the Cache Creek Group. In places, as near the head of Windy Arm, they are green, highly altered and superficially resemble the Cache Creek volcanic rocks, but can generally be distinguished from the latter by their porphyritic texture.

10. Mount White Area

Upper Paleozoic rocks near Mount White (Figs. 1, 2) were mapped by Mulligan (1963) and studied in

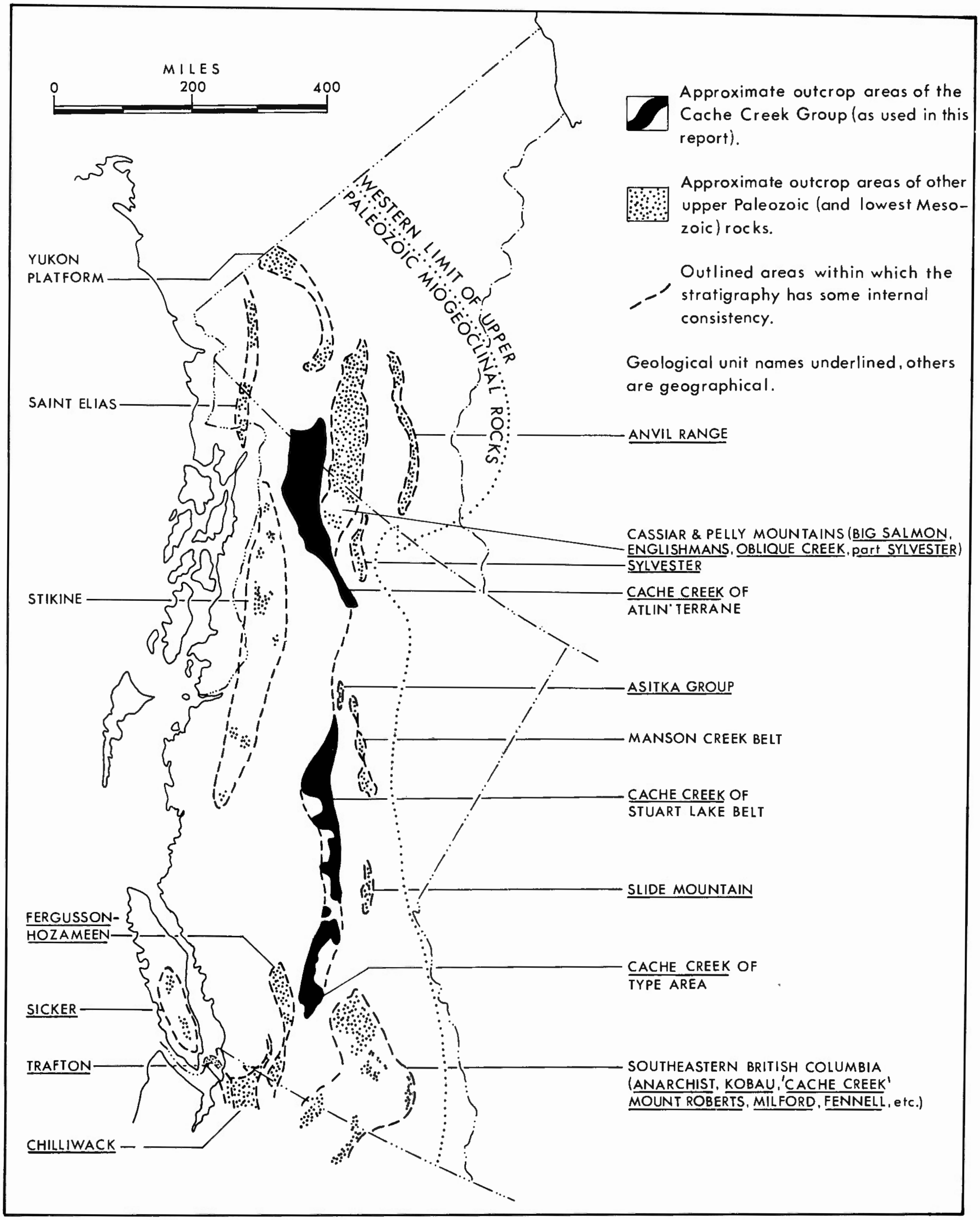


Figure 20. Distribution of Mississippian to Middle Triassic rocks in the western Canadian Cordillera.

detail by Link (1965). The following summary is largely taken from their work.

In the area there are three lithological sequences, separated by thrust faults (Link, 1965, p. 132). Structurally lowest and north of the Alaska Highway are massive basic volcanic rocks of either late Paleozoic or early Mesozoic age. South of the Alaska Highway is Middle Pennsylvanian to Lower Permian carbonate of the Horsefeed Formation underlying Mount White where it forms the lower limb of a major anticline overturned to the northwest. Structurally highest is a succession of chert, argillite, siltstone, greywacke and conglomerate equivalent at least in part to the Kedahda Formation elsewhere in the Atlin Terrane. The stratigraphic relationships between these three sequences is not known.

i. Permo-Triassic volcanic rocks. Included under volcanic rocks are mainly altered basic flow rocks, pyroclastic rocks and minor chert. The flow rocks are in part prehnitized altered basalt that is fairly typical of the Cache Creek Group, but more commonly are fine grained amphibolite. The pyroclastic rocks consist in large part of semiopaque, lithic fragments but include abundant pyroxene grains, somewhat typical of lower Mesozoic volcaniclastic rocks in the region (e.g. Monger, 1969, p. 27). This sequence is in contact with Upper Triassic carbonate but the nature of the contact is unknown. As these rocks show some of the characteristics of typical Cache Creek volcanics, the altered amphibolitic volcanics below (?) the Horsefeed Formation near Tagish Lake, and early Mesozoic volcanic rocks, it is not possible to estimate their age by lithological comparison.

ii. Horsefeed Formation. The Horsefeed Formation is the northeastern extension of the carbonate near Tagish Lake. It attains a maximum thickness of about 5,000 feet. Massive aphanitic limestone with scattered skeletal fragments predominates, but the older part contains much crinoidal fusulinid calcarenitic limestone. Fusulinids of Middle Pennsylvanian and Early Permian age only are known, but there is no physical feature marking the hiatus between the two faunas.

iii. Kedahda Formation. The sequence south of Mount White consists of bedded chert similar to that in the Kedahda Formation elsewhere, together with argillite, siltstone, greywacke and conglomerate. The latter two components are abundant and far fresher than in any other upper Paleozoic clastic rocks of the region. There is little doubt that the clastic rocks are interbedded with the chert, and, according to Link (1965, p. 29, p. 115) all degrees of silicification exist between the chert and argillite, although sandstone and conglomerate generally are less silicified. This phenomenon has been noted in the Kedahda Formation south of Sentinel Mountain. The greywacke is characterized by abundant detrital hornblende grains, in some cases making up to 30 per cent of the whole, and volcanic rock fragments containing hornblende or hornblende and feldspar fragments in a fine-grained matrix. The age of this sequence is not known, but alteration of hornblende in many of these rocks is negligible and it should be possible to obtain a radiometric age from these sandstones to give a maximum age to this sequence.

Summary of lithologies and their origin

1. Ultramafic Rocks

Ultramafic rocks in the Atlin Terrane have only been studied in detail by Aitken (1953, p. 81), but are briefly described in several reports (Aitken, 1959, p. 32; Wheeler, 1961, p. 88; Mulligan, 1963, p. 58; Monger, 1969, p. 25). Most extensive are elongate bodies, such as the Nahlin body, that occur along faults bounding the Atlin Terrane. Other more equidimensional bodies, called the Atlin Intrusions by Aitken (1953, p. 21) lie within the Atlin Terrane on Sentinel Mountain, Chikoida Mountain, at Atlin, and northeast of the settlement. Still others are associated with Permo-Triassic (?) volcanic rocks at the northwestern end of the terrane.

These rocks are predominantly enstatite-bearing peridotite or harzburgite, and dunite, partly or wholly serpentinized, and serpentinite of indeterminate origin. Locally they contain irregular lenses and layers of pyroxenite, some of which contain clinopyroxene that may form poikilitic crystals enclosing olivine grains.

Closely associated with the ultramafic rocks are gabbro, basic diorite, foliated amphibolite, diabase and, most commonly, enclosing basic volcanic flow rocks. Generally, the contacts of ultramafic rocks are tectonic, manifested by sheared, contact surfaces or totally foliated ultramafic lenses enclosed by massive basic volcanics. However, Souther (1971, p. 43) reported tabular bodies of gabbro and basic diorite forming subparallel swarms that clearly intrude the peridotite, but many of these are bounded by zones of intense shearing or disrupted into rectangular boudins. Diabasic rocks locally enclosed by ultramafic rocks on Sentinel Mountain are probably similar. Although this association of ultramafic and mafic volcanic rocks is that of ophiolites, it should be emphasized that nowhere in the Atlin Terrane has the characteristic stratigraphic ophiolite succession of ultramafic rock, through gabbro, diabase and basalt been recognized.

The age of the ultramafic rocks can only be inferred indirectly from the probable age of the enclosing volcanic rocks by assuming the two to be genetically related. Volcanic rocks near Nakina Lake are premid to Late Mississippian and those on Sentinel Mountain Early Mississippian and Middle to Late Pennsylvanian. North of the Atlin Terrane, in Teslin map-area, ultramafic rocks intrude rocks as young as Upper Triassic and/or Jurassic age but possibly these were originally upper Paleozoic, re-intruded during later tectonic movements.

As noted by Mulligan (1963, p. 62), the ultramafic rocks, with their associated basic volcanics and gabbros, are the "alpine type" of Benson (1926, p. 6).

More than twenty years ago, Aitken (1953, p. 127) noted that "the ultramafic rocks are thought to be the refractory part of a basic primary layer of the earth which underwent partial melting to give rise to the Permian and Triassic (?) volcanic rocks and related intrusions". Recent workers (e.g. Coleman, 1971), using the results of oceanographic studies, have drawn the analogy between ophiolites and the crust of deep ocean basins. The ultramafic rocks in these situations are believed to represent both residual mantle material depleted of its basic fraction and, to a far lesser extent, ultramafic cumulates differentiated from the basic fraction.

2. Volcanic Rocks

Volcanic rocks in the Atlin Terrane belong to five stratigraphic units: (1) the Nakina Formation, exposed in the southwestern facies belt near Opal Lake, Nakina Lake, Sentinel Mountain and possibly Mount O'Keefe, consisting largely of basalt of probable Mississippian and Pennsylvanian ages; (2) possibly correlative metabasalt of greenschist grade near Tagish Lake and (?) Mount White; (3) the French Range Formation exposed in the northeastern facies belt near Hall and Dease lakes of Permian age, which differs from the Nakina Formation in that pyroclastic rocks are abundant and rare siliceous rocks are present; lenticular bodies of mainly altered basalt of Pennsylvanian and Permian ages in the (4) Kedahda and (5) Horsefeed formations.

These rocks are predominantly fine grained, generally non-porphyritic, grey-green but locally maroon, altered basalts and less common diabases. They formed in a submarine environment as evidenced by local pillow lavas, pillow breccias and intercalated and gradational contacts with chert and carbonate horizons containing marine fossils. Some rocks may have been extruded in very shallow water because they are interbedded with carbonate whose textures indicate a shallow water origin. Other volcanic rocks such as those intercalated with chert, may have formed at any depth.

The mineral assemblages of most of these rocks are those of spilites. They contain the assemblages albite - clinopyroxene - chlorite, albite - chlorite, albite - chlorite - epidote, etc., reported as being typical of spilites by Vallance (1960, p. 31). In the fine-grained rocks the feldspars are altered to fine-grained, semi-opaque aggregates of albite and epidote, with interstitial chlorite probably representing glass, and the pyroxenes are typically fresh. Although alteration of the feldspar in the diabasic rocks is typically to albite and epidote, plagioclase as basic as labradorite is locally preserved, but the pyroxene may be uralitized. Alteration of some of the rocks near Tagish Lake is still more intense, for primary textures are lost, actinolite or blue-green hornblende predominate, and biotite occurs in places.

Chemically, most of the flow rocks and diabases are basalts, with no marked separation between rocks belonging to different units (Table 1). The average alkali content falls between that of the spilites and unaltered basalts, but individual analyses are present in which the alkali content is closer to that of either the average spilite or normal tholeiitic or alkalic basalt (Table 2, *see* p. 10).

Definition of these rocks as altered basalts is probably all that can be done with the information available. The term is more descriptive than spilite, which could probably be used. Vallance (1965, p. 480) concluded that "spilite flows are most reasonably interpreted as rapidly chilled basalts which have undergone diagenetic or low-grade metamorphic adjustments involving redistribution of components". Amstutz (1968) argued in favour of a restricted usage of "spilite" based on fabric features, but felt that any apparent chemical differences between basalts and spilites could be caused largely by sampling difficulties. Recent studies of alteration of submarine basalts on the floors of oceans have indicated that not only does element redistribution occur but also addition and removal of elements. For example, Hart (1973) suggested that such alteration is due to (1) low-temperature sea floor weathering and (2) prograde and retrograde metamorphism due to high heat flow near oceanic ridges or behind island arcs. For major elements, in the weathering process, Al_2O_3 and TiO_2 are constant, K_2O and H_2O are gained and CaO, Na_2O and MnO lost, and in metamorphism on the ocean floor, Na_2O, SiO_2 and MgO are gained and Ca and Fe lost. In addition, further reorganization might occur during tectonization and metamorphism when the rocks are incorporated in mountain chains. If these processes have taken place, which in view of the alteration seems possible, then it is not feasible to employ the available chemical information to attempt to classify the altered basalt into tholeiitic, alkaline or calc-alkaline varieties, particularly as such classifications draw heavily on the highly mobile alkalis (*see* Irvine and Baragar, 1971, p. 525).

The association of alpine-type ultramafic rocks with some of these basalts is important. Ultramafic rocks occur particularly with rocks of the Nakina Formation and are found in the metamorphosed volcanic rocks between Tagish Lake and Mount White, but are not present in the French Range Formation. If this association can be regarded as a disrupted ophiolite, and if the analogy can be drawn between ophiolites and oceanic crust, then it is possible that the Nakina Formation and possibly the metamorphosed rocks near Tagish Lake, together with the ultramafic rocks, represent oceanic crust and mantle on which all later rocks included in the Cache Creek Group were deposited. Later volcanic rocks, including the French Range Formation, may be seamounts or even isolated flows that accumulated on this oceanic basement.

3. Non-carbonate sedimentary rocks

Included in 'non-carbonate sedimentary rocks' are mainly chert and argillaceous material with less abundant sandstone and minor breccia composing much of the Kedahda Formation. These lithologies form most of the central facies belt and are important both in the northeastern facies belt where they underlie and possibly overlie the French Range and Teslin formations, and in the southwestern facies belt where they underlie, overlie and are probably facies equivalents of the Horsefeed Formation. Although topographically less prominent than other upper Paleozoic rock types they are spatially more widespread than any others in the Atlin Terrane. It is difficult to gain an idea of their true thickness because of the lack of marker horizons, but apparent thicknesses commonly range downwards from more than 5,000 feet, although Link (1965, p. 27) reported a thickness of nearly 25,000 feet in the predominantly sandy facies south of Mount White.

All gradations exist between relatively pure chert, which is common, and relatively rare pelite. Chert generally forms beds about 1 to 4 inches thick, with regular to slightly wavy bedding surfaces, separated by pelitic layers ranging in thickness from laminae up to about ½ inch thick. It is typically pale grey to grey-brown, but it may be maroon, brick red, green, or, rarely orange. In many places it contains probable radiolaria, represented by small circular patches of recrystallized quartz in the aphanitic chert matrix. These rocks are typical bedded, radiolarian ribbon cherts.

An increase in the content of argillaceous material appears to result in the chert bed becoming more argillaceous, rather than in an increase in thickness of the interlayered pelite, and forms the very common pelitic chert and cherty pelite. In places chert forms the uppermost layer of graded sandstone, siltstone, cherty argillite and chert beds. Near Dease Lake, pelitic chert is metamorphosed to finely laminated quartzose phyllite and phyllitic quartzite, but elsewhere the main evidence of metamorphism is the phyllitic sheen of the interbedded pelitic layers.

The sandstones form thin to massive beds which in places are graded, and elsewhere (e.g. Link, 1965, p. 22) show large-scale crossbedding. They consist of varying amounts of volcanic and sedimentary detritus. Near Dease Lake, Hall Lake, Mount White and Sentinel Mountain epiclastic volcanic sandstones are composed up to 80 per cent of variably altered, lithic fragments of basalt, pumice and hornblende feldspar porphyry, up to 50 per cent plagioclase feldspar, up to 30 per cent hornblende, 10 per cent or less quartz, commonly the clear, beta-quartz, rare pyroxenes and chert, and argillite fragments (Aitken, 1959, p. 22; Mulligan, 1963, p. 37; Link, 1965, p. 48; Monger, 1969, p. 5). The high percentage of hornblende is remarkable. Primary volcanogenic hornblende is not known in any of the upper Paleozoic volcanic rocks in the Atlin Terrane. Near Mount Farnsworth, in the central facies belt, greywackes contain sedimentary grains in which chert, carbonate and argillite fragments predominate, although volcanic detritus is invariably present. Many of these rocks, particularly those from the Mount White area, are remarkably fresh, but others, such as those near Dease Lake have a penetrative secondary foliation parallel with bedding, manifested by flattening of the clasts.

The breccias are commonly coarser equivalents of the sandstone lithologies, but near Nakina and Tagish lakes, local carbonate breccias at the upper contact of the Horsefeed Formation with the Kedahda Formation mark an unconformity between the two units.

Contacts of the chert and cherty pelite and volcanic rocks are commonly gradational or interfingering. Tuffs and flows of the Nakina Formation near Nakina Lake and metabasalt of unknown age near Tagish Lake are overlain and partly gradational with chert and pelite. Underlying chert and pelite shows similar contacts with pyroclastic rock of the French Range Formation, but sharp conformable contacts with flow rocks.

The contacts between the non-carbonate rocks and the carbonates are critical in the interpretation of the environment of deposition of the former. The non-carbonate rocks contain relatively little evidence of the environment in which they formed other than that they were deposited generally under quiescent conditions, presumably below wave base. The carbonates, on the other hand, are the most useful rocks for interpreting the environment in which they were deposited. Therefore, where contacts between carbonates and non-carbonates can be shown to be primary and depositional and particularly where carbonates and non-carbonates are interbedded, then the overall environment of deposition is presumably that which can be interpreted from the carbonates. Carbonates occur as relatively thin units within chert and pelite of the Kedahda Formation and also form the thick Horsefeed and Teslin formations. The thin carbonates are conformable with the enclosing rocks and because they are not disrupted and have locally gradational contacts, they appear to have been deposited with the non-carbonate, mainly chert and cherty pelite sequence, rather than sliding en masse into it. All are marine, but most, such as the Permian limestone near Mount Farnsworth and the Mississippian limestones northwest and southeast of Nakina Lake, appear to have formed in shallow water, as they contain algal detritus in places but do not show the characteristics of limestone turbidites such as grading (*see* Meischner, 1964). Others, cuh as the dark Middle Pennsylvanian limestone on the southwest side of Sentinel Mountain and Mississippian limestone north of Sentinel Mountain on McKee Creek, are possibly of deeper water origin. The upper contact of cherty argillite of the Kedahda Formation with the Horsefeed Formation is conformable and the lowest carbonate, massive crinoidal calcarenite, is probably of shallow water origin. From this type of evidence, the non-carbonate rocks, at least where they are in contact with carbonates, appear to have formed in both shallow and possibly deeper water.

This is somewhat at variance with the general opinion that most bedded radiolarian cherts accumulated in deep water, a conclusion initially based on the occurrence of radiolarian oozes in modern oceans and the dissolution of carbonates in deeper parts of the ocean (e.g. Davis, 1918, p. 356). Evidence of the geological record tends to support deposition in deep water (Grunau, 1965, p. 199). However, Danner (1967b, p. 42) found similar relationships to those in the Atlin Terrane in other upper Paleozoic rocks in southern British Columbia and concluded that there the cherts were of shallow water origin. Recently Folk (1973) studied bedded chert of somewhat different character from these in the Marathon Basin, Texas and concluded that chert, in general, may form in a wide range of environments. In the Atlin Terrane, the non-carbonate rocks may have been deposited in a shallow water environment where they occur with carbonate, but elsewhere perhaps formed in deeper water.

4. Carbonates

Carbonates in the Atlin Terrane comprise the Teslin and Horsefeed formations and units within the Kedahda Formation. The Teslin Formation is of Permian age, is restricted to the northwestern facies belt and attains a thickness of 2,000 feet. The Horsefeed Formation ranges in places from Upper Mississippian to Upper Permian, but elsewhere is restricted to the Pennsylvanian and/or Permian and is in the southwestern facies belt. It has a maximum thickness of about 5,000 feet of carbonate, but with included pods of volcanic rock is locally more than 7,000 feet thick. Carbonates in the Kedahda Formation are of Mississippian, Pennsylvanian and Permian ages, occur in all facies belts and have maximum thicknesses of a few hundred feet.

The carbonates have three general characteristics. Firstly, they are lensoidal or pod-like on all scales. This character is certainly primary and depositional across the regional strike, but is probably exaggerated by 'telescoping' during deformation. The Mississippian to Permian Horsefeed Formation in the type-area is 5,000 feet thick. Twenty-five miles to the north, near Mount Farnsworth, lowest Permian carbonate forms lenses a few hundred feet thick in chert and pelite of the Kedahda Formation. Twenty-five miles further north of this, the Permian Teslin Formation near Hall Lake is about 1,000 feet thick. Along strike, the evidence supporting a depositional origin for the lensoidal character, or a secondary, deformational origin, is equivocal. The carbonate is thick, always more than 2,000 feet, shows similar lithological changes at similar times, but is not coeval everywhere. The second characteristic is that the carbonates are massive, with bedding where visible generally more apparent from a distance than close-up. Thirdly, they are commonly pure, with little admixed noncarbonate material except near contacts with other lithologies.

The dominant lithology in the Teslin Formation is of Late Permian age and is pale grey weathering, dark grey to black, aphanitic limestone and dolomitic limestone that in places contains fine laminations and anastomosing sparry calcite patches of probable algal origin. Beds of breccia composed of angular and platy carbonate and minor chert fragments and fusulinid coquinas occur locally. The older parts of the Teslin Formation are crinoidal and/or fusulinid calcarenitic limestones and calcarenites that near contacts with the French Range Formation are tuffaceous and near the Kedahda Formation are argillaceous.

Carbonate lithologies in the Horsefeed Formation show a similar range to those in the Teslin Formation, but by far the most common lithology is massive, pale grey to buff grey, porcelaneous, crinoidal and fusulinid calcarenitic limestone. This lithology is of Pennsylvanian to mid-Permian age in the type-area, Early Permian near Opal Lake, Late Pennsylvanian and Early Permian at Sentinel Mountain and Pennsylvanian and Early Permian near Tagish Lake. Material of algal origin is present in minor amounts as fragmented calcareous algae, both 'free' and forming nuclei of oolites in the relatively rare oolitic calcarenites, and as laminated algal coatings on grains. The basal, Upper Mississippian part of the formation in the type-area is massive, crinoidal calcarenite to calcarenitic limestones with large crinoid columnals and these large columnals also characterize the oldest, Early Pennsylvanian limestone near Tagish Lake. In most areas, the predominant calcarenitic limestone passes upwards into mid-Permian and younger, locally laminated, algal aphanitic limestone and dolomitic limestone similar to that in the upper part of the Teslin Formation. Overlying rocks in the type-area are Upper Permian aggregate and foraminiferal calcarenitic limestones that locally may grade into carbonate breccia at the base of the upper part of the Kedahda Formation.

Most limestones in the Kedahda Formation are light-coloured, calcarenitic limestones and calcarenites. Mississippian limestones near Nakina Lake and Sentinel Mountain are mainly massive, pale grey crinoidal calcarenitic limestones that contain scattered oolites, dasyclad algae, small foraminifera and corals. In places they are argillaceous, cherty and tuffaceous where they grade into rock of these lithologies. Lowest Permian limestone near Mount McFarlane is pelletal, calcarenitic, fusulinid limestone. Exceptions to this are dark grey calcarenitic limestone with scattered crinoids, and fusulinids in an abundant, dark, lime-mud matrix of Pennsylvanian age, southwest of Sentinel Mountain, and Mississippian and ? Lower Permian carbonate that is dark grey to black, graphitic and cherty aphanitic limestone in McKee Creek, north of Sentinel Mountain.

Most of the carbonates appear to have formed in shallow water, at least within the photic zone, as is shown by the presence throughout of algal material in massive, 'non-turbiditic' carbonate. Two main environments are represented. The first is that manifested by the calcarenitic limestones and calcarenites that form the Pennsylvanian to Lower Permian parts of the Horsefeed Formation, some carbonates in the Kedahda Formation, and older parts of the Teslin Formation. These perhaps accumulated as sub-tidal banks and shoals. The light colour of these rocks is suggestive of well-oxygenated, open water. Local current action is indicated by the moderately well-sorted calcarenites and rare oolitic calcarenites, but rare corals and grains bounded by laminating algae suggest a stable, non-shifting sub-stratum elsewhere. The other main environment, predominant in the Teslin Formation and the mid and Upper Permian part of the Horsefeed Formation, is represented by the light-weathering, dark grey to black aphanitic limestone and dolomitic limestone with algal laminations and local breccias, that probably formed in extremely shallow, protected waters such as lagoons or on broad carbonate mud flats. The laminated algal carbonates texturally re-

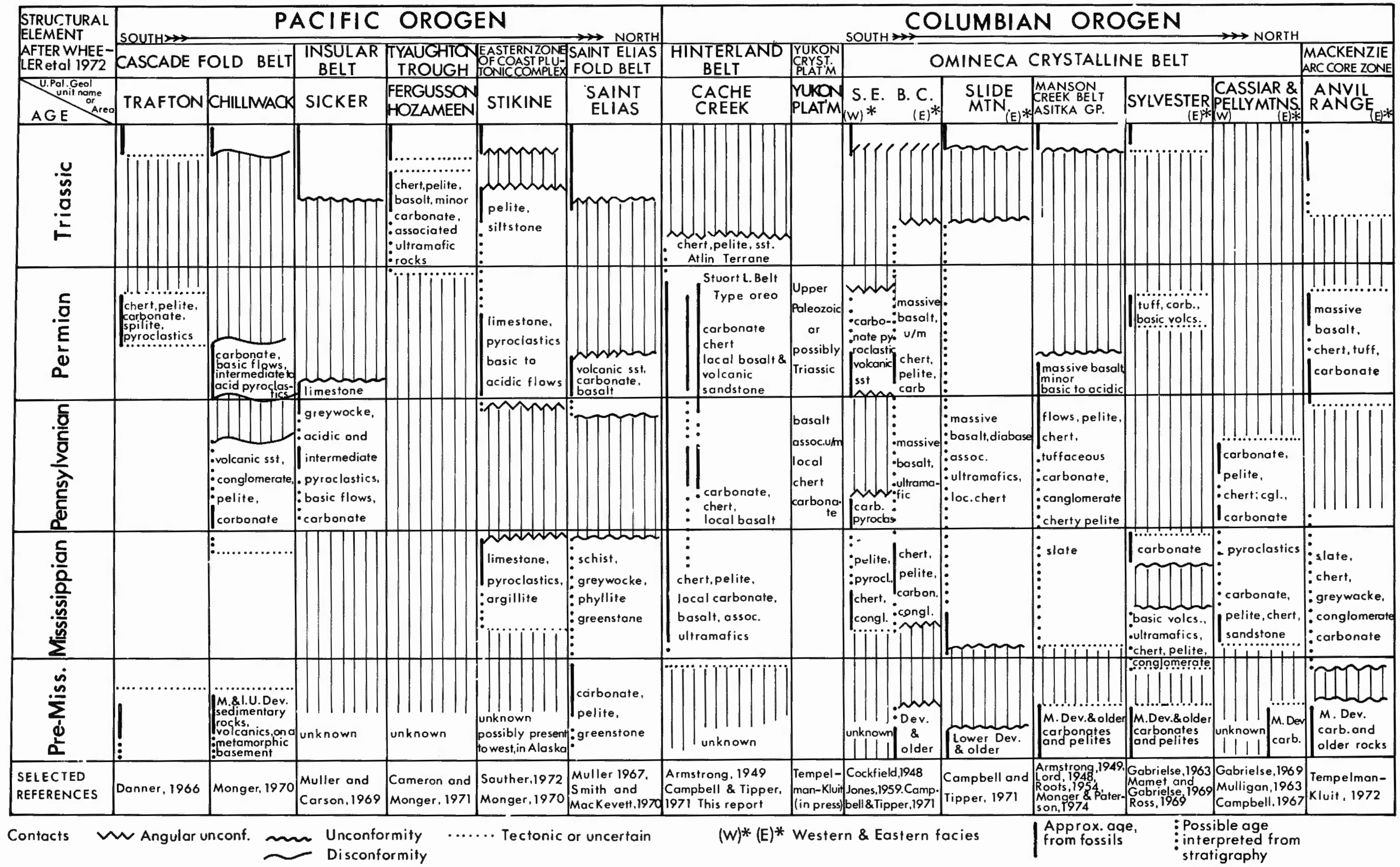


Figure 21. Correlation of upper Paleozoic to Triassic rocks in the western Canadian Cordillera.

semble rocks formed on intertidal mud flats. The colour is indicative of a lack of oxygen and restricted circulation and the breccias are perhaps material torn up and redeposited during storms (Monger, 1969, p. 23). Textural evidence thus indicates that some carbonates accumulated from latest Mississippian to Early Permian time, as subtidal banks and shoals. In mid to Late Permian time, a relative lowering of sea level, perhaps of only a few feet, produced intertidal lagoonal conditions. Carbonate breccias containing Lower Permian fossils, and those locally unconformably above Upper Permian to Upper Pennsylvanian carbonate, presumably represent local uplift and erosion.

If this interpretation is valid, the carbonates represent an interval of remarkable crustal stability from, at least locally, latest Mississippian to Late Permian time, an interval of 90 million years. During this time subsidence apparently kept pace with deposition. The average rate of subsidence varies from about 55 feet per million years in the type-area of the Horsefeed Formation to about 83 feet per million years near Tagish Lake. These figures are comparable with those of other thick long-lived carbonate accumulations such as the Bahama Banks, an average of about 85 feet per million years, from at least the beginning of the Cretaceous to the present, about 135 million years (Lynts, 1970) or the Gavrovo massif in the Alpine chains of Greece (90 feet per million years, from Triassic to Eocene, about 150 million years, Temple, 1968). This stable behaviour is in marked contrast not only with the Mesozoic of the region (Gabrielse and Wheeler, 1961, p. 28), but also with that shown by coeval rocks about 50 miles to the south in the Stikine area, where there appears to be a major stratigraphic and structural break between Mississippian and Permian rocks (Fig. 21; Monger, 1970).

The only carbonates that may represent deeper water deposition are the dark carbonates in the Kedahda Formation, near Sentinel Mountain. Their fine grain size, predominance of lime-mud, dark colour and absence of algal structures differentiate them from most other carbonates, but may merely represent accumulation in an enclosed, protected environment with no great depth significance.

Attention was drawn earlier to the apparently anomalous situation of shallow water carbonate contiguous to, and locally interbedded with, radiolarian chert and argillite that is generally interpreted as being of deep water origin. True deep water carbonates, such as well-bedded, very fine grained carbonate, perhaps interstratified with chert or pelite, or regularly graded carbonate turbidites with shallow water fossils, have not been recognized in the Atlin Terrane. Gradational and conformable contacts of probable shallow water carbonates with enclosing chert and argillite suggests that at least some of the latter rocks are of shallow water origin. It is possible that some carbonates are allochthonous, either as the result of penecontemporaneous sliding of the carbonates from shallow to deep water, or due to tectonic displacement at a later date, as suggested for example, for shallow water carbonate in the ophiolite and radiolarite belt of Oman by Alleman and Peters (1972, p. 675, p. 691). Poorly exposed contacts between chert and carbonate, bedding plane faults, and internal imbrication of carbonate such as near Tagish Lake are certainly permissive of this type of relationship. However, in Oman, mainly Permian and Triassic carbonate bodies lie in Upper Jurassic and Cretaceous cherts, shales and turbidites. Here the chert-pelite "matrix" making up much of the Kedahda Formation is largely coeval with the carbonates. The Kedahda Formation is almost certainly entirely pre-Upper Triassic as the Upper Triassic on both sides of the Atlin Terrane consists mainly of volcanic and volcaniclastic rocks. Thin Mississippian, Pennsylvanian and Permian carbonates are clearly interbedded and in gradational contact with chert and pelite. The basal Upper Mississippian Horsefeed Formation in the type-area conformably overlies argillite and chert containing pods of Upper Mississippian limestone, suggesting that at least in this place there is no disruption between the two main lithologies. Laterally, the thick carbonates of the southwestern facies belt appear to pass northward into the predominantly chert-pelite assemblage of the central facies belt. In the light of this, perhaps the best model of the later Cache Creek environment is one of high-standing carbonate platforms surrounded by deep water basins containing mainly chert and pelite.

Depositional history of upper Paleozoic rocks in the Atlin Terrane

Following is a summary of the possible depositional history of upper Paleozoic rocks in the Atlin Terrane:

(1) A basement of oceanic crust was formed in Mississippian time that is represented by basic volcanic rocks of the Nakina Formation and associated ultramafic rocks. It is not known whether this basement formed as open ocean floor, as suggested by Monger *et al.* (1972) or as a marginal basin, as in the model proposed by Churkin (in press). The former suggestion was based (1) on the relatively low content of clastic material in the Cache Creek Group in comparison with that in coeval flanking rocks, implying that the former rocks were considerably removed from any source of detritus, (2) on the exotic 'Tethyan' or 'Asian' fusulinid faunas (Monger and Ross, 1971), and (3) on the local blueschist metamorphic mineral assemblages that could suggest some kind of subductions process has taken place, perhaps accompanied by great lateral shortening. The latter model envisages a marginal basin behind upper Paleozoic arc-like rocks now in southeastern Alaska and the Coast Mountains. Monger *et al.* (1972) suggested the arc-like rocks were brought in later, by early Mesozoic transcurrent movement. All that can be said is that the composition of the oldest rocks in the Atlin Terrane is suggestive that they once were oceanic crust.

(2) Radiolarian chert, argillite, and local Mississippian shallow water limestone of the Kedahda Formation and coeval volcanic rocks including diabasic sills were laid down on this crust.

(3) This type of sedimentation continued through

Pennsylvanian and Permian time in the central facies belt and in pre-Permian time in the northeastern facies belt. Interbedded carbonates are generally of shallow water origin, but overall the water may well have been deep, by analogy with depths suggested by radiolarian chert and pelite sequences elsewhere (Grunau, 1965). Volcanic sandstones derived from largely andesitic terranes are locally important in the northeastern facies belt and sandstone and breccia derived in part from carbonate and chert sequences are found in places in the central facies belt.

(4) In the southeastern facies belt, carbonate sedimentation initiated in Late Mississippian and Early Permian time, resulting in the great thicknesses of carbonate of the Horsefeed Formation. These are of shallow water, subtidal and locally intertidal origin, presumably accumulated as great high-standing platforms and reflect conditions of extreme tectonic stability, as deposition apparently kept pace with subsidence throughout most of their 90-million-year-long development. Reasons for this carbonate build-up are not known. Possibly, from its apparently elongate form, it formed on an elevated ridge of the sea floor, although subjacent rocks are commonly chert and pelite, rather than the volcanic rocks that might be expected.

(5) Volcanic rocks, both basic flows and pyroclastic rocks were extruded in the northeastern facies belt in the Permian. Thick Permian carbonates were deposited both on these and on chert and pelite of the Kedahda Formation. The oldest carbonates accumulated in shallow, but subtidal, water, whereas the predominant, Upper Permian rocks were laid down in part intertidally. Mid-Permian carbonates in the Horsefeed Formation reflect similar conditions that are presumably due to a relative lowering of sea-level in mid- to Late Permian time.

(6) Finally, although carbonate breccias indicate local erosion of the carbonate units, there was probably a return to deeper water at the end of the Permian and possibly into the Triassic, because in most areas cherts and pelites appear to overlie the carbonates.

STRUCTURE OF THE ATLIN TERRANE

Internal structure and metamorphism

All upper Paleozoic rocks in the Atlin Terrane are deformed, but the style and intensity of the deformation varies considerably. Some of the variations can be ascribed to differences of metamorphic grade and others to different competancies in rocks of the same grade.

The metamorphic grade over much of the terrane is the prehnite-pumpellyite facies. In the mafic volcanic rocks primary textures are generally preserved and pyrogenic feldspars commonly saussuritized, with albite remaining as the determinable feldspar. Primary calcic feldspars are preserved in some diabases near Sentinel Mountain. The index minerals pumpellyite and prehnite occur sporadically, as does actinolite, indicative of the transition of these rocks to the greenschist facies. Rocks of somewhat higher grade are found near Dease and Tagish lakes. Near Dease Lake, actinolite is common in the mafic volcanic rocks and the presence of local blue amphiboles and lawsonite suggests that these rocks are transitional to the blueschist facies. Massive greenstones along Windy Arm of Tagish Lake have mainly lost any traces of primary texture, and consist in large part of actinolite or blue-green hornblende with interstitial albite and local biotite that indicates greenschist facies.

In rocks of the common, subgreenschist, prehnite-pumpellyite facies, the style of deformation is strongly dependent on lithology. Massive volcanic flow rocks are very competent and apparently deformed mainly by faulting. Thick massive carbonates are commonly competent and deformed either by forming folds of great amplitude and wavelength with complementary faults, such as those near Nakina Lake (Fig. 10) or by faulting, as near Tagish Lake (Fig. 18). In some areas, as near Dease Lake, the carbonate generally behaved competently but locally deformed by recrystallization and flowage (Monger, 1969, p. 30, Fig. 3). On the outcrop scale, dolomite layers in carbonates have crudely preserved primary textures, and behaved competently, whereas interlayered calcite appears to have recrystallized and flowed. Sandstone and pyroclastic rocks in most parts of the terrane appear to be internally unstrained and behaved moderately competently unless thinly bedded. In the Dease Lake area, however, they are semischists with flattened clasts, or schists. Pelite and chert assemblages are generally incompetent and the normal style of mesoscopic structures in these rocks is irregular folds or crumples and faults (Fig.), with at best a poorly developed fracture cleavage in the pelitic layers. Near Dease Lake, these rocks contain rare isoclinal folds with an axial plane, phyllitic cleavage, and superimposed, later, irregular structures with strain-slip or crenulation cleavages. An important result of these differences in competency is that during deformation stratigraphic contacts between different lithologies readily become faults, and subsequently it becomes hard to evaluate whether contacts are stratigraphic or bedding plane faults. The former are demonstrable where the contacts between contiguous units are gradational, and the latter where exotic rock-types occur along the contact or where there is lithological or faunal repetition or omission. In many places, unfortunately, such evidence is not available.

The Dease Lake area is the only part of the Atlin Terrane where two phases of regional deformation are clearly demonstrable. There is a penetrative early foliation parallel with bedding and with axial planes of rare isoclinal mesoscopic folds best developed in the chert and pelite assemblages (Monger, 1969). Most secondary minerals, including the blue amphiboles, lie in the plane of foliation and were presumably produced at the same time. These folds and cleavage bedding intersections have an orientation that was probably roughly north-south prior to later deformation. The only major structures possibly related to this deformation are some faults nearly parallel with bedding in the central part of the French Range (Fig. 2). They may represent thrusts and slides formed during this early deformation and subsequently folded. Later structures deform bedding and the early foliation, and are sporadically occurring, irregular, asymmetric tight and open folds and associated strain-slip (or crenulation) cleavages that are best developed in thin bedded and/or well foliated rocks. These folds commonly have horizontal fold axes that trend about 120 degrees and display a predominant south-southwestward directed sense of movement. The map-pattern and the geometry of the major structures results largely from this later deformation.

The later structures are possibly of early Late Jurassic age. The only secondary planar structure in Upper Triassic or Lower Jurassic argillite and siltstone of the Nazcha Formation, immediately north of Dease Lake area across the Thibert Creek Fault, is a fracture cleavage with the same trend as the strain-slip cleavage in the upper Paleozoic rocks. These structures could be analogous to the late structures in the upper Paleozoic rocks. The difference in style could be due to the fracture cleavage being produced in effectively mechanically isotropic rocks whereas the crenulation cleavage is formed in well-foliated rocks. More importantly, both the trend and style of the predominantly south-southwest-directed, later folds are compatible with the reverse and thrust faults bounding the Atlin Terrane on the south. These can be dated as post-Bajocian (Middle Jurassic) - pre-Upper Cretaceous, with the probable movement in early Late Jurassic time (Souther, 1971, p. 50-51).

On the basis of structural and stratigraphic evidence the age of the early deformation is post-Late Permian, pre-Upper Triassic but from radiometric data it could be the same as the later deformation. The early structures appear to represent a deformational episode completely divorced from the later one as the two sets of minor structures are not coaxial, and thus it seems probable that they have not formed as the result of a decrease in metamorphic grade during one long-lived episode. Secondly, adjacent Upper Triassic and Lower Jurassic rocks only contain one set of structures perhaps correlative with the later structures in the upper Paleozoic rocks, and on this basis it seems possible that the early deformation was pre-Upper Triassic. However, whole rock K-Ar ages of 165±27 m.y. (Middle Jurassic) and 129±20 m.y. (Lower Cretaceous) done by the Geological Survey of Canada on crossite-quartz schists, with the crossite parallel with the early foliation, are more compatible with the earlier structures being formed at about the same time as the later ones in the early Late Jurassic. However, although the two crossite-quartz schist localities are from about the same stratigraphic level and only 4 miles apart, the ages are markedly dissimilar. As the rocks have undergone folding and crenulation during the later episode, it is possible that there has been either argon loss from the rocks giving the younger age, and that the older age represents the time of early deformation, or else both numbers have been updated from a still older, Permo-Triassic, episode of deformation. It is of interest that Lower and Middle Triassic K-Ar ages (211, 214, 216 and 218 m.y.) have been obtained from blueschist terranes in a similar regional setting in the Stuart Lake belt of the Cache Creek Group near Pinchi, about 350 miles along trend to the south-southeast (Paterson, 1973).

For the remainder of the Atlin Terrane there is clear evidence of only one episode of major, regional, deformation, although it is possible that the deformational history is similar to that near Dease Lake. Minor structures are not systematically developed as near Dease Lake and consist mainly of irregular crumples, or rarely, tight or isoclinal folds with sub-horizontal fold axes in bedded cherts and pelites, and shear and fault zones in volcanic rocks and limestones. As noted earlier, many contacts are marked by bedding-plane faults. These faults could represent either slip parallel with bedding caused by competency differences, or an earlier period of thrusting and sliding with the faults subsequently refolded (as is possible near Dease Lake) or both. Rock-units are parallel with the regional trend in the northeastern facies belt, but elsewhere show considerable divergences from it. These divergencies possibly are due more to the lensoidal nature of the units, to the intrusion of discordant granitic plutons, and to post-intrusive faults that are normal to the regional strike, than to any systematic, through-going, deformational episode at some angle to the northwesterly regional trend. Near Hall Lake, the rock-units trend parallel with the regional strike, although rare minor fold axes with near vertical axial planes plunge at up to 25 degrees and deformation appears to have taken place by a combination of folding and faulting, with no systematic direction of movement apparent (Fig. 7). In the Nakina Lake area, deformation has taken place by folding and faulting predominantly parallel with the regional trend, with many fault planes marked by serpentinite slices (Fig. 10). Near Mount O'Keefe faults parallel with bedding and with the regional trend are the dominant structures. Structures in the Sentinel Mountain area trend east-west, and thus diverge considerably from the regional trend. Mississippian and Pennsylvanian mafic and ultramafic rocks and cherts in the core of the Sentinel Mountain structure that appear to be squeezed-up along bounding faults by the deformation which produced the steep dips in the rocks, could equally represent a thrust sheet overlying Permo-Pennsylvanian carbonate and chert folded with the underlying rocks during later deformation (Fig. 16). The dominant structures near Tagish Lake appear to be bedding plane faults that imbricate thick Pennsylvanian and Permian carbonate and volcanic rocks of the Horsefeed Formation (Fig. 18). These structures indicate a sense of movement towards the southwest. Finally, Link (1965, p. 131) has shown that the thick carbonate forming Mount White is mainly inverted, and has interpreted it as the lower limb of an anticline overturned to the north-northwest and separated from structurally overlying and underlying rocks by thrust faults.

External relationships

It is possible that the Atlin Terrane is largely an allochthonous, thick sheet, overthrust to the southwest on to lower Mesozoic rocks, although Souther and Armstrong (1966) and Souther (1971) felt that it was the result of largely vertical uplift. The critical information for the interpretation comes in large part from the southwestern boundary of the Atlin Terrane. At the southeastern end of the boundary, it is a zone of thrust faults that dips northerly at angles of 50 degrees or less (Gabrielse, 1966 and pers. comm.). "Later" structures in the upper Paleozoic rocks near Dease Lake show trends parallel with this and a predominant south-southwestward sense of movement and so are compatible in geometry with the thrust faults. Farther to the northwest, south of Nakina Lake, Souther (1971, p. 44) named the continuation of this zone the Nahlin Fault, and noted that it was vertical or dipped steeply to the northeast. The steepness of the fault plane, plus the steep dips of bedding and structures in the upper Paleozoic rocks and the shallower dips in the Mesozoic rocks lead Souther and Armstrong to their suggestion that the Atlin Terrane resulted from largely vertical uplift. Subsequent work has shown that upper Paleozoic rocks in the Stikine area which underlie the lower Mesozoic rocks southwest of the Atlin Terrane are very different from those to the northeast (Monger, 1969). In the Stikine, volcanic rocks are mainly pyroclastics, the carbonates are commonly well-bedded and sheet-like, there are few bedded cherts, the Permian fusulinid faunas are completely different (*see* Pitcher, 1960; Monger and Ross, 1971) and there is probably a major unconformity separating the Mississippian and Permian rocks. The Atlin Terrane retains its lithological and paleontological similarities over a width of 60 miles, and Permian rocks in the Stikine have similar stratigraphy to those near Terrace, 250 miles to the south (J.K. Rigby, pers. comm.). These two extensive upper Paleozoic assemblages are less than 30 miles apart, and the total lack of any transition between the two makes it possible that there is considerable juxtaposition of the two assemblages. Because upper Paleozoic rocks in the southeast end of the Atlin Terrane are thrust over the Mesozoic rocks, and some structures within the terrane such as those near Tagish Lake are compatible with overthrusting, it seems likely that the juxtaposition south of the Nahlin area is by thrust faulting. The vertical and steep reverse faulting south of Nakina Lake may merely be the upturned edge of the thrust sheet. Furthermore, the narrower width of the belt of upper Paleozoic rocks, the higher metamorphic grade and the flatter thrust faults near Dease Lake may indicate proximity to the base of the overthrust sheet.

The interpretation of the southwestern boundary of the Atlin Terrane as a zone of overthrusting, makes it possible to understand the nature of the transverse, predominantly northeast trending, boundary at the northern end of the terrane. The western end of the boundary, between Carcross and the northern end of Tagish Lake is the probable Crag Lake Fault across which upper Paleozoic rocks on the south are separated from Lower Jurassic sedimentary strata similar to those south of the Nahlin Fault (Wheeler, 1961). Farther northeast, between Tagish and Teslin lakes is a complex, poorly exposed and poorly known area in which "Permo-Triassic" volcanic and ultramafic rocks apparently interfinger with Upper Triassic strata. If the western part of the Atlin Terrane is allochthonous, and thrust over the Lower Jurassic strata, then the Paleozoic rock south of Crag Lake valley could be downdropped on a post-thrusting fault, with, subsequently, Paleozoic strata eroded off north of the fault. The area where "Permo-Triassic" and Upper Triassic rocks interfinger could represent some kind of a root zone, above which the upper Paleozoic rocks are largely autochthonous.

The northeastern boundary of the Atlin Terrane is the Teslin lineament, of which the Thibert Creek Fault is a segment. This lineament extends from the southeastern end of the Atlin Terrane for 400 miles to the northwest into the Yukon Crystalline Platform. It is the boundary that separates little metamorphosed rocks of the Atlin Terrane and lower Mesozoic rocks, from variably metamorphosed upper Paleozoic strata and Mesozoic granitic rocks to the northeast that comprise the core of the Cassiar Mountains and the eastern part of the Yukon Crystalline Platform. In places, such as north of Dease Lake, this lineament is a fault, marked by small ultramafic bodies and narrow partly fault-bounded slices of Upper Triassic to Lower Jurassic volcanic and sedimentary rocks. Elsewhere it is obscured by Mesozoic granitic rocks.

Upper Paleozoic rocks northeast of the Teslin lineament are the Oblique Creek Formation (Watson and Mathews, 1944, p. 14), Sylvester Group (Aitken, 1959, p. 15), Big Salmon Complex (Mulligan, 1963, p. 19), which are mainly greenschist and locally amphibolite facies metamorphic rocks, unnamed mainly metasedimentary rocks (Gabrielse, 1969, p. 13, 15) and little metamorphosed strata such as the Englishmans Group (Mulligan, 1963, p. 27). The metamorphic rocks consist of schist, gneiss, amphibolite, greenstone, marble and quartzite and the less metamorphosed limestone, slate, quartzite and minor conglomerate. The stratigraphic relationships between these assemblages are poorly known, but the Sylvester Group and Big Salmon Complex are at least in part equivalent, and overlain by the Englishmans Group. Fossils of Early Mississippian age (Kinderhook/Osage) are known from the Englishmans Group and Early to Middle Pennsylvanian from unnamed sedimentary rocks (Mulligan, 1963, p. 28; Gabrielse, 1969, p. 16). These rocks were probably metamorphosed in Early or Middle Triassic time as indicated by potassium-argon ages of 214±25 m.y. and 222 m.y. on muscovite from schist of the Big Salmon Complex.

The origin of the Teslin lineament is unknown other than that it is at least in part a fault zone. As the metamorphic grade northeast of the fault zone is higher than that of partly coeval rocks to the southwest, there is probably some vertical movement on the lineament, with the northeast side uplifted. The length and relative straightness of the Teslin lineament indicates that it could be a strike-slip fault, but the internal stratigraphy of upper Paleozoic units to the northeast is too poorly known to compare it with the stratigraphy of the Cache Creek Group. Some units, such as the Oblique Creek Formation, could well be more metamorphosed equivalents of the Cache Creek Group, whereas others are very different. However, the metamorphic assemblages northeast and southwest of the Teslin lineament appear to belong to different facies series. Those to the northeast are intermediate pressure, classical "Barrovian" type, whereas those to the southwest are at least in part of the high-pressure low-temperature (blueschist) facies series. If the ages of metamorphism of these two facies series are coeval, namely Triassic, and the evidence to the southwest is only permissive of this, then the Cache Creek rocks of the Atlin Terrane and the upper Paleozoic rocks in the Cassiar Mountains constitute a paired metamorphic belt (Miyashiro, 1961). Paired metamorphic belts have come to be regarded as marking consuming margins between plates, in plate tectonic theory (e.g. Dewey and Bird, 1970), and so there could originally have been great lateral separation between rocks in the Cache Creek Group and those to the northeast in the Cassiar Mountains.

EVOLUTION OF THE ATLIN TERRANE

The following simplistic model, shown in Figure 19, summarizes the possible evolution of the Atlin Terrane, and its relationship to surrounding geological elements.

1. Late Paleozoic deposition

Oceanic crust, or possibly the crust of a marginal basin, represented by basic volcanic rocks of the Nakina Formation and associated ultramafic rocks in the Atlin Terrane, was formed in Mississippian time. On it was deposited chert, pelite and local pods of basic volcanic rock and carbonate of the Kedahda Formation. In the Late Mississippian, deposition in banks of carbonate of the Horsefeed Formation was initiated in the southwestern part of the Atlin Terrane and continued until the Late Permian. This represents an environment of remarkable tectonic stability listing about 90 m.y., with deposition keeping pace with subsidence over much of the time. In the northeastern part of the Atlin Terrane, basic volcanic rocks and pyroclastics of the Atlin Terrane, basic volcanic rocks and pyroclastics of the French Range Formation and overlying carbonates of the Teslin Formation, were laid down in Permian time.

The stratigraphy of partly coeval rocks in the Stikine area, southwest of the Atlin Terrane is very different, and the two areas cannot be correlated on the basis of lithology. Mississippian pyroclastic rocks, carbonates and sedimentary rocks are unconformably overlain by Permian carbonates and volcanics. These rocks were deposited on an unknown basement, that possibly is the pre-Ordovician, Ordovician to Devonian terrane exposed in the western part of southeastern Alaska, summarized by Brew *et al.* (1966).

No definite lithological correlation can be made to the northeast with upper Paleozoic rock exposed in the core of the Cassiar Mountains. Oldest fossiliferous rocks of Early Mississippian age are coeval with the oldest known rocks in the Atlin Terrane. Some metamorphosed assemblages have lithologies comparable with those in the Atlin Terrane, but others are different. Still farther to the northeast on the east side of the Cassiar Mountains is the post-Middle Devonian, pre-Upper Mississippian (in part; in part younger) Sylvester Group, that includes a mafic volcanic, ultramafic and chert assemblage, similar to the oldest parts of the Atlin Terrane. This unit lies with unknown relationship on Middle Devonian to Proterozoic miogeoclinal rocks. It is not known how far westwards these extend below the younger rocks, but no pre-Mississippian rocks are known in the core of the Cassiar Mountains.

2. Possible Triassic deformation and metamorphism, and Late Triassic volcanism

There is evidence for Triassic metamorphism and deformation in both the Stikine and Cassiar areas. That in the Stikine can be determined with some precision as post-Middle, pre-Upper Triassic, and is called the Tahltanian Orogeny (Souther, 1971, p. 49). In addition, the possibility exists that the 'early' deformation and related blueschist metamorphism near Dease Lake in the Atlin Terrane is of this age. If this is so, then it may be that the dissimilar upper Paleozoic assemblage in the Atlin Terrane, in the Stikine and in the Cassiar Mountains were brought close together this time by some process involving subduction. The general similarity of lower Mesozoic volcanic assemblages in the Stikine (Stuhini Group), southwest of the Atlin Terrane and those to the northwest along the Teslin lineament (Nazcha and Shonektaw formations) may indicate that these assemblages were not too far apart during the Upper Triassic. The only probable lower Mesozoic rocks known in the Atlin Terrane are two small occurrences of sedimentary rock near Sentinel Mountain and Nakina Lake that resemble parts of the Nazcha Formation.

3. Early Jurassic deposition

A clearly defined sedimentary basin, the Whitehorse Trough, developed in the Lower Jurassic, concomitantly with uplift to the west on the site of the Coast Plutonic Complex and uplift, at least in part, to the northeast, of the north end of the Omineca Crystalline Belt (Wheeler, 1961, p. 110). At the latitude of the Atlin Terrane, a conglomeratic, proximal facies lies to the southwest, along the Coast Plutonic Complex, and a turbidite, distal facies to the northeast, adjacent to the Atlin Terrane (Souther, 1971, p. 50). North of the Atlin Terrane, rocks of the proximal facies rim the crystalline terrains to the west and locally to the northeast. It is possible that the distal, deeper water facies were deposited on a topographically lower, "more oceanic" basement underlain by the Cache

Creek Group, whereas the proximal facies formed on higher, flanking, terrains in isostatic equilibrium with lighter basement rocks.

4. Early Late Jurassic deformation and uplift

The Atlin Terrane was uplifted at the end of the Middle Jurassic, so that it became a source of detritus for Upper Jurassic sediments farther south. This uplift was accompanied by the deformation that produced the 'later' structures in the Atlin Terrane and the thrust and reverse faults along its southern margin. To the southwest, the distal Lower Jurassic facies were thrust over the proximal facies. Souther and Armstrong (1966, p. 178) suggested that the distal facies slid off the uplifted Atlin Terrane. This may be so, but it seems possible that the actual uplift was related to underthrusting of the terranes to the southwest and that this underthrusting continued so that in the southeastern part of the Atlin Terrane at least the distal facies lies below the upper Paleozoic.

At some time after underthrusting, the region northwest of the Atlin Terrane was uplifted still more, and the allochthonous, overthrust Cache Creek rocks eroded off, exposing the Lower Jurassic rocks beneath. D. J. Tempelman-Kluit (1973) has suggested that the Yukon Crystalline Platform, northwest along strike from the Atlin Terrane is composed of an orthogneiss terrane to the northeast and a paragneiss terrane to the southwest, separated in part by a greenstone belt with associated ultramafic rocks of possible Permo-Triassic age. Perhaps this latter belt represents a 'root zone', and all that remains of the Cache Creek Group after deep erosion exposed the crystalline basement in the Yukon Crystalline Platform.

MINERAL DEPOSITS RELATED TO UPPER PALEOZOIC ROCKS OF THE ATLIN TERRANE

In general, mineral deposits are notoriously sparse in upper Paleozoic rocks of the Cache Creek Group in the Canadian Cordillera. One exception is placer gold, which has been worked in many places in the Cordillera near where the combination of alpine-type ultramafic rocks and greenstones (or altered basalt) occurs. Placer gold was worked extensively around Dease Lake at the end of the last century (Johnson, 1926), and near Atlin at the beginning of the present one (Aitken, 1959). Near Atlin, gold in quartz veins in altered serpentinite and greenstone is possibly the source of the placers.

Other deposits in the upper Paleozoic rocks, not related to later granitic intrusions, are rare. Asbestos occurs east of Dease Lake in serpentinized peridotite (Geology, Exploration and Mining in British Columbia, 1971, p. 451). Nickel has been reported from near Opal Lake (Ann. Rept. B.C. Dept. Mines, 1957). Copper and nickel occur in pyroxenite and peridotite east of Dease Lake, but the ultramafic rocks in which these deposits occur are somewhat different from the normal alpine-type ultramafics in the Atlin Terrane (Geology, Exploration and Mining in British Columbia, 1971, p. 47; T. Clark, Queen's University, pers. comm.). Jade occurs associated with the ultramafic rocks east of Dease Lake and could well be present near many of the major ultramafic bodies in the Atlin Terrane (Ann. Rept., B.C. Dept. Mines, 1961).

FUTURE GEOLOGICAL WORK IN THE ATLIN TERRANE

This study has merely outlined the gross stratigraphy and possible structure of the upper Paleozoic rocks in the Atlin Terrane. Now that the regional relationships are sketched in, future studied need to be carried out in more depth. The following topics are thought to be of particular importance.

1. Fusulinid biostratigraphy of the Horsefeed Formation

The Horsefeed Formation contains probably the most complete Tathyan fusulinid faunas in North America. Spot collections made during this study were for dating purposes and were compared with standard fusulinid sections in Japan and the U.S.S.R. Now that the areas with the most complete successions have been defined, they should be studied in detail to obtain the stratigraphic order of the North Americal Tethyan fusulinid faunas. This could be done by mapping a strip about 1 mile wide, rather than standard section measuring because of the nature of the rocks, and could best be done in the type area, about 9 miles northwest of Nakina Lake. A less complete section could be obtained near Tagish Lake. The results obtained would serve two purposes. Firstly, other North American Tethyan faunas could be compared with this standard section. At present, fusulinid faunas in the Stuart Lake belt of the Cache Creek Group, 250 miles away along strike, are correlated with those in the Atlin Terrane only by comparison with the standard Russian and Japanese faunas. Secondly, the possibility exists that the Atlin Terrane is allochthonous with respect to North America (Monger and Ross, 1971). Comparison of the fusulinid succession in the Atlin Terrane and other similar successions of Tethyan fusulinids around the Pacific might show similarities or differences that would have some bearing on the provenance of the Atlin Terrane.

2. Petrology of the Nahlin ultramafic and mafic body

As noted earlier, this assemblage of ultramafic and mafic rocks would seem to have many of the characteristics of an ophiolite complex. Whether this is so or not can only be determined by further study.

3. Chemistry of rocks in the Atlin Terrane

Standard, major element, chemical analyses have proved insufficient to define the original composition and thus to classify the mafic volcanic rocks in the Atlin Terrane. This classification is needed so that comparisons can be made, and analogues drawn with modern volcanic assemblages whose tectonic settings are known. Trace element and isotopic studies may prove to be the most useful means of defining the original composition of these rocks. In addition, the background metal content of non-carbonate rocks should be analyzed.

4. Age dating of blueschists near Dease Lake

The crossite-quartz schist localities near Dease Lake should be re-collected and studied in order to determine whether these rocks were formed in mid-Mesozoic time, as indicated by the available age-dates or are older, and hence to date the 'early' deformation in the Atlin Terrane.

5. Further detailed mapping

Certain areas of the Atlin Terrane, such as the areas near Nakina Lake, Tagish Lake and Sentinel Mountain, are worthy of far more detailed coverage than it was possible to give them during this study. Such studies would provide more definitive data on the stratigraphy and structural style of these rocks.

REFERENCES

Aitken, J.D.
1953: Greenstones and associated ultramafic rock of the Atlin map-area, B.C.; unpubl. Ph.D. thesis, Univ. California, Los Angeles.

1959: Atlin map-area, British Columbia; Geol. Surv. Can., Mem. 307.

Alleman, F. and Peters, T.
1972: The ophiolite-radiolarite belt of the North Oman Mountains, Eclogae Geol. Helvetiae, v. 65, p. 657-697.

Amstutz, G.C.
1968: Spilites and spilitic rocks; *in* Basalts: The Poldervaart Treatise on rocks of basaltic composition, v. 2, p. 737-753.

Armstrong, J.E.
1949: Fort St. James map-area, Cassiar and Coast districts, British Columbia; Geol. Surv. Can., Mem. 252.

Bain, R.J.
1964: The stratigraphy of the Permian Taku Group of the Tagish Lake area, Yukon Territory; unpubl. M.S. thesis, Univ. Wisconsin.

Benson, W.N.
1926: The tectonic conditions accompanying the intrusion of basic and ultrabasic igneous rocks; Nat. Acad. Sci. Mem. (Washington), Mem. 1, v. 19.

Brew, D.A., Loney, R.A. and Muffler, L.J.P.
1966: Tectonic history of southeastern Alaska; Can. Inst. Mining Met., Spec. Vol. 8, p. 149-170.

Cairnes, D.D.
1913: Atlin Mining District, British Columbia; Geol. Surv. Can., Mem. 37.

Cameron, B.E.B. and Monger, J.W.H.
1971: Middle Triassic conodonts from the Fergusson Group, northeastern Pemberton map-area, British Columbia; *in* Report of Activities, November 1970 to March 1971, Geol. Surv. Can., Paper 71-1, Pt. B, p. 94-96.

Campbell, R.B.
1967: Reconnaissance geology of Glenlyon map-area, Yukon Territory; Geol. Surv. Can., Mem. 352.

Campbell, R.B. and Tipper, H.W.
1971: Geology of Bonaparte Lake map-area, British Columbia; Geol. Surv. Can., Mem. 363.

Cann, J.R.
1971: Major element variations in ocean-floor basalts; Roy. Soc. London, Phil. Trans., Ser. A, v. 268, p. 495-505.

Christie, R.L.
1957: Bennett, Cassiar District, British Columbia; Geol. Surv. Can., Map 19-1957.

Churkin, M.
Paleozoic marginal ocean basin - volcanic arc systems in the Cordilleran fold belt; Soc. Econ. Paleontol., Mem. 19. (in press)

Cockfield, W.E.
1925: Explorations between Atlin and Telegraph Creek; Geol. Surv. Can., Summ. Rept., Pt. A, p. 25-32.

1948: Geology and mineral deposits of Nicola map-area, British Columbia; Geol. Surv. Can., Mem. 249.

Cockfield, W.E. and Bell, A.H.
1926: Whitehorse District, Yukon; Geol. Surv. Can., Mem. 150.

Coleman, R.G.
1971: Plate tectonic emplacement of upper mantle peridotites along continental edges; J. Geophys. Res., v. 76, p. 1212-1221.

Danner, W.R.
1965: Limestone of the western Cordilleran eugeosyncline of southwestern British Columbia, western Washington and northern Oregon; D.N. Wadia Commemorative Volume, Mining Met. Inst. India, p. 113-125.

Danner, W.R. (cont'd.)
1966: Limestone resources of western Washington; Washington State Div. Mine Geol., Bull. 52.

1967a: Devonian of Washington, Oregon and western British Columbia; Alberta Soc. Petrol. Geol., Int. Symposium on the Devonian System, p. 827-842.

1967b: Organic, shallow-water origin of bedded chert in the eugeosynclinal environment; Geol. Soc. Am., Program 1967 Annual Meetings, p. 42.

1968: The Cache Creek Complex in southern British Columbia and northern Washington; Can. Inst. Mining Met., Program for 70th Annual Meeting.

Davis, E.F.
1918: The radiolarian cherts of the Franciscan Group; Univ. California Publ., Dept. Geol. Sci. Bull., v. 11, p. 235-432.

Dawson, G.M.
1879: Preliminary report on the physical and geological features of the southern portion of the interior of British Columbia; Geol. Surv. Can., Rept. Prog. 1877-78, p. 1B-80B.

1889: Report on an exploration in the Yukon District, N.W.T., and adjacent northern portion of British Columbia; Geol. Surv. Can., Ann. Rept. for 1887, p. 5B-277B.

Dewey, J.F. and Bird, J.M.
1970: Mountain belts and the new global Tectonica; J. Geophys. Res., v. 75, p. 2625-2647.

Duffell, S. and McTaggart, K.C.
1952: Ashcroft map-area, British Columbia; Geol. Surv. Can., Mem. 262.

Dunham, R.J.
1962: Classification of carbonate rock types according to depositional texture; Am. Assoc. Pet. Geol., Mem. 1, p. 108-121.

Folk, R.L.
1973: Evidence for peritidal deposition of Devonian Caballos Novaculite, Marathon Basin, Texas; Am. Assoc. Pet. Geol. Bull., v. 57, p. 702-725.

Gabrielse, H.
1962: Cry Lake, British Columbia; Geol. Surv. Can., Map 29-1962.

1963: McDame map-area, Cassiar District, British Columbia; Geol. Surv. Can., Mem. 319.

1969: Geology of Jennings River map-area; Geol. Surv. Can., Paper 68-55.

Gabrielse, H. and Wheeler, J.O.
1961: Tectonic framework of southern Yukon and northwestern British Columbia; Geol. Surv. Can., Paper 60-24.

Gabrielse, H. and Souther, J.G.
1962: Dease Lake, British Columbia; Geol. Surv. Can., Map 21-1962.

Grunau, H.R.
1965: Radiolarian cherts and associated rocks in space and time; Eclogae Geol. Helvetiae, v. 58, p. 157-208.

Gwillim, J.C.
1902: Report on the Atlin Mining District, British Columbia; Geol. Surv. Can., Ann. Rept. for 1889, p. 5B-48B.

Hart, R.A.
1973: A model for chemical exchange in the basalt-seawater system of Oceanic Layer II; Can. J. Earth Sci., v. 10, p. 799-816.

Holland, S.S.
1964: Land forms of British Columbia; a physiographic outline; Brit. Columbia Dept. Mines Pet. Resour., Bull. 48.

Horowitz, A.S. and Potter, P.E.
1971: Introductory petrography of fossils; Springer-Verlag, New York, Heidelberg, Berlin.

Irvine, T.N. and Baragar, W.R.A.
1971: A guide to the chemical classification of the common volcanic rocks; Can. J. Earth Sci., v. 8, p. 523-548.

Johnson, W.A.
1926: Gold placers of Dease Lake area, Cassiar District, B.C.; Summ. Rept. for 1925, p. 33A-74A.

Jones, A.G.
1949: Vernon map-area, British Columbia; Geol. Surv. Can., Mem. 296.

Kerr, F.A.
1925: Dease Lake area, Cassiar District, British Columbia; Geol. Surv. Can., Summ. Rept. for 1925, Pt. A, p. 75-99.

Link, P.K.
1965: Stratigraphy of the Mount White - eastern Little Atlin Lake area, Yukon Territory, Canada; unpubl. Ph.D. thesis, Univ. Wisconsin.

Lord, C.S.
1948: McConnell Creek map-area, Cassiar District, British Columbia; Geol. Surv. Can., Mem. 251.

Lynts, G.W.
1970: Conceptional modes of the Bahamian Platform for the last 135 million years; Nature, v. 225, p. 1226-1228.

MacKevett, E.M., Jr.
1971: Stratigraphy and general geology of the McCarthy C-5 Quadrangle, Alaska; U.S. Geol. Surv., Bull. 1323.

Mamet, B.L. and Gabrielse, H.
1969: Foraminiferal zonation and stratigraphy of the type-section of the Nizi Formation (Carboniferous System, Chesteran Stage), British Columbia; Geol. Surv. Can., Paper 69-16.

Meischner, K.D.
1964: Allodapische Kalke, Turbidite in Riff-Nahen Sedimentations - Bechen; *in* Turbidites, p. 156-191, Elsevier Pub. Co.

Miyashiro, A.
1961: Evolution of metamorphic belts; J. Petrol., v. 2, p. 277-311.

Monger, J.W.H.
1969: Stratigraphy and structure of upper Paleozoic rocks, northeast Dease Lake map-area, British Columbia; Geol. Surv. Can., Paper 68-48.

1970a: Hope map-area, west-half, British Columbia; Geol. Surv. Can., Paper 69-47.

1970b: Upper Paleozoic rocks of Stikine Arch, British Columbia; *in* Report of Activities, April to October 1969, Geol. Surv. Can., Paper 70-1, Pt. A, p. 41-43.

Monger, J.W.H. and Ross, C.A.
1971: Distribution of fusulinaceans in the western Canadian Cordillera; Can. J. Earth Sci., v. 8, p. 259-278.

Monger, J.W.H., Souther, J.G. and Gabrielse, H.
1972: Evolution of the Canadian Cordillera; a plate-tectonic model; Am. J. Sci., v. 272, p. 577-602.

Monger, J.W.H. and Paterson, I.A.
1974: Upper Paleozoic and lower Mesozoic rocks of the Omineca Mountains; *in* Report of Activities, April to October 1973, Geol. Surv. Can., Paper 74-1, Pt. A, p. 19-20.

Morrow, D.W.
1972: An injection structure in a Permian limestone, northern British Columbia; J. Sed. Petrol., v. 42, p. 230-235.

Muller, J.E.
1967: Kluane Lake map-area, Yukon Territory; Geol. Surv. Can., Mem. 340.

Muller, J.E. and Carson, D.J.T.
1969: Geology and mineral deposits of Alberni map-area, British Columbia; Geol. Surv. Can., Paper 69-25.

Mulligan, R.
1963: Geology of Teslin map-area, Yukon Territory; Geol. Surv. Can., Mem. 326.

Nockolds, S.R.
1954: Average chemical compositions of some igneous rocks; Geol. Soc. Am. Bull., v. 65, p. 1007-1032.

Paterson, I.A.
1973: The geology of the Pinchi Lake area, central British Columbia; unpubl. Ph.D. thesis, Univ. British Columbia.

Pitcher, M.G.
1960: Fusulinids of the Cache Creek Group, Stikine River area, Cassiar District, British Columbia; Brigham Young University Res. studies, Geol. Ser. 7, no. 7.

Powers, R.W.
1962: Arabian Upper Jurassic carbonate reservoir rocks; Am. Assoc. Petrol. Geol., Mem. 1, p. 122-192.

Roots, E.F.
1954: Geology and mineral deposits of Aitken Lake map-area, British Columbia; Geol. Surv. Can., Mem. 274.

Ross, C.A.
1969: Upper Paleozoic fusulinacea: *Eowaeringella* and *Wedekindellina* from Yukon Territory and giant *Parafusulina* from British Columbia; Geol. Surv. Can., Bull. 182, Contributions to Canadian Paleontology, p. 129-134.

Ross, C.A. and Nassichuk, W.W.
1970: *Yabeina* and *Waagenoceras* from the Atlin Horst area, northwestern British Columbia; J. Paleontol., v. 44, p. 779-781.

Ruedisili, L.C.
1965: The stratigraphy and paleontology, Permian Taku Group, Windy Arm, Tagish Lake, Yukon Territory; unpubl. M.S. thesis, Univ. Wisconsin.

Seki, Y.
1961: Pumpellyite in low grade metamorphism; J. Petrol., v. 2, p. 407-423.

Selwyn, A.R.C.
1872: Journal and report of preliminary explorations in British Columbia; Geol. Surv. Can., Rept. Prog. 1871-1872, p. 16-72.

Smith, J.G. and MacKevett, E.M.
1970: The Skolai Group in the McCarthy B-4, C-4, and C-5 Quadrangles, Wrangell Mountains, Alaska; U.S. Geol. Surv., Bull. 1274-Q.

Souther, J.G.
1971: Geology and mineral deposits of Tulsequah map-area, British Columbia; Geol. Surv. Can., Mem. 362.

1972: Telegraph Creek map-area; Geol. Surv. Can., Paper 71-44.

Souther, J.G. and Armstrong, J.E.
1966: North-central belt of the Cordillera of British Columbia; Can. Inst. Mining Met., Spec. Vol. 8, p. 171-183.

Tempelman-Kluit, D.J.
1972: Geology and origin of the Faro, Vangorda, and Swim Concordant zinc-lead deposits, central Yukon Territory; Geol. Surv. Can., Bull. 208.

1973: Reconnaissance geology of Aishihik, Snag and part of Stewart River map-area, west-central Yukon; Geol. Surv. Can., Open File 161.

Temple, P.G.
1968: Mechanics of large-scale gravity sliding in the Greek Peleponnesos; Geol. Soc. Amer. Bull., v. 79, p. 687-700.

Thompson, M.L.
1965: Pennsylvanian and Early Permian fusulinids from Fort St. James area, British Columbia; J. Paleontol., v. 39, p. 224-234.

Vallance, T.G.
1960: Concerning spilites; Linneau Soc. New South Wales Proc., v. 85, p. 8-52.

1965: On the chemistry of pillow lavas and the origin of spilites; Mineral. Mag., v. 34, p. 471-481.

Watson, K. DeP. and Mathews, W.H.
1944: The Tuya - Teslin area, northern British Columbia; British Columbia Dept. Mines, Bull. 19.

Wheeler, J.O.
1959: Mesozoic tectonics of southern-central Yukon; Geol. Assoc. Can. Proc., v. 11, p. 23-43.

1961: Whitehorse map-area, Yukon Territory; Geol. Surv. Can., Mem. 312.

Wheeler, J.O. and Gabrielse, H.
1972: The Cordilleran structural province; Geol. Assoc. Can., Spec. Paper 11, Variations in Tectonic Styles in Canada, p. 1-81.

APPENDICES A and B

Table 1

Fusulinids from the Teslin Formation, near Hall Lake
Detailed locations are given on Figure 7

Location Number	G. S. C. Catalogue Number	Approximate Location	Name	Age
1	79431	4 miles SSW of northernmost part of Hall Lake[1]	*Pseudofusulina* cf. *P. caudata* Rauser *P.* cf. *P. decurta* Korzhenevskii	Early Permian; Asselian (probably early Asselian)
2	79432	4. 6 miles SSW of northernmost part of Hall Lake	*Pseudofusulina* (?) sp. or *Parafusulina* (?) *litugini* (Schellwien) *Robustoschwagerina* sp.	Permian, Artinskian
3	79433	5. 0 miles SSW of northernmost part of Hall Lake	*Mesoschubertella* cf. *M thompsoni* Sakagami *Pseudofusulina cushmani* Chen P. cf. *P. crassa* (Deprat) *P.* cf. *P. ambigua* (Deprat)	Early Permian, upper part of Japanese zone of *Pseudoschwagerina* (Sakmarian)
4	79434	0. 5 miles NE of northernmost part of Hall Lake	*Yabeina* cf. *Y. igoi* Morikawa and Suzuki *Nankingella* sp. *Rauserella* sp.	Late Permian, Japanese zone of *Yabeina shiraiwensis*
5	79435	1. 1 miles East of northernmost part of Hall Lake	*Parafusulina* sp. *Pseudodoliolina* cf. *P. ozawai* Yabe and Hanzawa *Neoschwagerina* sp. *Ozawainella* sp. *Boultonia* sp.	Late Permian, equivalent to Japanese subzone of *Neoschwagerina douvillei*
6	70436	1. 3 miles ENE of northernmost part of Hall Lake	*Neoschwagerina megaspherica* Deprat *Pseudodoliolina* cf. *P. ozawai* Yabe and Hanzawa *Boultonia* sp. *Nankingella* sp.	Late Permian, probably equivalent to subzone of *Neoschwagerina douvillei* of Japan
7	79437	200 yards NW of northernmost part of Hall Lake	*Neoschwagerina* sp. *Boultonia* sp. *Yabeina* sp.	Late Permian, equivalent to Japanese subzone of *Yabeina shiraiwensis*

Table 1 (cont'd.)

Location Number	G.S.C. Catalogue Number	Approximate Location	Name	Age
8	79438	1.4 miles ENE of northernmost part of Hall Lake	*Neoschwagerina* sp. *Pseudodoliolina* cf. *P. ozawai* Yabe and Hanzawa *Pseudofusulina* cf. *P. royandersoni* Thompson and others *Schubertella*? sp.	Late Permian, equivalent to Japanese subzone of *Neoschwagerina douvillei*
9	79439	2.4 miles ESE of northernmost part of Hall Lake	*Parafusulina* cf. *P. edoensis* (Ozawa)	Middle Permian, equivalent to part of Japanese zone of *Parafusulina*
10	79440	1.1 miles NE of northernmost part of Hall Lake	*Pseudodoliolina* cf. *P. ozawai* Yabe and Hanzawa	Late Permian, equivalent to Japanese subzone of *Neoschwagerina douvillei*
11	79441	1.2 miles NE of northernmost part of Hall Lake	*Parafusulina* (group of *P. kaerimizensis* (Ozawa)) *Neoschwagerina*? sp.	Middle Permian; probably from upper part of Japanese zone of *Parafusulina kaerimizensis* (= late Leonardian)
12	79442	1.3 miles due N of northern-most part of Hall Lake	*Parafusulina* cf. *P kaerimizensis* (Ozawa)	Permian, probably equivalent to Japanese subzone of *Parafusu-lina kaerimizensis*
13	79443	1.8 miles NNW of northernmost part of Hall Lake	*Pseudodoliolina* cf. *P. ozawai* Yabe and Hanzawa *P.* cf. *P. pseudolepida* (Depart) *Parafusulina* sp.	Late Permian; equivalent to Japanese subzone of *Neoschwagerina douvillei*
14	79444	1.8 miles NNW of northernmost part of Hall Lake	*Neoschwagerina* cf. *N. megaspherica* Deprat *Nankingella* sp. *Rauserella*? sp.	Late Permian, probably equiv-alent to *Neoschwagerina douvillei* subzone of Japan.
15	79445	2.3 miles N of northernmost part of Hall Lake	*Neoschwagerina* cf. *N craticulifera* (Schwager) *Rauserella* cf. *R. erratica* Dunbar and Skinner *Reichelina* sp.	Late Permian; equivalent to Japanese subzone of *N. craticulifera*
16	79446	2.1 miles N of northernmost part of Hall Lake	*Yabeina* cf. *Y. inouyei* (Deprat)	Late Permian; equivalent to Japanese subzone of *Yabeina shiraiwensis*

Table 1 (cont'd.)

Location Number	G.S.C. Catalogue Number	Approximate Location	Name	Age
17	79447	3.9 miles SE of northernmost part of Hall Lake	*Yabeina* cf. *Y. inouyei* (Deprat)	Late Permian; zone of *Yabeina shiraiwensis* of Japan
18	79448	4.0 miles SE of northernmost part of Hall Lake	*Neofusulina* cf. *N. lantenoisi* Deprat *Yangchienia*? sp. *Parafusulina* 2 spp.	Late Permian, equivalent to Japanese zone of *Parafusulina*
19	79449	3.8 miles SE of northernmost	*Boultonia* sp. *Pachyphloia* sp.	Middle Permian (late Leonardian) or Late Permian (early Guadalupian)
20	79450	4.7 miles SW of northernmost part of Hall Lake	*Parafusulina* cf. *P. edoensis* (Ozawa) *Neoschwagerina* sp. *Schubertella*? sp. *Nankingella* sp.	Middle Permian (= late Leonardian or early Guadalupian)
21	79451	5.6 miles SW of northernmost part of Hall Lake	*Misellina claudiae* (Deprat)	Middle Permian; equivalent to Japanese subzone of *Parafusuline kaerimizensis*
22	79452	5.6 miles SW of northernmost part of Hall Lake	*Neoschwagerina* cf. *N. megaspherica* Deprat *Parafusulina* sp.	Late Permian, probably subzone of *Neoschwagerina douvillei* of Japan

Fusulinids identified by C.A. Ross of Western Washington State College (G.S.C. Rept. No. Misc. 3-1972-CAR)

[1]Cobbles in breccia below main limestone

Table 2

Fossils from the Horsefeed and Kedahda Formations, near Nakina Lake

Location Number	G. S. C. Catalogue Number	Formation	Approximate Location	Fusulinids	Age
1	79394	Horsefeed	1 mile due S of west end of Victoria Lake	*Schubertella* cf. *S. kingi* Dunbar and Skinner *Pseudofusulinella* sp. *Triticites* cf. *T. haydeni* (Ozawa) *T.* cf. *T. biconica* Toriyama *T.* sp.	Early Permian, Asselian (probably lower part)
2	79393	Horsefeed (from float)	1 mile due S of west end of Victoria Lake	*Pseudoschwagerina* cf. *P. muongthensis* (Deprat) *Pseudofusulina* (*Rugosofusulina*) cf. *P.* (*R.*) *paragregaria* Rauser *P.* sp. 1 *P.* sp. 2	Early Permian, Asselian (probably lower part)
2	79395	Horsefeed (from float)	1 mile due S of west end of Victoria Lake	*Schubertella* cf. *S kingi* Dunbar and Skinner *Biwaella* cf. *B. omiensis* Morikawa and Isomi *Pseudofusulina* sp. 1 *Triticites* sp. *Pseudoschwagerina* cf. *P. muongthensis* (Deprat) *Oketaella* cf. *O. shiroishiensis* Morikawa and Isomi	Early Permian, Asselian (probably lower part)
3	79396	Horsefeed	Approximately 1. 3 miles SSE of west end of Victoria Lake	*Yabeina* (*Lepidolina*) cf. *Y.* (*L.*) *multiseptata* (Deprat) *Schwagerina* cf. *S. royandersoni* Thompson and others *Neoschwagerina* sp.	Late Permian, Zone of *Yabeina-Lepidolina* (= Kuman Stage of Japan and probably upper part of Guadalupian of southwestern U. S. A.)
4	79397	Horsefeed	1. 4 miles WSW of west end of Victoria Lake	*Fusulinella* cf. *F. bocki* Moeller	Carboniferous; upper Moscovian, probably Mjachkovian Horizon but possibly as old as Podolskian

Table 2 (cont'd.)

Location Number	G.S.C. Catalogue Number	Formation	Approximate Location	Fusulinids	Age
5	79398	Horsefeed	2 miles SSE of west end of Victoria Lake	*Pseudofusulina norikurensis* Igo	Early Permian, upper part of the Japanese "zone of *Pseudoschwagerina*"; probably equivalent to their subzone of *Pseudofusulina ambigua* zone (= Sakmarian)
6	79400	Horsefeed	2 miles SSE of west end of Victoria Lake	*Pseudofusulina ambigua* (Deprat)	Early Permian, subzone of *P. ambigua* (= Sakmarian)
7	79401	Horsefeed	4 miles S of east end of Victoria Lake	*Schubertella* sp. *Pseudofusulina*(?) cf. *P. gigantojaponica* (Kobayashi) *Parafusulina japonica* (Gumbel)	Permian equivalent to lower part of Japanese zone of *Parafusulina* (= lower Artinskian?)
8	79404	Horsefeed	4.3 miles NW of W end of Victoria Lake	*Pseudoschwagerina* cf. *P. moelleri* (Rauser) *Pseudofusulina* cf. *P. paragregaria* Rauser *Paraschwagerina* cf. *P. gigantea* (White) *Pseudofusulina* (*Rugosofusulina*) sp.	Early Permian, mid Asselian
9	79405	Horsefeed	4.6 miles NW of west end of Victoria Lake	*Pseudoschwagerina* cf. *P. sphaerica* Scherbovich *Pseudofusulina* (*Rugosofusulina*) cf. *P.* (*R.*) *shaktanensis* Suleimanov *P.* cf. *P. cervicalis* (Lee) *P.* cf. *P. densa* (Toriyama) *Schubertella* cf. *S. kingi* Dunbar and Skinner	Early Permian, late Asselian
10	79407	Horsefeed	6.3 miles WNW of west end of Victoria Lake	*Pseudoschwagerina* cf. *P. sphaerica* Scherbovich *Pseudofusulina* (*Rugosofusulina*) cf. *P.* (*R.*) *shaktanensis* Suleimanov *P.* cf. *P.*	age: Early Permian, late Asselian

Table 2 (cont'd.)

Location Number	G.S.C. Catalogue Number	Formation	Approximate Location	Fusulinids	Age
10 (cont'd.)				*cervicalis* (Lee) *Schubertella* cf. *S. kingi* Dunbar and Skinner	
11	79409	Horsefeed	6.3 miles WNW of west end of Nakina River and Horsefeed Creek	*Schubertella* cf. *S. melonica* Dunbar and Skinner *Pseudofusulina* sp.	Permian, possibly equivalent to uppermost part of Japanese zone of *Pseudoschwagerina* or, more likely, to lower part of the Japanese zone of *Parafusulina*
12	79410	Horsefeed	near location 11	*Parafusulina* cf. *P. edoensis* (Ozawa)	age: Permian; equivalent to Japanese subzone of *Parafusulina kaerimizensis* or subzone of *Neoschwagerina craticulifera*
13	79412	Horsefeed	Cairn, elevation 4,327', 2 miles SSW of confluence Nakina River and Horsefeed Creek	*Yabeina* cf. *Yabeina ozawai*	lower part of Word (early Late Permian)
14	79413	Horsefeed	1.5 miles S of confluence of Nakina River and Horsefeed Creek	*Parafusulina* cf. *P. edoensis* (Ozawa) *Schubertella* sp.	Permian; equivalent to the *Parafusulina kaerimizensis* subzone or *Neoschwagerina craticulifera* subzone)= late Artinskian; or = latest Leonardian to early Wordian
15	79414	Kedahda?	limestone conglomerate, 3 miles S of confluence of Nakina River and Horsefeed Creek	*Triticites* sp.	Late Carboniferous, probably early Virgilian
16	79415	Kedahda?	3 miles S of confluence of Nakina River and Horsefeed Creek	*Profusulinella* cf. *P. ovata* Rauser *Staffella (Parastaffella)* cf. *S. (P.) moelleri* (Ozawa) *Eoschubertella* cf. *E. gracilis* (Rauser)	Middle Carboniferous; Kaschirskian Horizon
17	79416	Horsefeed	10.5 miles E of confluence of Nakina River and Horsefeed Creek	*Parafusulina* cf. *P. edoensis* (Ozawa)	Middle Permian (= late Artinskian; or latest Leonardian or earliest Wordian; *see* 79413)

Table 2 (cont'd.)

Location Number	G.S.C. Catalogue Number	Formation	Approximate Location	Fusulinids	Age
18	79417	Horsefeed	10.5 miles E of confluence of Nakina River and Horsefeed Creek	*Yabeina* cf. *Y. inouyei* (Deprat)	Late Permian; equivalent to Japanese subzone of *Yabeina shiraiwensis*
19	79418	Horsefeed	8.5 miles ENE of confluence of Nakina River and Horsefeed Creek	*Triticites* cf. *T. pinguis* Dunbar and Skinner *Pseudofusulina (Rugosofusulina)* cf. *P. (R.) shaktanensis* Suleimanov *P.* sp. *Triticites* cf. *T. ventricosus* Schellwien	Early Permian; Asselian
20	79419	Horsefeed	4.8 miles ENE of confluence of Nakina River and Horsefeed Creek	*Schwagerina* cf. *S. satoi* (Ozawa) *Quasifusulina* sp. *Schubertella* sp.	Early Permian; lower part of Japanese zone of *Pseudoschwagerina* (= early Asselian)
21	79420	Horsefeed	4.5 miles ENE of confluence of Nakina River and Horsefeed Creek	*Neoschwagerina* cf. *N. megaspherica* Deprat *N.* cf. *N. akasakensis* Morikawa and Suzuki *Pseudodoliolina* cf. *P. ozawai* Yabe and Hanzawa *Nankingella* sp.	Late Permian; probably *Neoschwagerina douvillei* subzone of Japan
22	79421	Horsefeed	4.3 miles ENE of confluence of Nakina River and Horsefeed Creek	*Parafusulina* cf. *P. edoensis* (Ozawa)	Middle Permian (= late Artinskian or latest Leonardian or early Wordian)
23	79422	Horsefeed	8 miles ENE of confluence of Nakina River and Horsefeed Creek	*Pseudodoliolina speudolepida* (Deprat)	Late Permian; equivalent to Japanese subzone of *Neoschwagerina douvillei*
24	79423	Horsefeed	8.3 miles ENE of confluence of Nakina River and Horsefeed Creek	*Schwagerina* cf. *S. satoi* (Ozawa) *Quasifusulina* sp. *Schubertella* sp.	Early Permian; lower part of Japanese zone of *Pseudoschwagerina* (= early Asselian) (same fauna as 79419)
25	79424	Horsefeed	10.5 miles E of confluence of Nakina River and Horsefeed Creek	*Triticites* sp. *Staffella* sp.	Late Carboniferous; probably equivalent to late Missourian or early Virgilian

Table 2 (cont'd.)

Location Number	G. S. C. Catalogue Number	Formation	Approximate Location	Fusulinids	Age
26	79426	Horsefeed	1.5 miles NNE of summit of Sinawa Eddy Mountain	*Neoschwagerina* sp. *Parafusulina*? cf. *P. edoensis* (Ozawa) *Schwagerina roy-andersoni* Thompson and others *Pseudo-doliolina* cf. *P. pseudolepida* (Deprat)	Middle Permian; zone of *Neoschwagerina craticulifera* of Japan
27	79427	Horsefeed	0.5 miles E of summit of Sinawa Eddy Mountain	*Triticites* cf. *T. pinguis* Dunbar and and Skinner *Pseudo-fusulina* (*Rugosofusu-lina*) cf. *P.* (*R.*) *shaktanensis* Sulei-manov *Schubertella* sp. *Pseudofusulina* sp.	Early Permian, Asselian
28	79428	Horsefeed	0.8 miles ENE of summit of Sinawa Eddy Mountain	*Pseudoschwagerina* cf. *P. muongthensis* (Deprat) *Triticites* cf. *T. isaensis* Toriyama *T.* cf. *T. ellipsoidalis* Toriyama *T.* cf. *T. ventricosus* Schellwien *Schubertella* sp.	Early Permian, early Asselian
29	79429	Horsefeed	1.5 miles N of confluence of Katina Creek and Silver Salmon River	*Parafusulina* cf. *P. edoensis* (Ozawa)	Middle Permian; probably equivalent to lower part of Japanese zone of *Parafusulina* (subzone of *P. kaerimizensis*)
30	79430	Horsefeed	1.8 miles N of confluence of Katina Creek and Silver Salmon River	*Neoschwagerina* cf. *N. craticulifera* (Schwager) *N.* cf. *N. douvillei* Ozawa	Late Permian; Japanese sub-zone of *Neoschwagerina douvillei*

Location Number	G. S. C. Catalogue Number	Formation	Approximate Location	Corals	Age
A	79399	Kedahda	Ridge top, 1.3 miles NW of west end of Victoria Lake	?*Campophyllum* (*Skolekophyllum*) sp. tabulate coral - pos-sibly *Roemeripora* sp.	G. S. C. locations 79399, 79402, and 79403 contain the same coral fauna. The genera to which these corals have been tentatively assigned

Table 2 (cont'd.)

Location Number	G. S. C. Catalogue Number	Formation	Approximate Location	Corals	Age
B	79402	Kedahda	Ridge top, 1.5 miles NNW of west end of Victoria Lake	horn coral indet. tabulate coral - possibly *Roemeripora* sp.	suggest an Upper Carboniferous to Lower Permian age, but the upper age limits of these forms have not been established, so no definite conclusions can be drawn concerning the age of the collections
C	79403	Kedahda	Ridge top, 2 miles N of west of Victoria Lake	?*Campophyllum* (*Skolekophyllum*) sp. tabulate coral - possibly *Roemeripora* sp. Numerous Foraminifera	
D	82718	Kedahda	2.8 miles NW of west end of Nakina Lake	tabulate coral indet. poorly preserved horn coral, possibly the same as ?*Campophyllum* (*Skolekophyllum*) sp. of GSC location 79403	probably Middle Carboniferous (?Moscovian); age should be checked by foraminifers present.
E	82721	Kedahda	5.5 miles NW of west end of Nakina Lake	lithostrotionid coral, indet.	Carboniferous or Permian
J	79408	Horsefeed	9 miles W of west end of Nakina Lake	*Tschussovskenia* sp. ?*Protolonsdaleiastraea* sp.	These corals suggest an Early Permian age, age limits have not been established

Location Number	G. S. C. Catalogue Number	Formation	Approximate Location	Small Foraminifera	Age
C	73403	Kedahda	Ridge top, 2 miles N of west end of Victoria Lake	*Septabrunsiina* *Septaglomospiranella* *Septatournayella* *Eoforschia Uviella* *Uvatournayella* *Eoxtextularia* *Palaeotextularia* Endothyridae *Endothyra* *Latiendothyra* cf. *Globoendothyra*	Possibly Visean (Upper Mississippian)
D	82718	Kedahda	2.8 miles NW of west end of Nakina Lake	Endothyrid ghosts Globoendothyrid ghosts Palaeotextulariid ghosts	Undetermined Carboniferous Zone

Table 2 (cont'd.)

Location Number	G.S.C. Catalogue Number	Formation	Approximate Location	Small Foraminifera	Age
E	82719	Kedahda	5.5 miles NW of W end of Nakina Lake	*Archaediscus* sp. *Archaediscus* aff. *A.* approximatus Ganelina *Archaediscus* of the group *A. moelleri* Rauzer-Chernoussova *Calcisphaera* sp. *Earlandia* sp. *Endothyra* of the group *E. bowmani* Phillips *emend* Brady *Globoendothyra* of the group *G. globulus* d'Eichwald *Neoarchaediscus* sp. *Palaeotextularia* sp. *Zellerina discoidea* (Girty) *Zellerina* sp.	Zone 16_{inf} or 16_{sup}, Lower Chester age equivalent, latest Visean
F	82720	Base of Horse-feed	5.5 miles NW of west end of Nakina Lake	Apterrinnelids *Archaediscus* sp. *Asteroarchaediscus* sp. *Calcisphaera* sp. *Bradyina* sp. *Earlandia* sp. *Endothyra* sp. *Endothyra* of the group *E. similis* Rauzer-Chernoussova and Reitlinger. *Eostaf-fella* sp. *Neo-archaediscus grandis* (Reitlinger) *Neoarchaediscus* sp. *Palaeotextularia* sp. *Pseudoendothyra* sp. *Pseudoendothyra* of the group *P. Kremenskensis* Rozovskaia *Tetrataxis* sp. *Zellerina* sp.	Zone 18 (or slightly younger), Upper Chester age
G	82721	Kedahda	5.7 miles NW of west end of Nakina Lake	Apterinellids *Archaediscus* sp. *Archaediscus* of the group *A. krest-*	The assemblage suggests Zone 18, Late Early Namurian, Kinkaid age equivalent of the Chester Series

Table 2 (cont'd.)

Location Number	G.S.C. Catalogue Number	Formation	Approximate Location	Small Foraminifera	Age
G (cont'd.)				*ovnikovi* Rauzer-Chernoussova *Asteroarchaediscus* sp. *Biseriella* sp. *Calcisphaera laevis* Williamson *Cornuspira* sp. *Earlandia* sp. *Endothyra* sp. *Endothyranella* sp. *Endothyranopsis* sp. *Eotuberitina* sp. *Neoarchaediscus* sp. Palaeotextulariids *Planospirodiscus* sp. *Tuberitina* sp.	
H	C-22312	Kedahda	5.7 miles NW of west end of Nakina Lake (limestone pod at similar level ot location E)	*Archaediscus* sp. *Archaediscus* of the group *A. krestov-nikovi* Rauzer-Chernoussova. *Asteroarchaediscus* sp. *Biseriella* sp. *Biseriella parva* (Chernysheva) *Bradyina* sp. *Calcisphaera pachysphaerica* (Pronina) *Climacammina* sp. *Diplosphaerina* sp. *Earlandia* sp. *Earlandia* of the group *E. clavatula* (Howchin) *Earlandia* of the group *E. vulgaris* (Rauzer-Chernoussova and Reitlinger) *Earlandia* aff. *E. consternatio* Conkin *Endothyra* sp. *Endothyranella* sp. *Eostaffella* sp. cf. "*Haplophragmella*" sp. cf. *Mediocris* sp. *Mikhailovella* sp. *Pseudocornuspira* sp. *Planoendothyra* sp.	Equivalent to the upper part of the Peratrovitch, Zone 18 or slightly younger

Table 2 (cont'd.)

Location Number	G. S. C. Catalogue Number	Formation	Approximate Location	Small Foraminifera	Age
				Pseudoendothyra sp. *Tetrataxis* sp. *Zellerina* sp. and a new genus, a queer, spinose *Samarina* - looking Endothyranopsin	
I	C-22313	Kedahda	5.7 miles NW of west end of Nakina Lake (close to locality H)	*Calcisphaera* sp. *Climacammina* sp. *Endothyra* sp. *Eostaffella* sp. *Ungdarella* sp. *Zellerina* sp.	Age; as 22312

Fusulinids identified by C.A. Ross, Western Washington State College (G.S.C. Rept. No. Misc. 3-1972-CAR)
Corals identified by E.W. Bamber, Geological Survey of Canada (G.S.C. Rept. No. C3-1969-EWB and C-15-1967-EWB)
Small Foraminifera identified by B.L. Mamet, Université de Montréal.
Other fossil localities shown on map contain fossils tentatively identified as to age by the writer.

Table 3

Fossils from limestone pods in the Kedahda Formation, Sentinel Mountain area

Location Number	G. S. C. Catalogue Number	Approximate Location	Small Foraminifera	Age
1	82735	1.1 miles SE of summit of Sentinel Mountain	*Calcisphaera* sp. *Earlandia* sp. *Endothyra* sp. *Kamaena* sp. *Latiendothyra* sp. cf. *Spinoendothyra* ? sp. "*Radiosphaera*" sp. *Tetrataxis* sp.	The microfossils are poorly preserved and recrystallization is extensive. The assemblage is indicative of Late Tournaisian-Viséan and is therefore considerably older than 82721
2	C-24290	2 miles E of head of McKee Creek; approximately 2 miles SW of Spruce Creek	*Brunsia* sp. *Calcisphaera pachysphaerica* (Pronina) *Earlandia* of the group *E. vulgaris* (Rauzer-Chernoussova and Reitlinger) *Endothyra* of the group *E. bowmani* Phillips and Brady *Endothyra* of the group *E. similis* Rauzer-Chernoussova and Reitlinger *Endothyranella* sp. *Endothyranopsis crassus* (Brady) *Eoendothyranopsis* sp. *Eoendothyranopsis*? *robustus* (McKay and Green) *Globoendothyra paula* (Vissarionova) *Koninckopora inflata* (de Koninck) *Pseudocornuspira* sp. *Pseudoendothyra* sp.	Zone 15, Middle Late Viséan, Upper Meramec age equivalent
3	C-24181	South side valley, head of McKee Creek	cf. *Atractyliopsis* sp. *Archaediscus* of the group *A. krestovnikovi* Rauzer-Chernoussova *Brunsia* sp. *Calcisphaera* sp. *Earlandia* sp. *Earlandinella* sp. *Endothyra* sp. *Endothyra* of the group *E. bowmani* Phillips *emend* von Moller *Endothyranopsis* of the group *E. compressus* (Rauzer-Chernoussova and Reitlinger). *Enodthyranopsis compressus compressus* (Rauzer-Chernoussova and Reitlinger).	Zone 13, Middle Viséan

Table 3 (cont'd.)

Location Number	G.S.C. Catalogue Number	Approximate Location	Small Foraminifera	Age
3 (cont'd.)			*Eoendothyranopsis* of the group *E. pressus-rarus* (Grozdilova and Lebedeva). *Globoendothyra* sp. *Koninckopora* sp. *Koninckopora inflata* (de Koninck). *Koninckopora tenuiramosa* Wood *Mikhailovella* sp. *Parathurammina* sp. *Priscella* sp. *Pseudocornuspira* sp. *Pseudoendothyra* sp. *Skippella* sp.	
4	C-24291	1.5 miles NNE of summit of Sentinel Mountain	*Climacammina* sp. *Deckerellina* sp. *Endothyra* sp. *Endothyra* of the group *E. bowmani* Phillips and Brady. fusulinid ghost *Globivalvulina* sp. *Globivalvulina* of the group *G. bulloides* (Brady) "*Endothyranella gracilis* Rauzer-Chernoussova" of the Russian authors, not *Endothyranella gracilis* (Waters) *Palaeotextularia* sp. *Planoendothyra* sp. *Pseudocornuspira* sp. *Tetrataxis* sp.	Middle Moscovian or slightly younger
3	83739	South side of Valley, head of McKee Creek just above small foraminifer localit	?*Heritschioides* possibly *H. columbicum* (Smith) aulophyllid coral - possibly *Auloclisia* sp.	?Early Permian. This fauna appears similar to a lower Permian faunt in the Bowser Basin and has corals similar to those from the Screw Creek Formation (Early Pennsylvanian). The preservation is very poor, however, and this age assignment should be used with caution

Small foraminifera identified by B.L. Mamet, Université de Montréal (G.S.C. Report Misc. 1-BLM-1973 for localities 2, 4; others unreferenced)

Corals identified by E.W. Bamber, Geological Survey of Canada (G.S.C. Report No. C3-1969-EWB).

Table 4

Generic identifications of Middle Pennsylvanian and Early Permian fusulinids from a small area near Tagish Lake were made by J. W. Skinner (*in* Ruedisili, 1965). The writer covered a larger area than Ruedisili, found younger forms, and grouped them for field mapping purposes into the fine associations whose characteristics are listed below. In addition, microscopic identifications of small foraminifera were made by B. L. Mamet, University of Montreal.

Approximate Age	Nature of Fusulinid Fauna	Faunal zones of Ruedisili (1965) (Section C)	Figure
Late Permian (early Guadalupian)	Medium sized to large neoschwagerinids, possibly *Neoschwagerina*	---	
Mid-Permian (late? Leonardian)	Large schwagerinids, possibly *Parafusulina*	---	
Early Permian (*Wolfcampian*)	Small and medium sized schwagerinids, *Triticites* and *Pseudoschwagerina*	5, 6, 7, 8, 9	
Middle to Late Pennsylvanian (Desmoinesian and younger?[1])	Complex of forms, mainly of the family *Fusulinidae*, varying from small single fusulinids with straight septa to somewhat larger forms with fluted septa.	2, 3, 4	
Middle Pennsylvanian	Small simple fusulinids with straight septa	1	
Early Pennsylvanian (Morrowan)	Microscopic identifications only, by J. W. Skinner in Ruedisili (1965); probably *Profusilinella.*		

[1]Ruedisili found only Desmoinesian forms in the small area sampled by him. However, elsewhere in the Atlin Terrane (e. g. Nakina Lake area), later forms occur, as they probably do here.

Location Number	G. S. C. Catalogue Number	Approximate Location	Small Foraminifera	Age
1	C-22317	Cliff, 2 miles SE of the western tip of Bove Island in Tagish Lake	Very few small forams such as *Climacammina* of the group *C. moelleri* Reitlinger and *Tetrataxis* mixed with abundant fusulines. These ought to be determined by an expert	Moscovian or younger
2	C-22319	southeast point, Bove Island in Tagish Lake	*Asteroarchaediscus* sp. cf. *Biseriella* sp. *Calcisphaera* sp. *Diplosphaerina* sp. *Endothyra* sp. *Eostaffella* sp. *Eostaffella* of the group *E. acutissima* Kireeva. *Globivalvulina* sp.	Moscovian

Table 4 (cont'd.)

Location Number	G.S.C. Catalogue Number	Approximate Location	Small Foraminifera	Age
2 (cont'd.)			*Neoarchaediscus* sp. *Ozawainella* sp. *Pseudoglomospira* sp. *Tetrataxis* sp. *Tuberitina* sp.	
3	C-22320	near southwest end of Bove Island	*Asteroarchaediscus* sp. *Climacammina* sp. *Climacammina* of the *C. moelleri* Reitlinger. *Diplosphaerina* sp. *Endothyra* sp. *Eostaffella* sp. *Ozawainella* sp. *Pseudoglomospira* sp. *Pseudostaffella* sp. *Tuberitina* sp.	As 22319

Small foraminifera identified by B.L. Mamet, Université de Montréal.

APPENDIX B

Definition of the term 'Cache Creek Group' and its regional correlation

The history of the term 'Cache Creek Group', from its introduction by Selwyn in 1872 until 1949, was fully summarized by Armstrong (1949, p. 47-51). Armstrong defined the Cache Creek Group as "a very thick assemblage, 20,000 feet or more, of interbedded sedimentary and volcanic rocks, mainly of Permian age, but also probably in part of Pennsylvanian age. The whole of the Permian period may be represented. Foraminiferal limestones and ribbon cherts are characteristic of the group".

Since 1949, more information has become available, particularly from the systematic reconnaissance mapping of northern British Columbia. Aitken (1959) first employed the term Cache Creek Group for rocks in the Atlin Terrane, but Dawson (1889, p. 170B) had previously recognized the similarity of these rocks to those near Cache Creek in southern British Columbia. Cockfield (1948, p. 6-11), in part following Dawson (1879, p. 80B), used the term Cache Creek Group for rocks near Kamloops, east of the type area, and Jones (1949, p. 38-47) and Campbell and Tipper (1971, p. 19-23) extended this usage to rocks still farther east and north. However, Armstrong (1949, p. 50) noted that although these latter assemblages in southern British Columbia were in part lithologically similar to the type Cache Creek Group, namely in their foraminiferal limestones, they differed in that ribbon cherts are poorly represented. Danner (1968, p. 273) proposed the term Cache Creek Complex, to include all upper Paleozoic rocks of southern British Columbia including the Chilliwack and Sicker groups to the west, that are lithologically very different from the rocks of the type area. Used in this way, the term Cache Creek Group or Complex is synonymous with upper Paleozoic eugeosynclinal rocks of the southwestern Canadian Cordillera. The writer believes that the term Cache Creek Group is a useful one if the definition is restricted to a usage closer to that employed by the early workers. If used in this sense the unit has distinct lithologic, stratigraphic, paleontologic and geographic characteristics that distinguish it from other upper Paleozoic assemblages in the western Cordillera.

The distribution of upper Paleozoic rocks in the western Canadian Cordillera is shown in Figure 20. Regions in which the stratigraphy displays some internal consistency are distinguished. Figure 21 is a correlation chart of upper Paleozoic rocks, indicating lithologies, evidence of age and relationships with overlying and underlying units.

The term Cache Creek Group, as used in this report, is restricted to the rocks in the region immediately west of the Omineca Crystalline Belt, known as the Intermontane Belt or more precisely as the Hinterland Belt of the Columbian Orogen (Wheeler and Gabrielse, 1972, p. 26). It displays similar lithological characteristics for 800 miles along the regional trend and is continuous over much of this distance, from the Atlin Terrane in the north, through the Stuart Lake belt of Armstrong (1949, p. 32) in central British Columbia, to the area near the settlement of Cache Creek in southern British Columbia. Although details of stratigraphy are not known from the entire belt, characteristic lithologies are (1) abundant, thin-bedded, interlayered chert and pelite (ribbon chert), (2) massive, lensoidal carbonate bodies that in places are of considerable extent and thickness, (3) altered basic volcanic rocks with relatively little accompanying pyroclastic material and (4) associated alpine-type ultramafic rocks. Fossils are Mississippian, Pennsylvanian and Permian in the Atlin Terrane, Pennsylvanian and Permian in the Stuart Lake belt (Thompson, 1965) and Pennsylvanian and Permian in the south (Campbell and Tipper, 1971, p. 27-28; W.R. Danner, pers. comm.).

Lithological equivalents along the northern and southern extensions of the belt are not definitely known. Possibly, partial equivalents of the Cache Creek Group may be represented by upper Paleozoic or Triassic mafic volcanic and associated ultramafic rocks reported from the Yukon Platform to the north by Tempelman-Kluit (1973), and by the Trafton Sequence on the west side of the Cascade Mountains and San Juan Islands to the south described by Danner (1966, p. 72).

In contrast with the general lithologic homogeneity along the Cordilleran trend, direct lithological correlation across the trend is apparently impossible. In the north, the upper Paleozoic rocks of the Stikine area, at their closest only 30 miles southwest of the Atlin Terrane, include well-bedded, sheet-like carbonates of Permian and Upper Mississippian age that appear to show stratigraphic uniformity over a broad area, abundant pyroclastic rocks with minor flows, pelite and relatively little chert (J.K. Rigby; pers. comm., Monger, 1970b, p. 41). Pennsylvanian and possibly Mississippian rocks immediately northeast of the Atlin Terrane, known as the Big Salmon Complex, Oblique Creek Formation, Englishmans Group and parts of the Sylvester Formation show some lithological similarities to the Cache Creek Group but contain relatively much more clastic and pyroclastic material (Gabrielse, 1969, p. 9-18). One possible lithological correlative of the Cache Creek Group is the assemblage of mafic volcanic and ultramafic rocks, chert and pelite that comprise part of the Sylvester Group in McDame map-area, approximately 30 miles northeast of the eastern part of the Atlin Terrane. This assemblage can be dated only as post-Middle Devonian and pre-Upper Mississippian in part (Mamet and Gabrielse, 1969), but could be equivalent to the Lower Mississippian and (?) older Nakina Formation, the oldest part of the Kedahda Formation and associated ultramafic rocks in the southwestern part of the Atlin Terrane described in this report. Farther south in the Omineca Mountains, east of the Stuart Lake belt of Cache Creek rocks, upper Paleozoic rocks in several small, isolated areas display diverse lithologies. These areas include the Asitka Group (Lord, 1948, p. 10-15), upper Paleozoic and 'Cache Creek' rocks (Roots, 1954, p. 109-124) and the Manson Creek belt of the Cache Creek (Armstrong, 1949, p. 47). In these assemblages, bedded chert is generally a minor constituent or absent, acidic volcanic and pyroclastic rocks locally abundant, and limestone units thin, but local massive altered basic volcanics such as the Nina Creek greenstone of Armstrong (1949, p. 39) resemble some rocks of the Cache Creek Group. The only extensive limestone in this region is at least partly of Devonian age (Monger and Paterson, 1974). In southern British Columbia, the Cache Creek Group of Campbell and Tipper (1971, p. 18-24) is divided into a western and eastern part. The western contains abundant chert and massive carbonate and is contiguous with rocks in the type area of the Cache Creek Group, whereas the eastern part includes abundant volcaniclastic rocks and local limestone pods with little or no chert. Also in this area is the Slide Mountain Group (Campbell and Tipper, 1971, p. 14-18), composed of greenstone, with minor chert, pelite and breccia. Lithologically it resembles parts of the Cache Creek Group, but lacks major limestone bodies. It can be dated only as post-Early Mississippian and pre-Late Triassic. The Slide Mountain Group extends as far north as Prince George, and possibly continues into the Omineca Mountains, as the Nina Creek greenstone. West of the type-area of the Cache Creek Group in southern British Columbia, the Fergusson Group, a Middle Triassic assemblage of bedded chert, pelite, basic volcanics and associated ultramafic rocks (Cameron and Monger, 1971, p. 94-96) is lithologically similar to parts of the Cache Creek Group, but lacks major carbonates. Still farther west of the Chilliwack Group, of the Cascade Mountains, and the Sicker Group of Vancouver Island contain volcaniclastic rocks, basic to acidic volcanics, pelite, and sheet-like carbonates (Monger, 1970a, p. 6-10; Muller and Carson, 1969, p. 5-10).

The lithological dissimilarities of the Cache Creek Group, as used in this report, to flanking rocks of similar age are reflected by the contrasting character of the fusulinid faunas of Permian age, which have been studied more than any others, as they are the most common stratigraphically useful fossils (Monger and Ross, 1971). Fusulinids in the Cache Creek Group resemble Asian faunas, specifically whereas the rocks to east and west contain fusulinids that more closely resemble those in standard Permian biostratigraphic sections of the southwestern United States. Direct correlation between the two faunas is difficult but Ross and Nassichuk (1970) correlated ammonoid faunas associated with "Asian" fusulinids near Nakina Lake with similar ammonoid faunas in lower Upper Permian standard sections in the southwestern United States. These faunal differences and their possible cause have been ascribed to environmental differences by Danner (1965, p. 120) and to environment and possible tectonic juxtaposition of originally widely separated biogeographic provinces by Monger and Ross (1971).

Stratigraphic relationships of upper Paleozoic rocks to older and younger sequences in the Canadian Cordillera are given in Figure 21. The stratigraphic base of the Cache Creek Group has not been recognized anywhere, but rocks of equivalent age to the east generally overlie Devonian or older, miogeoclinal rocks. Units to the west may also have a crystalline basement, represented by Devonian strata and/or older metamorphics on the west side of the northern Cascades (Danner, 1967a, p. 830). The base has not been recognized in the Stikine area, but older rocks are known beneath similar upper Paleozoic rocks to the west in southeastern Alaska.

The Cache Creek Group is generally overlain by upper Mesozoic or Tertiary strata, except near Quesnel where it is overlain by Lower Jurassic rocks (H. W. Tipper, pers. comm.), and probable lower Mesozoic rocks are found locally in the Atlin Terrane. By contrast, the upper Paleozoic rocks nearly everywhere else are capped unconformably or disconformably by Upper Triassic, or rarely Middle Triassic or Lower Jurassic strata.

Major faults form the lateral boundaries of the Cache Creek Group belt wherever the contacts are not covered by upper Mesozoic and younger rocks or are in intrusive relationship with Mesozoic granitic rocks. In the Atlin Terrane, the Teslin lineament and Thibert Creek Fault lie to the northeast, and the Nahlin Fault system to the southwest. In the Stuart Lake belt, the eastern limit is bounded by the Pinchi Fault, and, where exposed below the cover of younger rocks at the northeastern extremity, the western contact is an east-dipping thrust fault (Monger and Paterson, 1974). Near Cache Creek, the eastern limits are covered, but the western boundary is the Fraser fault system.

The above brief review of lithology, paleontology and external relationships suggests that the Cache Creek Group is an unique, distinct, element in the Canadian Cordillera. Although similar lithologies, particularly limestones, are present in coeval rocks, other upper Paleozoic assemblages contain rocks not characteristic of, and lack rocks common to the Cache Creek Group. It is therefore suggested that the term 'Cache Creek Group' be restricted to the rocks in the Intermontane Belt composed mainly of four lithological types: bedded chert and pelite, limestone, basic volcanics and ultramafics. The Cache Creek Group thus includes the Taku Group at the northern end of the Atlin Terrain, and excludes rocks of the Manson Creek belt (Armstrong, 1949, p. 47; Roots, 1954, p. 120), the "eastern part of the Cache Creek Group" of Campbell and Tipper (1971, p. 19) and contiguous units in Nicola and Vernon map-areas (Cockfield, 1948, p. 6; Jones, 1959, p. 38).

The subdivision into formations of the Cache Creek Group in the Atlin Terrane was discussed at the beginning of this report. The writer feels that local formation names should be used within each area of the Cache Creek Group. Enough difficulty was encountered in correlating formations within the relatively continuous Atlin Terrane to deter usage outside this terrane. The next area, the Stuart Lake belt, is 200 miles south of the Atlin Terrane, with no intervening outcrop.